ing and is as variable as meteorological conditions.

An excellent resource is Chapter 44 of the ASHRAE 2007 Handbook – HVAC Applications. Among the factors to consider in establishing stack configuration, design, and height are: toxicity, corrosivity, and relative humidity of the exhaust, meteorological conditions, geometry of the building, type of stack head and cap design, adjacency of other discharged stacks and building intake, discharge velocity, and receptor population.

Exhaust stack discharge velocity shall be at least 3000 fpm (15.2 m/s) is required unless it can be demonstrated that a specific design meets the dilution criteria necessary to reduce the concentration of hazardous materials in the exhaust to safe levels (See Section 2.1) at all potential receptors.

A discharge velocity of 2500 fpm (12.7 m/s) prevents downward flow of condensed moisture within the exhaust stack. It is good practice to make the terminal velocity at least 3000 fpm (15.2 m/s) to encourage plume rise and dilution.

These factors affect the dilution of the exhaust stream and the plume trajectory. High discharge velocity and temperature increase plume rise, but high velocity is generally less effective than increased stack height.

Aesthetic conditions concerning external appearance shall not supersede the requirements of Sections 5.4.5 and 5.4.6.

In case there is a conflict, the requirements of Section 5.3.4 take priority. Some solutions that may be used are:

- An evaluation of the stack design that will account for the effects of problem structures should be undertaken. The evaluation should provide estimates of the expected concentration levels of exhaust contaminants at surrounding air intakes. Appropriate physical modeling (wind tunnel, mock-up or water flume) or numerical modeling using appropriate methods (Computational Fluid Dynamics or other advanced numerical methods) should be undertaken as discussed in Chapter 44 of the ASHRAE 2007 Handbook – HVAC Applications. The limitations of the technique utilized should be understood and evidence should be provided that the results are conservative or accurate for the case being modeled. When physical modeling is used, procedures discussed in the EPA Guideline for Modeling of Atmospheric Diffusion (Office of Air Quality Planning and Standards, EPA-600/8-81-009, April 1981) should be employed.
- Treatment of the discharge gas may permit a lower and esthetically acceptable stack. The technology of gas-treating equipment is outside the scope of this standard except as described in

Any architectural structure that protrudes to a height close to the stack-top elevation (i.e., architectural structure to mask unwanted appearance of stack, penthouses, mechanical equipment, nearby buildings, trees or other structures) shall be evaluated for its effects on re-entrainment

The air intake or exhaust grilles shall not be located within the architectural screen or mask unless it is demonstrated to be acceptable.

Section 9.2.
- Appendix 3 is provided to assist the designer in understanding stack height determination and evaluation methods.

5.4.7 Recirculation of Room Exhaust Air

Non-laboratory air or air from building areas adjacent to the laboratory is permitted as part of the supply air to the laboratory if its quality is adequate.

In many laboratory settings, the laboratory is purposely kept at a slight negative differential pressure with respect to adjacent building spaces. In this situation, air flows from the adjacent spaces into the laboratory through building cracks and doorways, at least when open. This may be highly desirable; if not, this flow can be reduced, but not completely eliminated, by use of double-door anterooms, with corresponding consumption of interior space and some hindrance to traffic.

5.4.7.1 General Room Exhaust

Air exhausted from the general laboratory space (as distinguished from laboratory chemical hoods) shall not be recirculated to other areas unless one of the following sets of criteria is met:

1) Criteria A

- The concentration of air contaminants generated by maximum credible accident will be lower than short-term exposure limits required by 2.1.1;
- There are no extremely dangerous or life-threatening materials used in the laboratory; and
- The system serving the laboratory chemical hoods is provided with installed redundancy, emergency power, and other reliability features as necessary, or

2) Criteria B

- Provision of 100% outside air, whenever continuous monitoring indicates an alarm condition;
- Recirculated air is treated to reduce contaminant concentrations to those specified in 2.1.1; and

Some laboratories have no general exhaust, so there is no flow to consider recirculating.

Devices that are intended to provide heating and/or cooling by recirculating the air within a laboratory space (i.e., fan coil units) are exempt from this requirement

- Recirculated air is monitored continuously for contaminant concentrations or provided with a secondary backup air-cleaning device that also serves as a monitor (via a HEPA filter in a series with a less efficient filter, for particulate contamination only). Refer to Section 9.3.1.

5.4.7.2 Hood Exhaust

Exhaust air from laboratory hoods shall not be recirculated to other areas.

