**ANSI/ASHRAE 110-1995**
**Supersedes ANSI/ASHRAE 110-1985**

# ASHRAE® STANDARD

AN AMERICAN NATIONAL STANDARD

# Method of Testing Performance of Laboratory Fume Hoods

Approved by the ASHRAE Standards Committee February 2, 1995; by the ASHRAE Board of Directors February 2, 1995; and by the American National Standards Institute April 14, 1995.

ASHRAE Standards are updated on a five-year cycle; the date following the Standard number is the year of ASHRAE Board of Directors approval. The latest copies may be purchased from ASHRAE Customer Services, 1791 Tullie Circle, NE, Atlanta, GA 30329.



ISSN 1041-2336



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**(This foreword is not a part of this standard but is included for information purposes only.)**

## FOREWORD

*The performance of a laboratory fume hood in providing protection for the worker at the face of the hood is strongly influenced by the aerodynamic design of the hood, the ventilation of the laboratory room, and by other features of the laboratory in which it is installed. Therefore, there is a need for a performance test that can be used in the field to establish an "as used" performance rating, including the influences of the laboratory arrangement and its ventilation system.*

*This standard defines a reproducible method of testing laboratory fume hoods. It does not define safe procedures. However, laboratory hoods are considered by many to be the primary safety devices in conducting laboratory operations.*

*There are many important factors in the safe operation of laboratory hoods that are not described in the standard. These include:*

1. *Cross-drafts. Air currents may, by creating turbulent air pockets, draw contaminants from the hoods. Such cross-drafts could be caused by air supply diffusers or grilles, open windows or doors, or rapid movements of people in front of the hood.*
2. *Work procedures. There is substantial evidence to suggest that all work in a hood should be conducted as far back in the hood as practical. Typically, users have standardized the requirement that all work should occur at least 6 inches behind the face of the hood. However, significantly improved protection can be achieved by working farther than 6 inches from the face of the hood.*
3. *Internal obstructions. The location of too much laboratory equipment (bottles, glass, etc.) in the hood will disturb airflow patterns into the hood.*
4. *The procedure being performed. The intrinsic hazard of the procedure being performed can affect the level of safety required by the user.*
5. *Thermal challenge. Heat produced in the hood can cause significant disturbance in hood performance and even cause leakage of warm and possibly contaminated air from the top of the hood or from behind the sash.*
6. *Rate of response. The transient state or interval required for a variable-air-volume hood to respond to a rapid opening of the sash, or the time interval required for a hood to respond to a change in static pressure in the main exhaust duct serving multiple hoods, may affect hood performance.*

*In short, there are many factors to consider in evaluating the safety of a laboratory hood installation. This standard will provide one tool in evaluating such safety.*

*The test presumes a conditioned environment. No test can be devised that would, conducted once or infrequently (viz., annually), reflect the results that would be obtained in a unconditioned laboratory with various conditions of windows, wind velocity, etc.*

*The procedure is a performance test method and does not constitute a performance specification. It is analogous to a method of chemical analysis, which prescribes how to analyze for a chemical constituent, not how much of that substance should be present. Another analogy would be a method for measuring airflow; it prescribes how the flow should be measured, not how much it should be.*

*The desired hood performance should be defined as a result of the cooperative efforts of such people as the user, the chemical hygiene officer, and the applications engineer. It should be noted that the performance test does not give a direct correlation between testing with a tracer gas and operator exposures. Many factors, such as the physical properties of the material, the rate and mode of evolution, the amount of time the worker spends at the face of the hood, and several other factors, must be integrated, by a trained observer, into a complete evaluation of worker exposure. The performance test does, however, give a relative and quantitative determination of the efficiency of the hood containment under a set of specific, although arbitrary, conditions. The same test can be used to evaluate hoods in the manufacturer's facilities under (presumably) ideal conditions or under some specified condition of room air supply or during the commissioning of a new or renovated laboratory before the user has occupied the laboratory.*

*This method consists of three tests:*

1. *flow visualization,*
2. *face velocity measurements, and*
3. *tracer gas containment.*

*The flow visualization and face velocity tests should always precede tracer gas testing for a thorough evaluation of hood performance. The flow visualization and face velocity tests can be conducted without the tracer gas test as a combination of a quantitative velocity measurement and a qualitative evaluation of hood performance. This portion of the standard could be used in the testing and balancing of new facilities and periodic tests of many hoods at a large facility. The full test procedure (visualization, face velocity, and tracer gas) is a quantitative measurement of a hood's containment ability and is useful for hood development and rigorous evaluation of hood performance.*

*This standard may be used as part of a specification once the required control level has been determined. Three alternative ratings can be determined, depending on the condition of the test. An "as manufactured" (AM) test would be conducted at the hood manufacturer's location and would test only the design of the laboratory hood independent of the laboratory environment. An "as installed" (AI) test would be conducted in a newly constructed or renovated laboratory after thorough testing and balancing has been completed but before the user has occupied the laboratory. Consequently, the test would include the influences of the laboratory environment, such as the aerodynamic design of the hood, the supply air system, the geometry of the room, and the exhaust air system. The final test would be an "as used" (AU) test in which the investigator accepts the hood and the condition in which the user has established the hood.*

*This includes obstructions within the hood, maladjustment of the baffles, thermal challenge within the hood, and other factors.*

If this standard is to be used as part of a specification, the following criteria must be specified:

*a) Sash design position or positions*
*b) Average face velocity*
*c) Range of face velocities*
*d) Average face velocity for sash at 25% and 50% of the design hood opening*
*e) Performance rating*
*f) Sash movement performance rating*
*g) Response time for VAV hoods*
*h) Percentage of auxiliary air supply*

*This standard does not constitute an engineering investigation of what the causes may be for poor performance or of ways to improve the performance. The test may, of course, be used as an aid to such an investigation.*

*The test protocol provides for the hood sash to be placed at the design opening. Since operation of the hood with the sash opened may be beyond the design criteria, it is prudent to also conduct the tests with the hood fully open to test potential conditions of misuse.*

*A properly designed hood installed in a properly designed laboratory may still be misused. For example, the user may have the hood too full of laboratory equipment or may be using the hood for storage space. The possibilities are too varied to specify closely. Therefore, the test procedure is to be conducted on the hood "as is." The equipment in the hood should be operating normally.*

*Although the test uses a tracer gas to evaluate the performance of laboratory fume hoods, the procedure is valid when the contaminant is a particulate. Fine dust, small enough to be of health significance, will be carried along with the hood air currents in a fashion similar to the transport of a gas. However, the test is not applicable to operations where the contaminant is released violently, such as particulate from some types of grinding operations or gases from a high-pressure tubing leak. These conditions are abnormal, and a typical or "standard" laboratory fume hood is not appropriate for such conditions.*

*The test may be used to evaluate the performance of an auxiliary air hood for protecting the worker at the hood face. It does not attempt, nor is it intended, to measure the ability of the hood to capture the auxiliary supply air.*

*Sometimes the performance of the laboratory hood under dynamic conditions is critical for complete evaluation. This test procedure can be modified to evaluate a dynamic challenge; however, the number of possible variables that could be tested is beyond a performance test. Specific operations, such as a pedestrian walking past the hood, laboratory doors opening, and specific actions at the hood, are only a few of the challenges that could be expected at the hood. This test method addresses only the dynamic challenge of sash movement. Variable-air-volume (VAV) hoods place a significant emphasis on the sash movement and the potential effect on hood performance. However, some constant-volume hoods may also experience a decrease in protection when the sash is moved.*

## 1. PURPOSE

The purpose of this standard is to specify a quantitative and qualitative test method for evaluating the fume containment of a laboratory fume hood.

## 2. SCOPE

**2.1** This method of testing applies to conventional, bypass, auxiliary air, and VAV laboratory fume hoods.

**2.2** This method of testing is intended primarily for laboratory and factory testing but may be used as an aid in evaluating installed performance.

## 3. DEFINITIONS

**air supply fixtures:** devices or openings through which air flows into the laboratory room. For the purpose of this standard, all accessories, connecting duct adapters, or other mounting airways shall be considered part of the supply fixture and reported as a unit or assembly. Some specific supply fixtures are defined as follows:

> **grille:** a louvered or perforated face over an opening.
> **register:** a combination grille and damper assembly.
> **diffuser:** an outlet designed to mix supply air and room air and to distribute it in varying directions.
> **perforated ceiling:** perforated ceiling panels used to distribute the air uniformly throughout the ceiling or a portion of the ceiling. Filter pads may be used to achieve a similar result.

**auxiliary air:** unconditioned or partially conditioned supply or supplemental air delivered to a laboratory at the laboratory fume hood to reduce room air consumption.

**control level:** the average measured concentration of gas, parts of tracer gas per million parts of air by volume (ppm), that is not exceeded at the hood face with a 4.0 Lpm release rate.