Hood exhaust air meeting the same criteria as noted in Section 5.4.7.1 shall only be recirculated to the same work area where the hood operators have control of the hood work practices and can monitor the status of air cleaning.

For most laboratories, recirculation of laboratory chemical hood air should be avoided. Laboratory chemical hood air usually contains significant amounts of materials with differing requirements for removal. Providing air-cleaning equipment to permit safe recirculation represents a high capital and operating cost, especially when redundancy and monitoring requirements are considered.

Refer to the current version of NFPA 45 for its position on recirculation of laboratory chemical hood air when using flammables.

Some “single purpose” laboratories might find it practical to recirculate laboratory chemical hood air; the requirements are similar to those in Section 5.3.7.1 criteria B. See Section 4.2 for more information.

6 Commissioning and Routine Performance Testing

6.1 Performance specifications, tests, and instrumentation

6.1.1 Specifying Laboratory Fume Hood Performance

Test specifications used for selecting a hood, in commissioning or in routine testing, shall refer to the applicable ANSI/ASHRAE 110 defined performance tests or to a test standard recognized to be equivalent.

ANSI/ASHRAE 110 defines three different test scenarios, “As Manufactured, As Installed and As Used.”

Specification and procurement of laboratory fume hoods shall be based on “As Manufactured” ANSI/ASHRAE 110 defined performance tests conducted on a representative hood (or prototype hood) that demonstrate

”As Manufactured” tests, usually performed at the hood manufacturer’s facility, are conducted to determine whether the hood is adequately designed to provide adequate hood containment.

The performance tests to be witnessed, referenced or otherwise shall include

- airflow visualization tests,
- auxiliary air velocity tests (if applicable,)
- cross drafts velocity tests,
- exhaust flow measurements,
- face velocity tests,
- hood static pressure measurement, and
- tracer gas containment tests

The tests shall be conducted under constant volume conditions where exhaust and air supply flow are stable and exhibit no more than 5% variation from set-point.

the required level of performance. In addition, the tests are conducted to determine appropriate operating specifications. It is only necessary to perform these tests on one hood for each unique hood design or mode.

Credible catalog data on the fundamental performance and capabilities of a hood as it comes from the manufacturer are useful. The designer can then specify the unit with confidence that it will perform as per the manufacturer's catalog data. It is recommended that the manufacturers' tests be conducted or witnessed by the laboratory owner and design professional, and/or independent third party.

The containment tests should be conducted over the range of possible operating configurations afforded by the hood design (i.e., sash position, baffle configurations, etc.) and at different target face velocities or exhaust flow rates to determine operational boundary conditions and hood limitations.

Proper containment of a laboratory fume hood is affected by a number of factors including design of the hood, design of the laboratory, and design and operation of the ventilation systems. Controlled tests enable elimination of one variable: design of the hood. Therefore, performance problems encountered after installation can be attributed to other factors.

Where possible, containment tests should be conducted according to methods described in the most recent ANSI/ASHRAE 110 standard equal to or more challenging than the standardized test.

ANSI/ASHRAE 110 does not specify a face velocity. The standard yields a performance rating in the form of AM yy, AI yy, or AU yy where, AM means "as manufactured," AI means "as installed," and AU means "as used." The symbol yy represents the average 5-minute concentration of tracer gas measured in the breathing zone of a mannequin used to simulate a hood user.

The ANSI/ASHRAE 110 standard recommends a gas generation rate of 4 L/m. However, other generation rates (i.e., 1 L/m or 8 L/m) can be specified by the design professional or responsible person

(2.3) when deemed appropriate.

Testing at different operating configurations will help to identify operational limitations or worst-case operating conditions. This information helps the design professional in their work and can then be relayed to the hood users to ensure proper work practices that minimize potential for exposure.

6.1.2 Performance Tests

The following performance tests shall be conducted as indicated and as prescribed in the commissioning plan, laboratory ventilation management plan, or as directed by the responsible person.

6.1.2.1 Airflow Visualization Tests

Airflow visualization tests shall be conducted as described in the ANSI/ASHRAE 110–1995, Method of Testing Performance of Laboratory Fume Hoods.

The tests shall consist of small-volume generation and large-volume generation smoke to identify areas of reverse flow, stagnation zones, vortex regions, escape, and clearance.

Visible escape beyond the plane of the sash when generated 6 in. (15.2 cm) into the hood shall constitute a failure during the performance test.