**face velocity:** average velocity of air moving perpendicular to the hood face, usually expressed in feet per minute (fpm) or meters per second (m/s).

**fume hood system:** an arrangement consisting of a fume hood, its adjacent room environment, and the air exhaust equipment, such as blowers and ductwork, required to make the hood operable.

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

**Lpm:** litres per minute.

**laboratory fume hood:** a boxlike structure enclosing a source of potential air contamination, with one open or partially open side, into which air is moved for the purpose of containing and exhausting air contaminants, generally used for bench-scale laboratory operations but not necessarily involving the use of a bench or table. This test presumes a benchtop laboratory hood. Other applications are discussed in Appendix A.

**performance rating:** a series of numbers and letters consisting of the letters AM, AI, or AU and a two- or three-digit number,

AM yyy
AI yyy
AU yyy

where AM identifies an "as manufactured" test, AI identifies an "as installed" test, AU identifies an "as used" test, and yyy is the control level of tracer gas established by the test. A test rating of AU 0.5, for example, would indicate that the hood controls leakage into the laboratory to 0.5 ppm at the manikin's sensing point with the tracer gas release rate of 4.0 Lpm (70 mL/s). (This release rate is specified in 4.1.)

**positional sash movement effect:** the maximum peak tracer gas concentration observed during a series of sash movement tests at one ejector and mannikin position.

**positional control level:** the average tracer gas concentration at a position during a test.

**ppm:** parts of tracer gas per million parts of air by volume.

**release rate:** the rate of release (Lpm), in actual litres per minute, of tracer gas during a hood test. (See 4.1.)

**sash movement effect:** the maximum of the positional sash movement effects for all the positions tested on a hood.

**sash movement performance rating:** a series of letters and numbers consisting of the letters SME-AM, SME-AI, or SME-AU and a two- or three-digit number,

SME-AU yyy
SME-AI yyy
SME-AM yyy

where SME means "sash movement effect," AM means "as manufactured," AI means "as installed," AU means "as used," and yyy equals the sash movement effect, ppm. A test rating of SME-AM 10, for example, would indicate that the peak concentration of tracer gas measured during a sash movement test under the "as manufactured" test, with a tracer gas release rate of 4.0 Lpm (as required in 4.1), was 10 ppm.

**specified rating:** the hood performance rating as specified, proposed, or guaranteed in either the purchase of the hood, in the design and construction of the laboratory, or both.

**titanium tetrachloride:** the chemical $TiCl_4$ that generates white visible fumes used in preliminary testing in laboratory fume hoods. (**CAUTION:** Titanium tetrachloride is corrosive and irritating; skin contact or inhalation shall be avoided.)

For other definitions, refer to *Terminology of HVAC&R.*[1]

## 4. INSTRUMENTATION AND EQUIPMENT

### 4.1 Tracer Gas

The tracer gas shall be sulfur hexafluoride, or a gas of similar molecular weight and stability, supplied from a cylinder capable of maintaining 30 psig (200 kPa [gage]) at the test release rate for at least one hour. The tracer gas release rate shall be 4.0 Lpm. One pound of sulfur hexafluoride will provide 4 litres per minute for approximately 19 minutes at sea level. (One kilogram of sulfur hexafluoride will provide 4 litres per minute for approximately 42minutes [70 mL/s for 40 min].)

**4.1.1** The tracer gas shall be commercial grade or reagent grade. Since the detection instrument is calibrated by the actual tracer gas, 100% pure gas is not required. Low-grade mixtures are inappropriate since they significantly reduce the limit of detection for the test.

**4.1.2** Substitution of another tracer gas may be made if the standard tracer gas is deleterious to materials in the hood or laboratory or if there would be significant interference in the detection of the tracer gas. In such event, 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.

### 4.2 Ejector System

The tracer gas ejector system shall be as shown in Figures 1-3 (with I-P units) and Figures 4-6 (with SI units). The tracer gas is piped to the ejector, and the ejector is equipped with a block valve and a pressure gauge. The tracer gas passes through a critical orifice, entrains air through the holes in the side of the ejector tube, and is distributed through a wire mesh outlet diffuser.

### 4.3 Critical Orifice

**4.3.1** The flow rate of the tracer gas is determined by the upstream pressure and size of the orifice. The size for the orifice using sulfur hexafluoride as tracer gas, at a flow rate of 4.0 Lpm and a nominal upstream pressure of 30 psig (200 kPa [gage]), is 0.025 in. (0.64 mm).

**4.3.2** The orifice size and pressure will give the approximate flow rate of tracer gas; however, the actual flow rate must be measured (see 4.3.3). Convert the measured value to standard conditions: 70°F (20°C) at one atmosphere.

**4.3.3** The ejector system release rate shall be calibrated within 24 hours preceding a test and each time the orifice plate is changed.

### 4.4 Detector Instruments

The detector instrument shall be a continuous-reading instrument specific for the tracer gas.

**4.4.1** The range of detection of the instrument shall be at least from 0.01 ppm to 100 ppm.

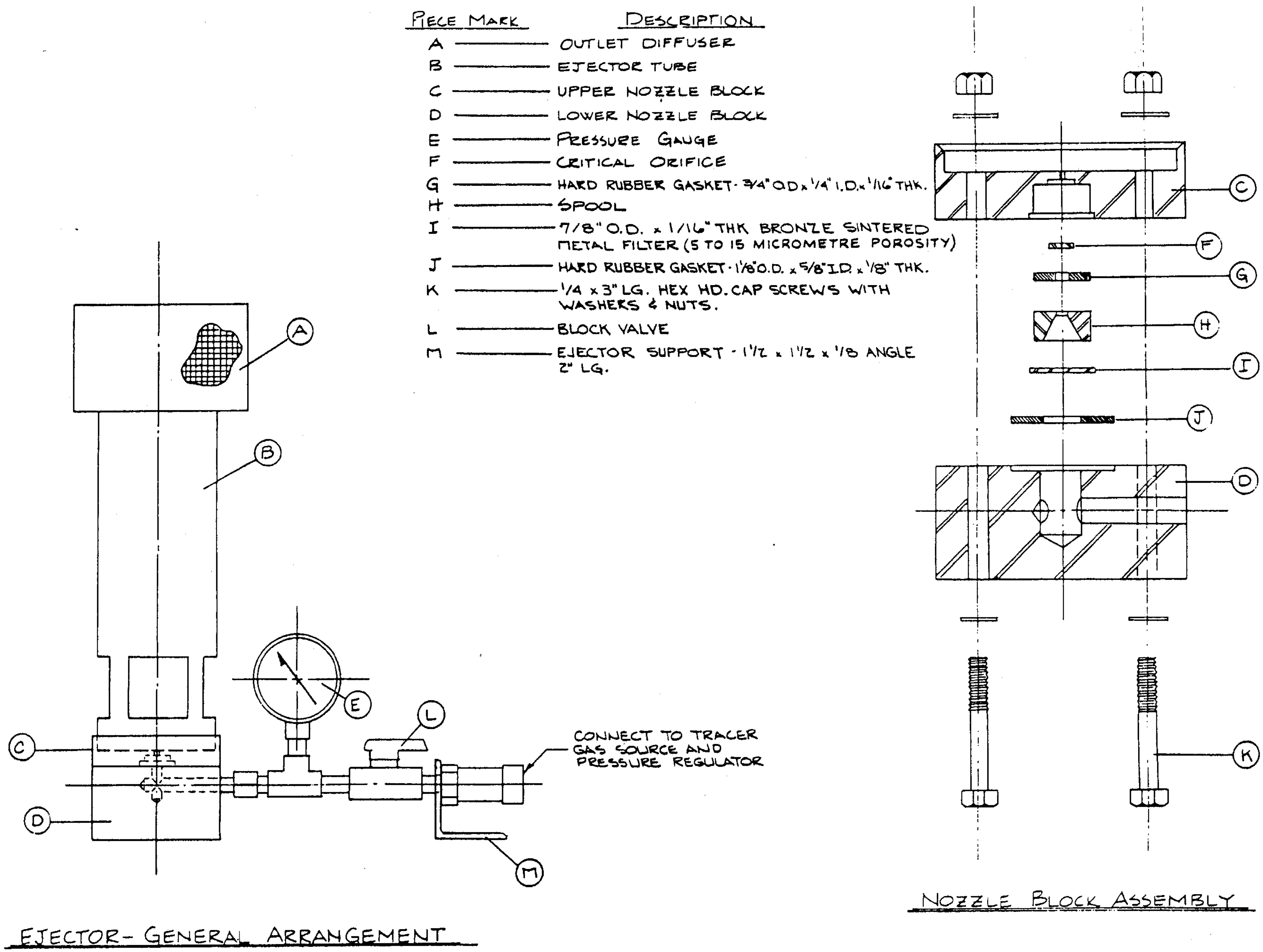


**Figure 1** *Ejector assembly, I-P units.*

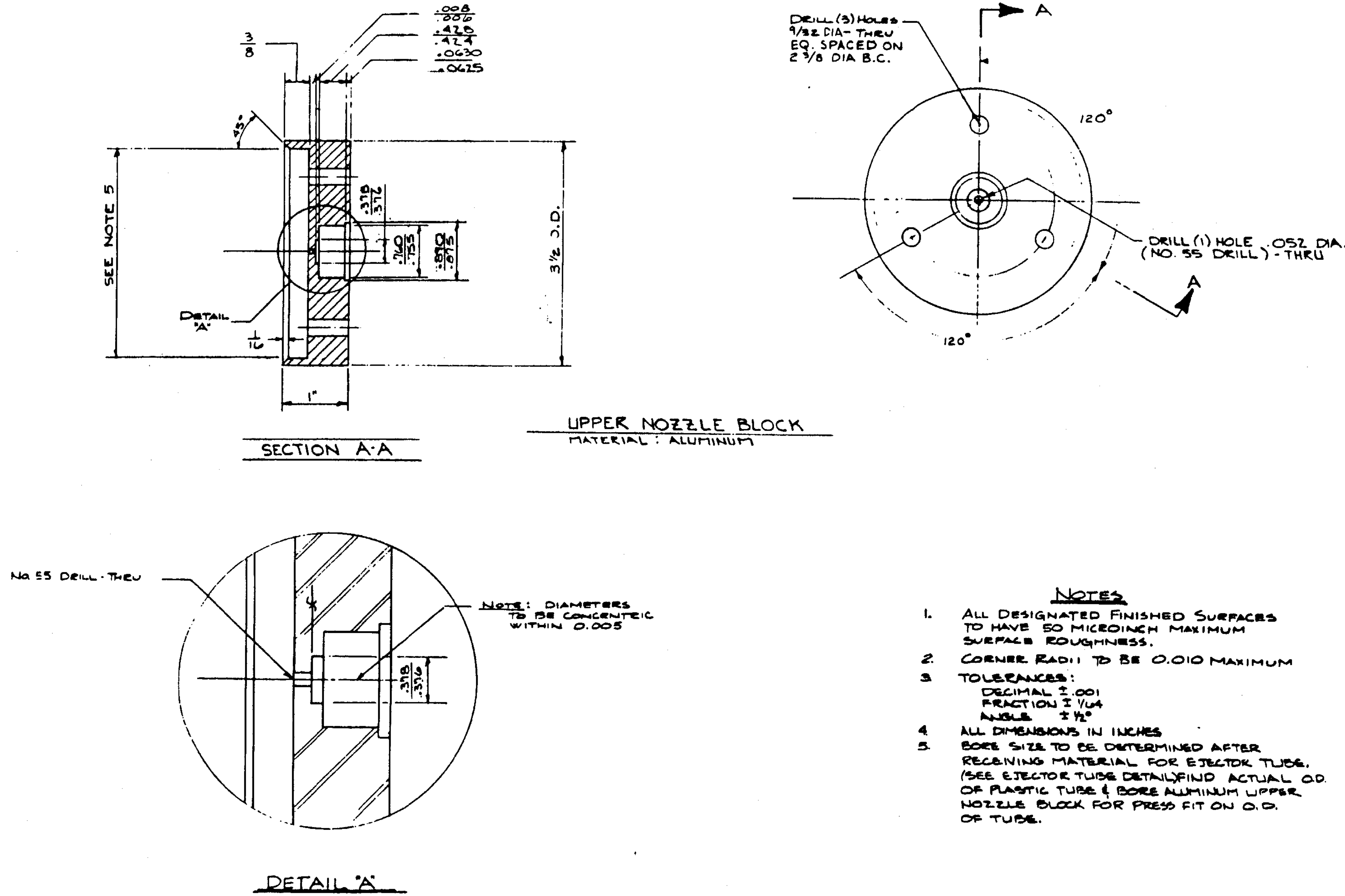


***Figure 2*** *Ejector upper nozzle block, I-P units.*

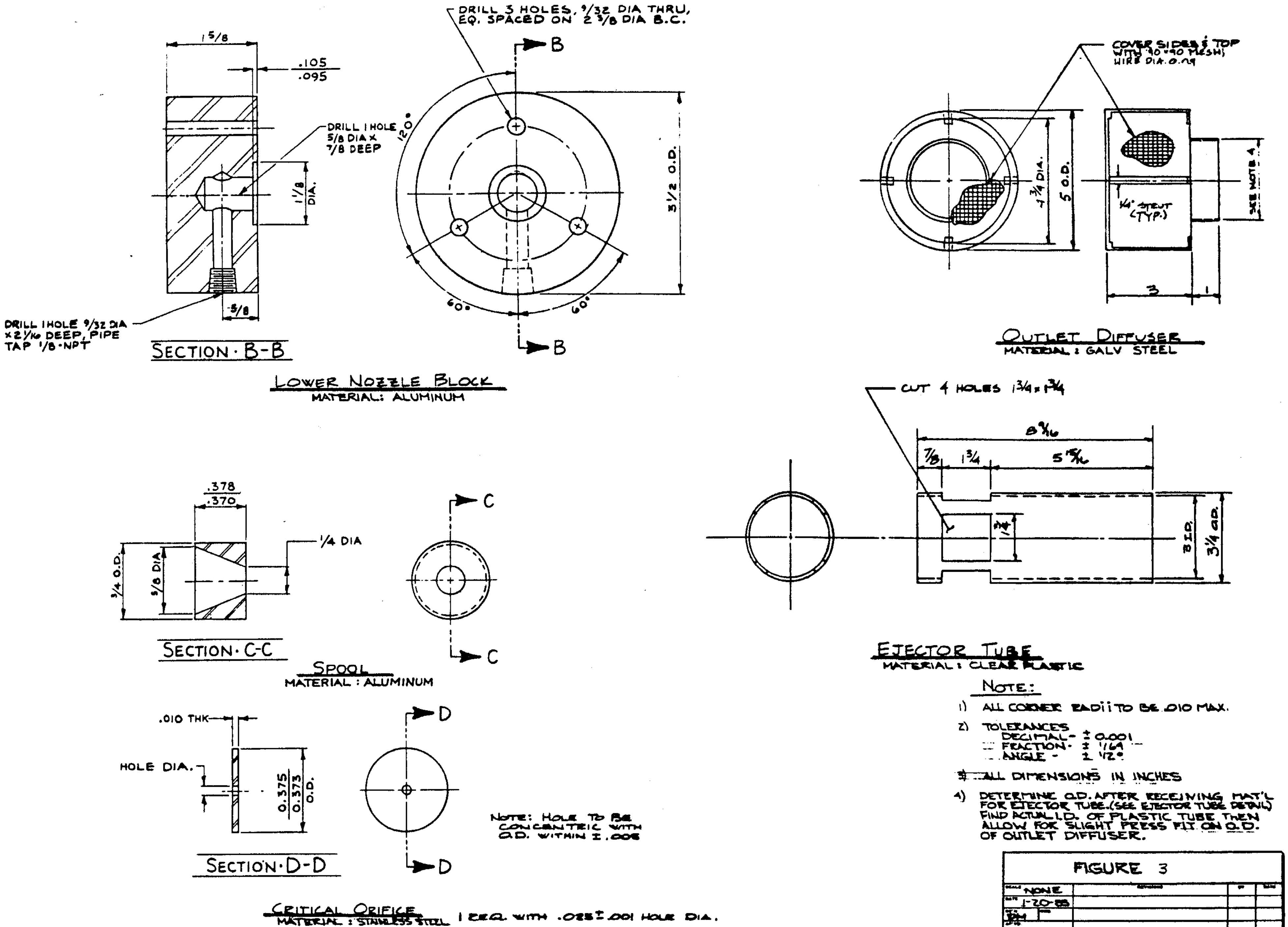


*Figure 3* *Ejector details, I-P units.*

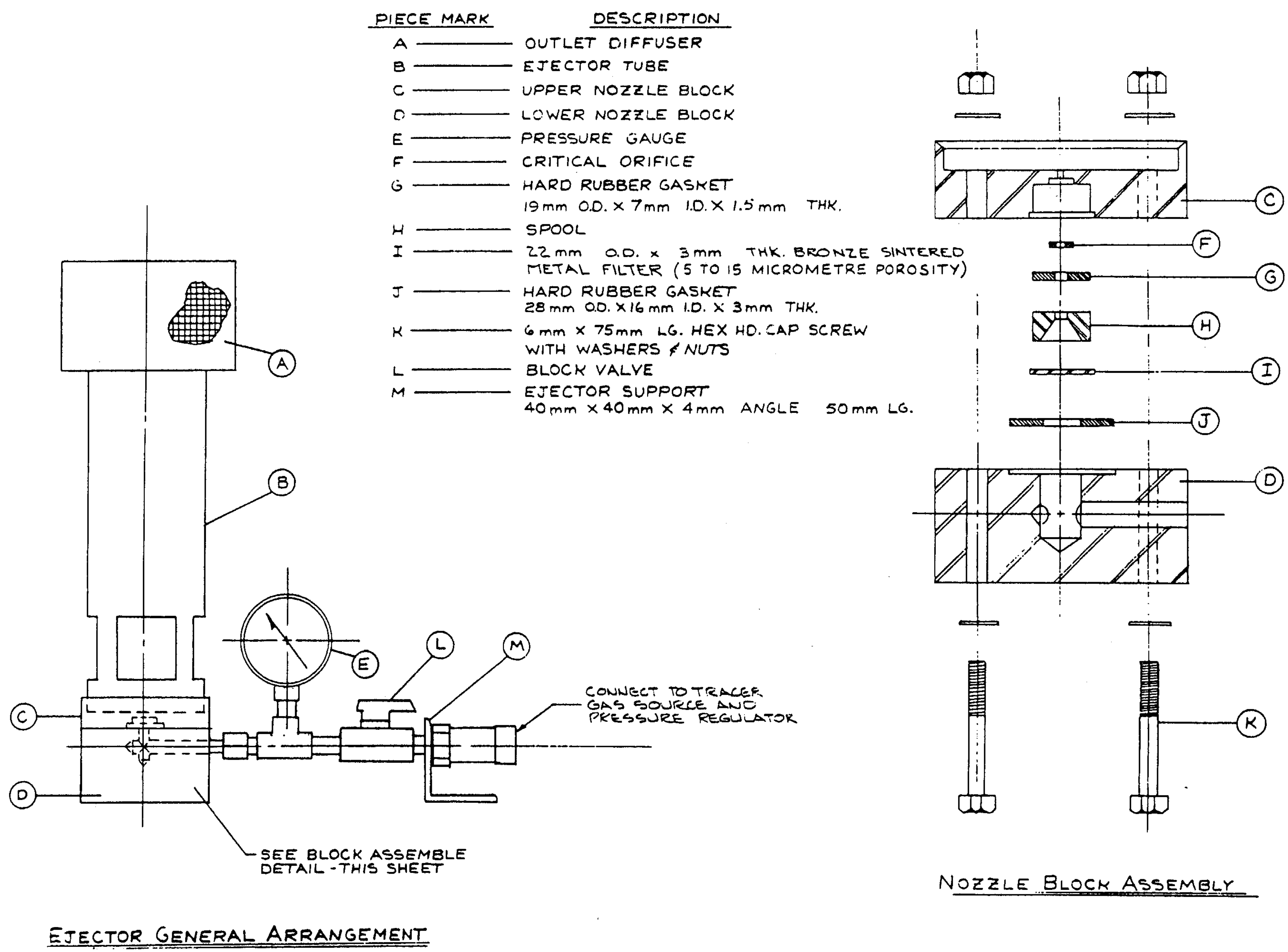


***Figure 4*** *Ejector assembly, SI units.*

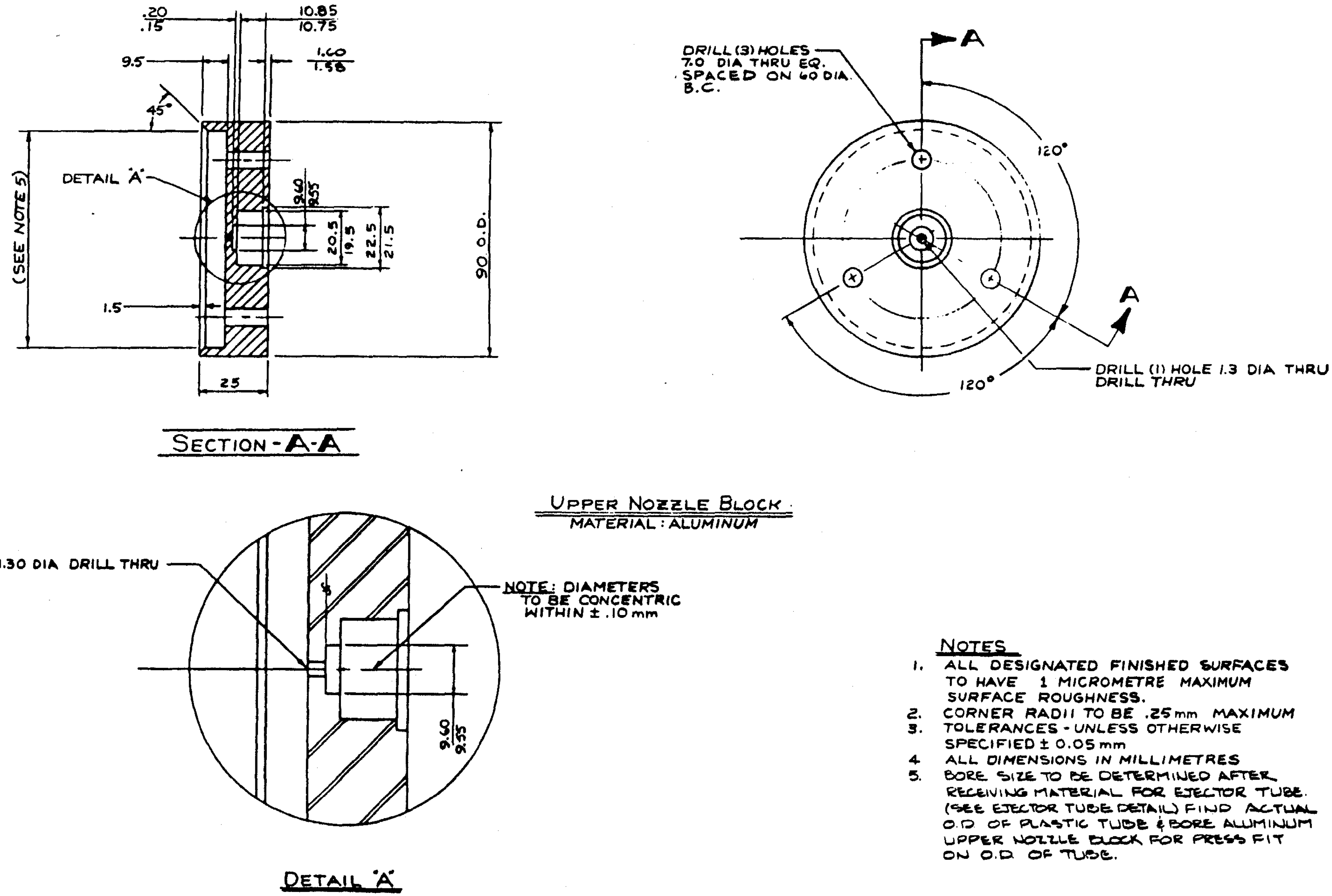


***Figure 5*** *Ejector upper nozzle block, SI units.*

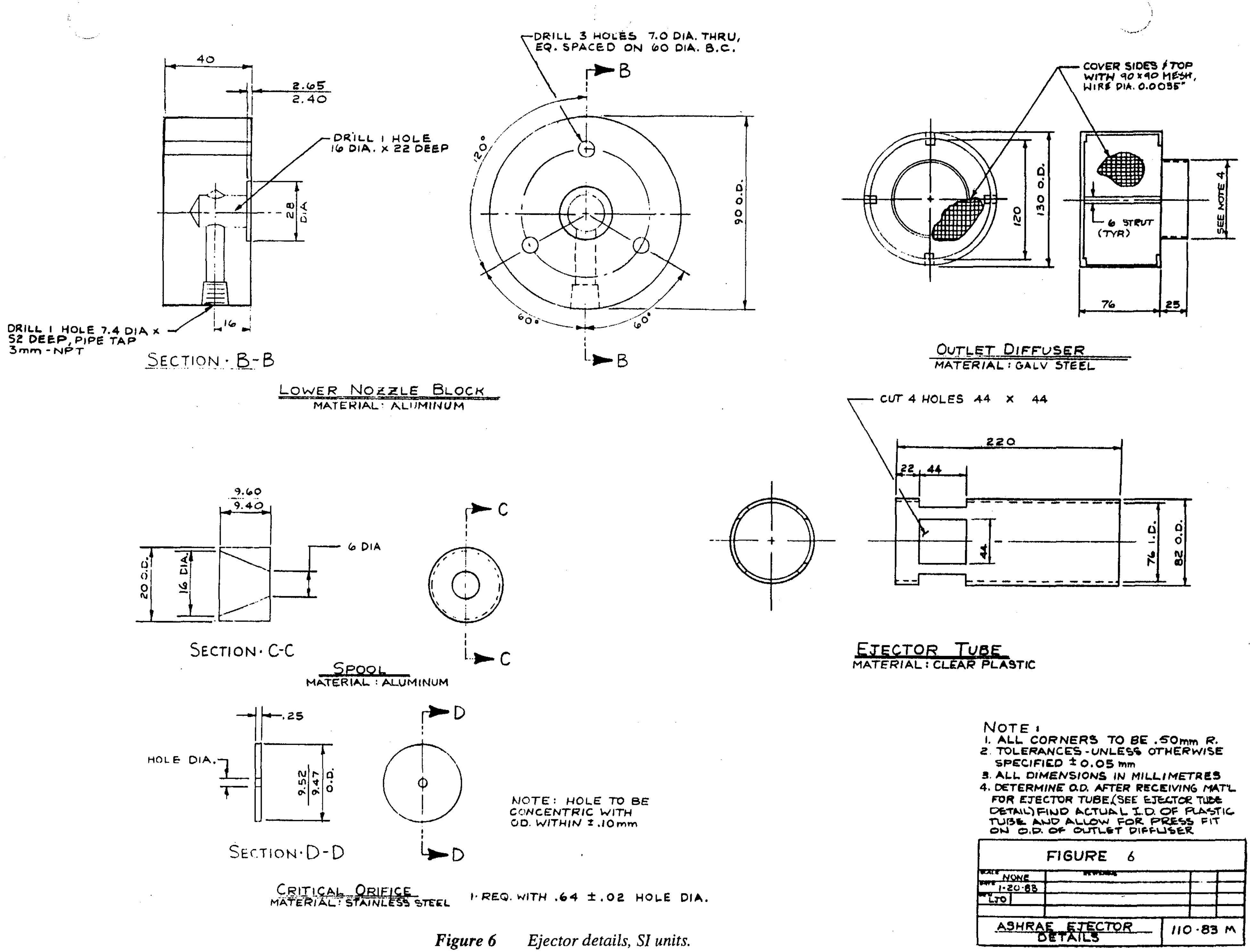


***Figure 6** Ejector details, SI units.*

**4.4.2** The accuracy of the instrument shall be ±10% of the reading for concentrations above 0.1 ppm and ±25% for concentrations between 0.01 ppm and 0.1 ppm. The repeatability of the instrument shall be ±1% of the reading at 50 ppm tracer gas concentration.

**4.4.3** The response time shall not exceed 10 seconds for 90% indication of actual concentration.

**4.4.4** The instrument shall not exhaust more than 50 Lpm.

**4.4.5 Calibration**

**4.4.5.1** The detectors shall be calibrated with a known concentration of tracer gas within 24 hours preceding a test. The methods for calibration shall be those furnished or specified by the detector manufacturer and shall use the tracer gas as a standard.

**4.4.5.2** Verify the detector calibration within 24 hours following the hood test. If more than 10% change has occurred, in the range of 5 to 50 ppm, between calibration and verification, the hood test is void.

### 4.5 Recorder

The strip chart recorder or datalogger shall have accuracy better than ±0.5% of full scale.