Smoke tests are valuable because they indicate the direction of airflow through the opening and within the hood enclosure when the smoke plume is visible. Smoke particles are rapidly diluted to the extent where they may not be visible even though significant concentrations may exist in the invisible plume. Smoke tests should be used only as an indication of flow direction and absence of visible smoke should not be interpreted as an absence of smoke. Users of smoke should note that smoke tubes and candles can be caustic and detrimental to the user, test equipment, and apparatus in the hood.

Attempts to improve airflow patterns should be attempted by adjusting the baffles and slot widths, redirecting room air currents, or changing the opening configuration by moving the sash panels. Closure of the sashes resulting in an opening smaller than the design opening may represent a “restricted use” condition.

Often the most devastating area for reverse flow is behind the airfoil sill on bench-top-mounted hoods. An improperly designed airfoil or lack of an airfoil will cause reverse flow along the work surface within 6 in. (15.2 cm) of the sash plane. Reverse flow in this region is particularly worrisome as the wake zone that develops in front of a hood user could overlap with the reverse flow zone.

Dynamic challenges should be evaluated.

6.1.2.2 Auxiliary Air Velocity Tests

For auxiliary air hoods, the face velocity shall be measured with the auxiliary air turned off unless room pressurization would change significantly to affect exhaust flow. Where exhaust flow would be affected by turning off the auxiliary airflow, auxiliary air must be redirected from the hood opening so as not to interfere with flow into the hood while conducting the face velocity traverse.

The velocity of the auxiliary air exiting the auxiliary air plenum shall be measured to determine the magnitude and distribution of air supplied above the hood opening.

The average auxiliary air velocity shall be determined from the average of grid velocities measured across the plenum outlet.

Hood face velocity is usually defined as air speed in a direction normal to the plane of the hood face opening. For auxiliary air hoods in standard operation, the directional component of the air velocity is not normal to the hood face plane. Accurate determination of the flow direction and derivation of the horizontal and vertical components of the velocity vector require very sophisticated instrumentation because of the low air speeds involved. Hence, measuring the hood's face velocity with the auxiliary air shut off is an acceptable measure of hood exhaust volume, if turning off the auxiliary air does not upset the room air balance enough to reduce significantly the volume extracted by the hood exhaust system.

Face velocity measurements should be determined with the supply air off or with special devices designed to eliminate the effect of the auxiliary air at the hood face. For example, supply air from the auxiliary air plenum can be temporarily redirected away from the sash opening by use of a portable baffle, hand held or otherwise placed beneath the supply air discharge without blocking off the supply air flow.

NOTE: The 90% capture efficiency should be tested by material balance by introducing a tracer gas into the auxiliary airstream and sampling the hood exhaust. Flow volume and sampling should be in accordance with EPA methods 1, 2, and 17 (40 CFR 60, Appendix A) or by other methods mutually agreed on by all parties.

The auxiliary air supply plenum located above the top of the hood face and external to the hood should be designed to distribute air across the width of the hood opening so as not to affect containment.

Excessive auxiliary air velocity can interfere or overcome air flowing into the hood opening and cause escape from the hood.

The downflow velocities should be measured approximately 6 in. (15.2 cm) above the bottom edge of the sash positioned at the design opening height.

6.1.2.3 Cross-Draft Velocity Tests

Cross-draft velocity measurements shall be made with the sashes open and the velocity probe positioned at several locations near the hood opening to detect potentially interfering room air currents (cross drafts). Record measurement locations.

Over a period of 10–30 sec., cross-draft velocities shall be recorded approximately 1 reading per second using a thermal anemometer with an accuracy of +5% at 50 fpm (0.25 m/s) or better.

The average and maximum cross-draft velocities at each location shall be recorded and not be sufficient to cause escape from the hood.

Cross draft velocities shall not be of such magnitude and direction as to negatively affect containment.

More test locations may be required or can be useful for determining cross-draft velocities past the hood opening. Vertical and horizontal components of cross-draft velocities should be measured at each location.

Increasing face velocity may not make the hood more resistant to cross drafts. However, increasing face velocity may:

- Increase the required volume of room air supply and increase difficulties with ensuring proper room air distribution.
- Increase exhaust of expensive conditioned air.

Excessive cross-draft velocities (>50% of the average face velocity) have been demonstrated to significantly affect hood containment and should be identified and alleviated. Ideally, cross-draft velocities should be less than 30%.

If the supply tracks the exhaust, measure the cross drafts at the maximum conditions.

6.1.2.4 Exhaust Flow Measurements

The volumetric flow exhausted from a laboratory fume hood shall be determined by measuring the flow in the exhaust duct using industry-approved methods.

See the current version of ACGIH®'s *Industrial Ventilation: A Manual for Recommended Practice*, or ANSI/ASHRAE 41.2–1987 (RA 92), for measuring flow.

The hood exhaust flow should be adjusted to achieve the target average face velocity at the design opening and to achieve the specified flow with the sash closed.

Typically, exhaust flow can be predicted from the area of the opening multiplied by the design face velocity. However, infiltration of air into the hood through openings other than the face may require approximately 5–10% more exhaust flow than calculated. The exhaust flow and variance from the calculated flow should be determined to enable proper specification of flows for design of the ventilation systems.

Failure to determine the total exhaust flow required to achieve the desired average face velocity may result in under sizing of the exhaust system or improper specification of supply volume to achieve required lab pressurization or differential airflow.

Calculation of exhaust flow from face velocity measurements multiplied by hood face area is not a measurement of exhaust flow and due to the reasons stated above, true exhaust flow can vary significantly from the calculated exhaust flow. In addition, the accuracy of face velocity measurements can affect the accuracy of the average face velocity used to calculate exhaust flow. Face velocities measured at the plane of the sash opening using hot-wire anemometers or pressure grid assemblies can be subject to significant error due to turbulence at the opening and direction of airflow over the probes where average face velocities could vary from actual by 5–20%.

6.1.2.5 Face Velocity Tests

Once adequate performance has been established for a particular hood at a given benchmark face velocity using the methods described herein, that benchmark face velocity shall be used as a periodic check for continued performance as long as no substantive changes have occurred to the hood or other aspects that affect hood performance.

Substantive changes include: changes in hood setup; hood face velocity control type, set point, range, and response time; exhaust system static pressure, control range and response time; the hood operating environment including lab/furniture geometry, supply air distribution patterns, and volume; and room pressure control range and response time.

Face velocity measurements shall be made with the sash in the Design Sash Position. The Design Sash Position is the maximum opening or configuration allowed by user standards, SOPs, or the Chemical Hygiene Plan, whichever is applicable, and used in the design of the exhaust system to which the hood is connected.

The face velocity of a combination sash is sometimes determined with the sash closed and the horizontal windows open. For "set-up" conditions, the determination of the actual face velocity may not be unique. The face velocity of combination sash hoods should identify the sash position where the tests were conducted.

The sash position at which benchmark face velocity is measured shall be recorded with the face velocity measurement and reproduced each time measurements are taken.

It is important to use the same sash position for successive periodic performance measurements.

A decrease in the average face velocity below 90% of the benchmark velocity shall be corrected prior to continued hood use.

This magnitude of decrease may impair performance.

Face velocity increases exceeding 20% of the benchmark shall be corrected prior to continued use.

An increase in individual hood average face velocity not exceeding 20% of the benchmark face velocity will probably not significantly alter hood performance and is acceptable with no corrective action. It should be noted, however, that there is an unnecessary increase in operating cost with increased face velocities. Increases exceeding 20% and the accompanying increase in supply flow rates may degrade performance due to increased impingement and cross-draft velocities. In addition, an increase in face velocity at the measured hood may indicate a decrease in face velocity at other hoods in the exhaust systems.

In constant volume systems, the face velocity will increase with reduced sash height. Although the face velocity could be three times or more than the design face velocity, the hood performance does not usually deteriorate because the hood opening is reduced (which often improves performance) and the lowered sash acts as a partial barrier.

Supply and exhaust system capacities should be observed in the event of hood face velocity increases as volume shifting may occur, depriving other hoods of adequate airflow.

Periodic dynamic testing should be performed when significant changes have occurred or to evaluate the response of a VAV system.

The average face velocity alone is inadequate to describe hood performance. Face velocity is not a measure of containment but only the speed of air entering the face opening. Hood performance should be determined from tests of hood containment. Average face velocity should only be used as an indicator of proper system operation.

Refer to section 3.3.1, for information about analysis of face velocity data and recommended criteria.

The accuracy of face velocity measurements can be affected by numerous factors including instrument accuracy, measurement technique, hood aerodynamics, room air conditions (cross drafts), and exhaust flow stability. Average face velocities and grid velocities can be significantly affected by turbulence (temporal variation) and direction through the opening (spatial variation). Multiple readings taken over time at each grid location are recommended to provide more accurate velocity measurements. Cross drafts can also bias face velocity data by creating turbulence at the opening and variations in face velocity readings.