### 4.6 Manikin

The manikin shall be a three-dimensional clothing-display manikin. It shall be supported so that its height is 67 in. (1700 mm). The shoulder height shall be 56 ± 1 in. (1420 ± 20 mm) and shoulder width 16 ± 1 in. (410 ± 20 mm). The arms of the manikin shall hang at its side, and the manikin shall be of reasonably human proportions. The support shall be so designed as not to interfere with airflow at the hood while the manikin is positioned as shown in Figure 7. The manikin shall be clothed in a smock, coveralls, or reasonably snug-fitting garment typical of laboratory attire or of clothing requirements for the laboratory or the intended hood use. The manikin geometry shall allow its positioning to be as described in 7.6.

### 4.7 Face Velocity Measuring Instruments

Face velocity measurements shall be made with a recently calibrated mechanical or electrical anemometer. Refer to *ANSI/ASHRAE 111-1988, Practices for Measurement, Testing, Adjusting, and Balancing of Building Heating, Ventilation, Air-Conditioning, and Refrigeration Systems.*[2] The anemometer shall be capable of measuring in the range of 50 to 400 fpm (0.25 m/s to 2.0 m/s) with an accuracy of ±5% of the reading.

### 4.8 Smoke

**4.8.1 Local Generation** The smoke shall be titanium tetrachloride smoke. Smoke generation can be obtained by means of a plastic bottle containing an ampule of titanium tetrachloride. When the ampule is broken and the bottle squeezed, a highly visible plume of titanium tetrachloride is generated. This smoke can show airflow patterns within the hood. (**CAUTION:** Titanium tetrachloride is corrosive and irritating; skin contact or inhalation shall be avoided. Care must be exercised when using titanium tetrachloride to minimize the effects on the hood.)

**4.8.2 Large-Volume Generation** A method of providing a large, visible volume of smoke shall be available. For more information, see Appendix A.

### 4.9 Miscellaneous

Miscellaneous auxiliary equipment, such as a tape measure, extension cords, small wrenches, data sheets, or notebooks, shall be provided as needed.

## 5. TEST CONDITIONS

### 5.1 Room Ventilation

**5.1.1. General** Room ventilating systems, both supply and exhaust, including fume hood exhaust, shall be in full normal operation. Airflow systems in the laboratory shall be properly commissioned prior to this test. This includes calibration of airflow controls, calibration of automatic temperature controls, balance of supply air, conduct of a duct traverse on the exhaust duct and, if used, on the auxiliary air duct, and balance of the total exhaust flow. If the laboratory has standard procedures limiting the number of hoods in use at any one time, the conditions of use corresponding to the standard procedures shall be established.

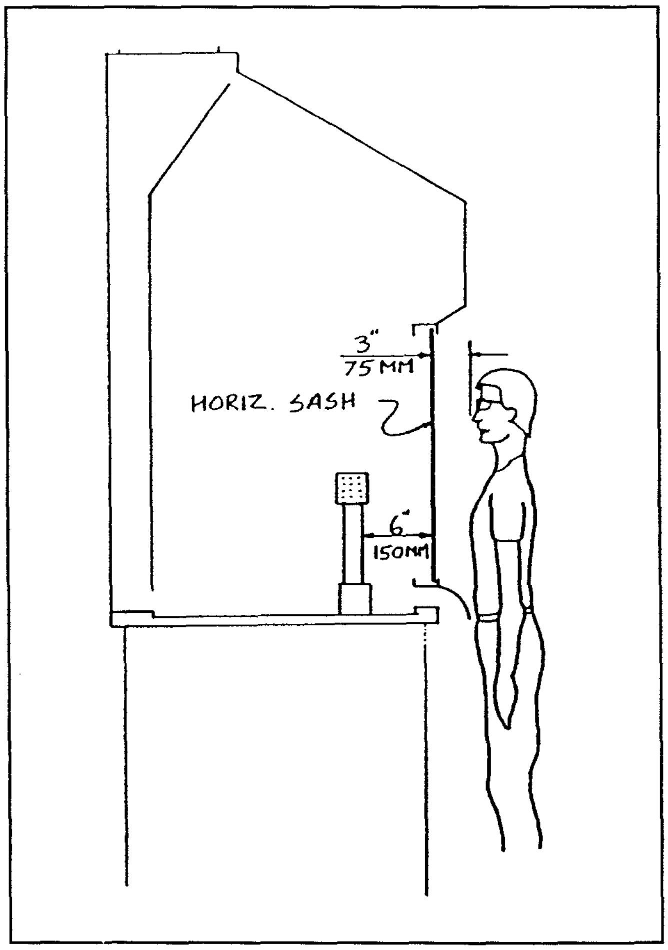


*Figure 7 Manikin and ejector position.*

**5.1.2 Manufacturer's Test Laboratory** The following additional requirements shall apply when testing in a manufacturer's test laboratory.

**5.1.2.1** The manufacturer's test lab shall have minimum drafts or crosscurrents. Measured crosscurrents in an area 5 ft (1.5 m) from the face of the hood shall be no greater than 30 fpm (0.15 m/s).

**5.1.2.2** The manufacturer's test lab shall have room pressurization control capable of measuring and maintaining a pressure differential of 0.02 in. w.g. (5 Pa) below the static pressure outside the test room.

**5.1.2.3** The manufacturer's test laboratory shall have the hood volumetric flow measured using *ANSI/ASHRAE 41.2-1987, Standard Method for Laboratory Airflow Measurement,*[3] and hood static pressure measured per *ANSI/ASHRAE 41.3-1989, Standard Method for Pressure Measurement,*[4] in the center of the exit plane at the top plane of the collar(s).