The average face velocity shall be determined by the method described in the current version of ANSI/ASHRAE 110 Method of Testing Performance of Laboratory Fume Hoods.

Face velocity measurements shall be made by dividing the hood opening into equal area grids with sides measuring no more than 12 in. (30.5 cm). The tip of the probe shall be positioned in the plane of the sash opening and fixed (not handheld) at the approximate center of each grid. Grid measurements around the perimeter of the hood opening shall be made at a distance of approximately 6 in. (15.2 cm) from the top, bottom, and sides of the opening enclosure.

Multiple readings at each grid point will help determine more accurate average face velocities when turbulent air is present at the hood opening. Multiple readings can be acquired with the use of time constants for meters so equipped or use of a data logger or data acquisition system attached to a computer.

The average face velocity shall be the average of the grid velocity measurements.

Each grid velocity shall be the average of at least 10 measurements made over at least 10 seconds.

The plane of the sash shall be defined as the exterior surface of the outer most glass panel.

Manufacturers have been defining the sash plane somewhat subjectively, thus making it difficult for users to compare face velocity data and AM containment test results. This definition from ANSI/ASHRAE 110 aims to lessen the subjectivity in AM as well as AI and AU testing.

6.1.2.6 Hood Static Pressure Measurements

The hood static pressure shall be measured above the outlet collar of the hood at the flows required to achieve the design average face velocity.

For test method, refer to current version of ANSI/ASHRAE 41.3. Hood static pressure is a measure of the resistance imposed on the exhaust system by the hood. Determination of hood static pressure is required to ensure proper system design. Typical hood static pressures range from 0.1 to 0.75 in.wg (25 to 187 Pa) at face velocities between 80 to 120 fpm (0.41 to 0.61 m/s). However, the hood static pressure will depend on the hood design and exhaust flow.

6.1.2.7 Tracer Gas Containment Tests

The tracer gas containment tests shall be conducted as described in the ANSI/ASHRAE 110–1995, Method of Testing Performance of Laboratory Fume Hoods or by a test recognized to be equivalent.

A control level for 5-minute average tests at each location conducted at a generation rate of 4 L/m shall be no greater than 0.05 ppm for "as manufactured" tests and 0.10 ppm for "as installed" (AM 0.05, AI 0.1).

Escape more than the control levels stated above shall be acceptable at the discretion of the design professional in agreement with the responsible person (2.4.2). The "as used" 0.10 ppm level or more is at the discretion of the responsible person (2.3).

Tracer gas tests enable the ability to quantify the potential for escape from a laboratory fume hood.

The test data need to be made available by the manufacturer for each specific model and type of hood so a potential buyer can verify proper containment or compare one manufacturer's hood containment against another.

Values for control level may not be suitable for establishing hood safety, as the tracer gas test methods may not adequately simulate actual material use, risk, or generation characteristics. In addition, the tracer gas test does not simulate a live operator, who may increase potential for escape due to operator size, movements near the hood opening, or improper hood use.

Hood containment should be evaluated at different mannequin heights to represent workers of different height.

AM 0.05 can be achieved with a properly designed laboratory fume hood. It should not be implied that this exposure level is safe. Safe exposure levels are application specific and should be evaluated by properly trained personnel (SEFA 1-2002).

6.1.3 Test Instrumentation

All test instrumentation utilized for the tests prescribed throughout this section shall be in good working order and shall have been factory calibrated within 1 year of the date of use. (See 8.6.1, Air Velocity, Air Pressure, Temperature and Humidity Instruments)

6.2 Commissioning of Laboratory Ventilation Systems

6.2.1 Commissioning Process

All newly installed, renovated, or moved hoods shall be commissioned to ensure proper operation prior to use by laboratory personnel.

Commissioning tests are conducted to ensure that laboratory ventilation systems operate according to design specifications and are capable of meeting control objectives under resulting operating conditions. The extent of the commissioning process depends on the complexity of the systems along with the anticipated risk associated with work to be conducted in the laboratory.

6.2.2 Commissioning Authority

The commissioning process shall be overseen by a responsible person or commissioning authority.

The commissioning authority should be someone who represents the interests of the system owner and should be knowledgeable in the design and operation of laboratory ventilation systems. In addition, the commissioning authority should be experienced with collection and analysis of test data.

The commissioning authority may develop the commissioning plan in conjunction with information provided by potential equipment suppliers and contractors, owner personnel, and project design professionals.

A commissioning team consisting of personnel directly involved in the design, installation, and use of the new