### 5.2 Hood Condition

**5.2.1 Sash Position** The sash or sashes shall be located in the design position or positions.

**5.2.2 Auxiliary Air Hoods** If the hood has an auxiliary supply, the supply shall be in operation. If the supply is capable of convenient adjustment by laboratory personnel, the adjustments shall be as specified.

### 5.3 Other Activity

General activity shall be maintained in as normal a state as possible during an "as used" test. The test shall be conducted with the normal hood apparatus in place and operating, except where clearance must be provided for the ejector.

### 5.4 Background Level

If air contaminants are present that are sensed by the detector as tracer gas at more than 10% of the presumed control level, use of such materials shall cease until background readings fall below 10% of the presumed control level or until substitution of tracer gas (4.1.2) shall be implemented.

### 5.5 Preliminary Data

**5.5.1** A sketch of the room shall be prepared indicating the location of significant equipment. Minimum data shall include a general layout of the room and location(s) of the test hood and other hoods.

**5.5.2** A sketch of the air supply system indicating the type of supply fixture (grilles, registers, ceiling diffusers, perforated ceiling, other) shall be made. Other activities in the room shall be indicated. Information on the number of other fume hoods and their condition of operation is required.

**5.5.3** The hood type and size, sash configurations, presence of an airfoil, beveled entries, sash stops, and position of baffles shall be noted.

**5.5.4** The location of material storage and the amount of work surface space occupied by materials within the hood shall be noted.

**5.5.5** The tracer gas detector and the sample rate shall be identified.

## 6. FLOW VISUALIZATION AND VELOCITY PROCEDURE

### 6.1 Flow Visualization

This test is a visualization of a hood's ability to contain vapors. The test consists of both a small local challenge and a gross challenge to the hood. The intent of this test is to render an observation of the hood performance as it is typically used. Visible smoke is provided by means of a plastic bottle that contains an ampule of liquid titanium tetrachloride. Once the ampule is broken and the bottle squeezed, the plastic bottle will release a visible, persistent plume if titanium dioxide can be used to visualize airflow. Other sources of persistent, neutral buoyancy aerosols could provide the same visualization of the airflow.

**6.1.1 Local Visualization Challenge**

**6.1.1.1** The operation of the bottom air bypass air foil shall be tested by running the smoke bottle under the air foil. Smoke shall be exhausted smoothly and not be entrained in the vortex at the top of the hood.

**6.1.1.2** A stream of smoke shall be discharged from the bottle along both walls and the floor of the hood in a line parallel to the hood face and 6 in. (150 mm) behind the face of the hood and along the top of the face opening.

**6.1.1.3** A stream of smoke shall be discharged from the bottle in an 8 in. (200 mm) diameter circle on the back of the hood. Air movement toward the face of the hood shall be defined as reverse airflow, and lack of air movement shall be defined as dead air space. Smoke shall be generated at the work top of the hood and along all equipment in the hood. All the smoke shall be carried to the back of the hood and exhausted. Airflow patterns and time for hood clearance shall be observed and noted.

**6.1.1.4** If there is visible smoke flow out of the front of the hood, the hood fails the test and will receive no rating.

**6.1.2 Large-Volume Visualization Challenge** A suitable source of smoke or other visual challenge shall be used to release a large volume in the center of the sash opening on the work surface 6 in. (150 mm) inside the rear edge of the sash. Some smoke sources generate a jet of smoke that produces an unacceptably high directional component to the challenge to the hood (see A-6.1.2 for acceptable methods). Care is required to ensure that the generator does not disrupt the hood performance, leading to erroneous conclusions. It must be noted that containment is best observed from the side of the hood face. A release of smoke from the hood that is steady and visible is an indication of failure. Equipment in the hood, such as heating devices and agitators, shall operate during a test to determine if it contributes to leakage. Airflow patterns and time for hood clearance shall be observed and noted.

### 6.2 Face Velocity Measurements

A 1.0 ft$^2$ (300 mm × 300 mm) imaginary grid pattern shall be formed by equally dividing the design hood opening into vertical and horizontal dimensions. Velocity readings shall be taken with a calibrated anemometer fixed at the center of the grid spaces. The anemometer shall be held in the plane of the hood sash and perpendicular to the opening.

**6.2.1** Face velocities shall be integrated over a period of at least five seconds. If an anemometer is used that measures instantaneous point velocities, a minimum of four readings shall be taken at each point.

**6.2.2** Care shall be taken to stand to the side during measurement so as to affect the airflow as little as possible.

**6.2.3** The average of the velocity measurements shall be calculated, and the highest and lowest readings shall be noted.

### 6.3 Test Method for Variable-Air-Volume (VAV) Fume Hoods

**6.3.1** Verification shall be made that the VAV controls have been calibrated as defined by their manufacturer. This shall include calibration and adjustment of controllers, sensors, and VAV supply and exhaust boxes that are part of the system.

**6.3.2** The sash shall be adjusted to 25% of the design hood opening, and the face velocity allowed to stabilize. Face velocity measurements shall be conducted as defined in 6.2 and results recorded.

**6.3.3** The sash shall be adjusted to 50% of the design hood opening, and the face velocity allowed to stabilize. Face velocity measurements shall be conducted as defined in 6.2 and results recorded.

**6.3.4** The sash shall be opened to the full design hood opening, and the face velocity allowed to stabilize. Face velocity measurements shall be conducted as defined in 6.2 and results recorded. All measurements shall be recorded.

**6.3.5** Average face velocities for all sash positions shall be compared with design specifications.

### 6.4 VAV Response Test

**6.4.1** For this test, an anemometer must be used that has a display update frequency of at least 1 second and an internal time constant of 0.3 seconds or less.

**6.4.2** The hood sash shall be closed to 25% of the design hood opening, and the velocity probe mounted in a secure stand with the probe in the center of this opening. The probe shall be properly oriented to detect velocity perpendicular to the plane of the hood face. The face velocity shall be allowed to stabilize.

**6.4.3** The sash shall be fully opened in a smooth motion at a velocity between 1.0 ft/s (0.3 m/s) and 1.5 ft/s (0.5 m/s). Note: The tester shall stand to the side of the hood while opening the sash. On larger hoods, a tester on either side may be required. The time it takes from the start of the sash movement until the sash reaches the top and the time it takes from the start of the sash movement until the face velocity reaches and maintains, within 10%, the design face velocity shall be recorded.

## 7. TRACER GAS TEST PROCEDURE

**7.1** The detector shall be turned on and allowed time to equilibrate, and room background shall be determined. If the background is excessive (see 5.4), corrective procedures shall be implemented.

**7.2** Immediately before each test, the detector function shall be checked by subjecting the detector to a low concentration of tracer gas. If the detector does not respond properly, the hood test shall not be performed until the defect has been corrected. The detector shall at all times be operated in accordance with the manufacturer's instructions.

**7.3** The ejector shall be installed at a test position. For typical bench-type hoods, three positions are required: left, center, and right as seen looking into the hood. The left position is with the ejector centerline 12 in. (300 mm) from the left inside wall of the hood, center position is equidistant from the inside side walls, and right is 12 in. (300 mm) from the right inside wall. All positions are with the front of the ejector body 6 in. (150 mm) from the hood face. (See Figure 7.)

**7.4** The probe shall be positioned in the breathing zone of the manikin, with the breathing zone of the manikin 3 in. (75 mm) from the plane of the sash. (See Figure 7.)

**7.5** The detector probe shall be fixed in a position touching the face of the manikin in the region of the breathing zone, with the center of the probe 26 in. (660 mm) above the work surface and 3 in. (75 mm) in front of the sash (see Figures 8 and 9). The detector probe shall be attached to the manikin or fixed on a typical laboratory ring stand and clamp. Care shall be taken to ensure that any method of attaching the detector probe in the breathing zone of the manikin does not interfere with the flow patterns around the mannikin or probe.

**7.6 The tracer gas block valve shall be opened.**

**7.7** Manually or by recorder, the detector readings shall be observed and recorded for 5 minutes with a reading taken at least every 10 seconds. The positional control level is the

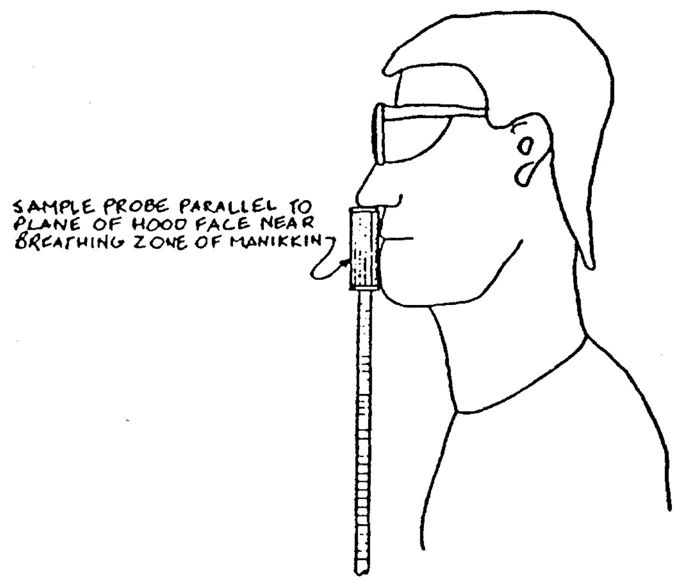


***Figure 8*** *Detector probe position.*

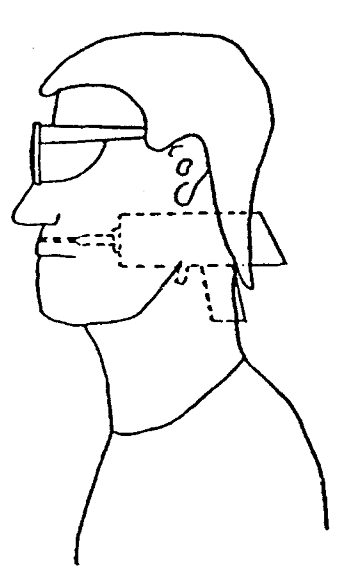

*Figure 9* *Detector position.*

average of the tracer gas concentrations during the five-minute test.

**7.8** The ejector and manikin shall be relocated to another test position and the measurements shall be repeated for each test position.

**7.9** The control-level rating of the hood shall be the maximum of the positional control levels for the three test positions (see 7.3).

**7.10** The performance rating of the hood shall be recorded as either AU yyy, AI yyy, or AM yyy, where yyy equals control level, ppm.

**7.11** With the manikin removed from the face of the hood and the block valve open to the ejector, the periphery of the hood openings shall be traversed with the probe. While standing away from the face of the hood, the probe shall be held 1 in. (25 mm) away from the edge of the hood opening and moved slowly around each opening at a rate of 3 in. (75 mm) per second. The maximum concentration and location observed during the traverse shall be recorded. Care shall be taken to stand to the side during measurement to affect flow as little as possible.

**7.12 Sash Movement Effect**

**7.12.1** The manikin shall be located at the appropriate test position with the sash at the design opening. The block valve shall be opened and the sash closed. After two minutes, a background level with the sash closed shall be determined. If tracer gas is detected with the sash closed, the test shall be terminated until the source of leakage is determined and eliminated. The sash shall be opened to the design opening in a smooth motion at a velocity between 1.0 ft/s (0.3 m/s) and 1.5 ft/s (0.5 m/s) while tracer gas is released and the tracer gas concentration shall be recorded. The peak levels shall be noted. After the system has stabilized (i.e., the face velocity has reached and maintained the design face velocity within 10%), but for a minimum of two minutes after opening the sash, the sash shall be closed at a rate between 1.0 ft/s (0.3 m/s) and 1.5 ft/s (0.5 m/s) while continuing to record the tracer gas concentration. The cycle shall be repeated three times.

**7.12.2** The *sash movement effect* (SME) is the maximum peak tracer gas concentration determined in 7.12.1. The *sash movement performance rating* of the hood shall be recorded as SME-AU yyy, SME-AI yyy, or SME-AM yyy, where yyy equals sash movement effect, ppm.

## 8. REFERENCES


1. *ASHRAE Terminology of HVAC&R, 1991.*
2. *ANSI/ASHRAE 111-1988, Practices for Measurement, Testing, Adjusting, and Balancing of Building Heating, Ventilation, Air-Conditioning, and Refrigeration Systems.*
3. *ANSI/ASHRAE 41.2-1987, Standard Method for Laboratory Airflow Measurement.*
4. *ANSI/ASHRAE 41.3-1989, Standard Method for Pressure Measurement.*


## APPENDIX A

The items in this appendix are numbered to correspond to subsections within the standard for the convenience of the standard user. Subject titles have also been provided where appropriate. All provisions are to enhance the user's understanding of the subject as well as the standard.

**A-3 (Air Supply Fixtures)** The list of air supply fixtures in Section 3, "Definitions," is not intended to be inclusive or complete. The investigator should describe all the fixtures, including size and location, throughout the test room.

**A-3 (Laboratory Fume Hood)** The test procedure presumes a bench-type laboratory fume hood. If other types of laboratory fume hoods are used, some modification of the test procedure will be required to reflect the departure from the presumed fume hood. For example, the position of the ejector in the walk-in fume hood must be critically evaluated before the performance test is conducted. In many instances, it would not be appropriate to place the ejector on the floor at the appropriate distance in from the side walls or at the center line.

**A-4.1 (Tracer Gas)** Although sulfur hexafluoride is specified, it may not be possible to use it in some laboratories without upsetting the operation within the laboratory. For example, a laboratory that has been doing trace fluoride analyses may not be able to operate while sulfur hexafluoride is released for hood testing purposes. In such cases, a substitute gas may be appropriate. That gas should be stable, nontoxic, non-odorous, and noncorrosive and able to be detected by the detector at an appropriate low level.

**A-4.1 (Tracer Gas Release Rate)** If desired, a different release rate can be established based on knowledge of the generation rate in the intended use.

**A-4.1.2 (Tracer Gas Substitution)** In some instances, the tracer gas may have a detrimental effect on the system. For example, for a hood with an activated carbon filter, sulfur hexafluoride may reduce the life of the carbon bed or replace toxic materials adhering to the carbon, resulting in an undesirable release.

**A-4.2 (Ejector System)** In some instances, it may be appropriate to remotely mount the pressure gage and block valve at the cylinder rather than at the ejector. However, since this will increase the pressure loss through the line, the calibration of the pressure gage and orifice (4.3.2) should be conducted with the connecting hose or tube in place.

**A-4.2 (Ejector System)** The mesh size of the screen influences the plume of gas generated by the ejector. Close adherence to the specification is required.

**A-4.3.1 (Critical Orifice)** Other tracer gas flow rates may be achieved by modifying the upstream pressure and/or replacing the orifice plate.

**A-4.3.3 (Critical Orifice)** The flow rate of the tracer gas may be measured with a bubble meter. Note: Altitude and temperature can affect actual flow rate.

**A-4.4 (Detector Instruments)** In some cases, an alternative method of collection may be used. An air-sampling pump and a gas bag can be used to collect a sample in the breathing zone of the manikin. The air sample can be analyzed by gas chromatography, and this method will determine the average concentration in the breathing zone of the manikin; however, it will not show the variation in concentration of the tracer gas concentration and so considerable information may be lost. Moreover, it cannot be used to determine the sash movement effect of the hood.

**A-4.6 (Manikin)** The standardized manikin is designed for a standard bench hood. The investigator may use a manikin that better represents the uses or special applications. For example, a handicap hood has different dimensions to accommodate a wheelchair. The manikin can be modified to simulate a chemist or technician at the face of the hood. The torso of the manikin can be placed in a wheelchair or the supports can be adjusted to represent the same geometry as would occur with a wheelchair. The critical value would be the height of the center line of the sensor above the work surface of the hood (24 in. or 610 mm) and the position relative to the hood opening. In a similar way, the manikin can be modified or adjusted to test walk-in or distillation hoods.

**A-4.7 (Face Velocity Measuring Instruments)** It is desirable to be able to record the output of the anemometer. For the dynamic tests, either a strip chart recorder or a datalogger would be adequate.

**A-4.8.1 (Smoke, Local Generation)** Liquid titanium tetrachloride can stain the hood and will produce a residue that must be cleaned up. If liquid titanium tetrachloride is used, apply masking tape to surfaces before applying titanium tetrachloride.

**A-4.8.2 (Smoke, Large-Volume Generation)** There are three generally available methods of generating smoke. Several manufacturers provide small smoke candles that generate copious smoke. It is important that the smoke generated not have a large directional component. Often it is sufficient to place the candle in a coffee can to dissipate this directional component. A second way to generate smoke is with a theatrical smoke generator. A third way is to use dry ice in hot water to generate a visible mist; however, this method does not provide a neutral buoyancy aerosol and may not be sufficient to demonstrate losses of air from the top of the laboratory hood. (See also A.6.1.2.)

**A-5.2.1 (Sash Position, Fully Open)** When the design documents describe a condition other than full-open sash, the user may operate the hood with the sash opened beyond the design condition, resulting in a lower face velocity than design. This could reduce the protection provided by the hood. The hood should be tested with the sashes full open to determine the effect of the misuse of the hood.

**A-5.2.1 (Sash Position, Combination Sashes)** If the hood has a combination sash—that is, a vertically sliding sash with horizontal panels—the hood should be tested with the vertical sash fully closed and the horizontal sashes adjusted to provide a maximum hood opening, with the horizontal panels positioned to the side opposite the hood from the location of the manikin or to both sides when the manikin is located in the center so as to provide the maximum face opening directly in front of the manikin. In addition, the hood should be tested at the same volumetric flow rate with the vertical sash fully open.

**A-5.2.1 (Sash Position, Variable-Air-Volume Hoods)** If a hood is provided with variable-air-volume control, the hood should be tested at the appropriate sash position or positions after the variable-air-volume control has equilibrated to provide constant volumetric flow. Prior to testing the hood, a velocity profile is required to ensure that the variable-air-volume system has adequate capacity to provide the predetermined face velocity. (See also A-6.4.)

**A-5.2.1 (Sash Position, Horizontally Moving Sash)** If the hood has a horizontally moving sash, the sash should be positioned so as to obtain the maximum face opening of the hood and so that the sash is remote from the section of the hood being tested (left, center, or right). (See Section 7.3.)

**A-5.3 (Other Activity)** The "as used" test is intended to be conducted within the hood as it is typically used. The exposure to the worker at the hood will be dependent upon a multitude of factors, including such things as the apparatus used in the hood, the use of heat-generating equipment, whether the hood is used as a storage cabinet, whether the equipment forces the worker to conduct this test too far forward, etc.

**A-5.5 (Preliminary Data)** Adequate data should be taken to allow for future interpretation of the test results. The number of unusual incidences that may occur are too many to be named, but the investigator should be observant and record any unusual situations.

**A-5.5.2 (Preliminary Data, Air Supply System Sketches)** In addition to indicating location and type of supply diffusers, attempts should be made to measure the residual velocity in the direction of the hood opening and to document cross-drafts at the face of the hood.

**A-5.5.3 (Preliminary Data, Hood Description)** Determination of the face opening should include the space between the airfoil and the work surface.

**A-5.5.4 (Preliminary Data, Materials within the Hood)** The location of materials inside the hood, especially in front of the manikin, may affect the control level.

**A-6.1.1 (Local Visualization Challenge)** Airflow at the sides and top of the hood face can be observed by means of a plastic bottle containing an ampule of titanium tetrachloride. When the ampule is broken and the bottle squeezed, a highly visible plume of titanium dioxide indicates the airflow patterns in the hood. Air movement toward the face of the hood is defined as reverse airflow, and lack of air movement is defined as dead air space. All the smoke should be carried to the back of the hood and exhausted. Smoke should be exhausted smoothly and not be entrained in the vortex at the top of the hood.

**A-6.1.2 (Large-Volume Visualization Challenge)** Smoke generation can produce a visible plume in the exhaust duct. It may be necessary to contact the fire department and possibly the local pollution control authority before discharging large quantities of smoke in the hood.

**A-6.1.2 (Large-Volume Visualization Challenge, Smoke Candles)** Any smoke candle should be ignited within the laboratory fume hood cavity so that the contaminants generated within the hood are quickly and efficiently controlled. The lighted candle should be moved about the fume hood work area, and areas near the ends of the hood, on the work surface, behind the sash, and at the top of the hood should be checked to verify that there is no reverse flow of air at these locations and that there is no escape from the hood enclosure.

Some smoke candles generate a jet of smoke that produces an unacceptably high challenge to the hood. To reduce this directional component, the smoke candle should be placed in a small can, approximately 4 inches (130 mm) in diameter and 6 inches (150 mm) high. The surface of the can could become warm, so the can should be held by a pair of pliers, tongs, or a similar device.

**A-6.1.2 (Large-Volume Visualization Challenge, Theatrical Fog)** An alternative approach to the smoke candle is theatrical fog or a smoke-generating machine. Both are capable of generating copious visible particulate with reasonable persistence and neutral buoyancy. Some fogs produce an aerosol that dissipates rapidly, leaving a contaminating residue in the hood. The output of the fogger or smoke generator can be directed into the hood by means of a long hose. This allows the investigator to locate the fog or smoke at any desired location. Since the fog or smoke may have momentum that could lead to an incorrect observation, a diffuser may be required to slow the fog or smoke.

**A-6.1.2 (Large-Volume Visualization Challenge, Smoke from Dry Ice)** Dry ice vapor can be used to visualize hood performance while being subjected to various challenges, such as room traffic and operations within the hood.The investigator is encouraged to anticipate the use of specific hoods and the peculiarities of installed locations and devise challenges to test with dry ice.

**Dry Ice Procedure:**

**(a)** Prepare for the test by weighing dry ice in a beaker and filling a stainless steel bowl with tempered water. The bowl should have a capacity of approximately 3 litres, with a diameter of approximately 20 centimeters. The bowl should contain one litre of water at 43°C (110°F). A 250 mL beaker should be filled with approximately 200 grams of dry ice. Texture of the dry ice is important, and pellets should be about 0.75 cm in diameter to provide the proper sublimation rate.

**(b)** The bowl containing tempered water should be placed inside the hood and positioned at the center on the face with the front edge of the bowl 6 inches (15 centimeters) behind the rear edge of the sash. The sash should be fully open.

**(c)** The dry ice pellets contained in the beaker should be deposited into the bowl and vapor dispersion observed. Containment is best observed from the side of the hood face. A release of vapor from the hood that is steady and visual is an indication of failure. No release of vapor past the face of the hood is considered acceptable.

**(d)** This test should be repeated while challenging the hood by moving across the front, reaching into the hood, and moving the sash. The bowl should be moved closer to the front of the work surface to determine where leakage is most pronounced. Equipment in the. hood such as heating devices and agitators shall be operated during a test to determine if they contribute to leakage.

**A-6.2.1 (Face Velocity Measurements)** In some hoods, there is considerable variation in the velocity readings at a fixed position. When the variations exceeds 15%, the range of variability should be noted and recorded and the average used in the computation of the face velocity. Wide variations might be an indication of room air currents or poor hood aerodynamic design that might negatively impact hood performance.

The procedure in 6.2 of the standard determines the face velocity of the laboratory hood but does not address the total volumetric flow through the hood or the total volumetric flow requirements at the exhaust fan. Leakage through the bypass, behind the hood sash, through the hood itself, and duct leakage can have a significant impact on the total exhaust flow; however, these factors are not addressed in this test procedure. To determine these values, a volumetric measurement as described in ANSI/ASHRAE 41.2-1987 (pitot traverse) would be required.

When measuring face velocity of an auxiliary air hood, the auxiliary airflow changes the face velocity produced by the hood exhaust. ANSI/ASHRAE Z9.5-1992, Laboratory Ventilation, states in paragraph 5.11.2, "the face velocity of the hood shall be determined with the supply air (auxiliary air) turned off." When measuring the face velocity of an auxiliary air hood, the condition of the auxiliary air should be noted and recorded.

**A-6.2 (Face Velocity Measurements)** Some laboratory hoods are designed with a sash plane that is not perpendicular to the flow of the air. If the ventilation measurements are taken as indicated in 6.2.1 of the standard, there may be a bias in the readings since many anemometers are sensitive to the direction of airflow. In such a case it may be necessary to hold the anemometer perpendicular to the airflow rather than the sash plane. This resulting velocity corresponds to the projected opening of the hood, not the actual opening.

**A-6.3 (VAV External Influences)** In an "as used" condition, it may be advisable to determine the external influence of other activities on the performance of the VAV controller. Since the laboratory pressure may influence the performance of the VAV controller, conduct a tracer gas test while opening and closing the door to the laboratory in such a way that the door movement does not cause a fanning action but does allow a pressure equalization with the corridor. Observe whether the controller modifies the hood exhaust rate and if there is a change in hood performance. Likewise, sash movements in hoods connected to the same exhaust system as the laboratory hood being tested could influence the hood performance. By opening and closing sashes on the other hoods while monitoring the VAV controller and the tracer gas concentration, the potential effect can be determined.

**A-6.3.2 (Test Method for Variable-Air-Volume [VAV] Fume Hoods)** The design opening is specified. In many cases it may be reasonable to test the hood with the sash or sashes fully open.

**A-6.4.3 (VAV Response Test)** Use of a recording device, such as a strip chart recorder or a datalogger, will reduce the chance for error during this measurement.

**A-7.3 (Ejector Test Position)** For hoods of unusual dimensions, the location of the ejector may require modifications. Alternative positions are possible and should be clearly identified in the test report. This becomes especially important with hoods of unusual dimensions or sash configurations.

**A-7.5 (Detector Probe Positions)** If the detector probe is amenable to it, insert the probe through the back of the head of the manikin so that the air sampled by the probe enters the probe through the approximate breathing zone of the manikin as shown in Figure 9.

The detector probe is to be fixed in position and not hand held. An investigator holding the probe could cause, by his/her presence, additional disturbance in airflow that may significantly change the hood performance.

The test procedure places the probe in the breathing zone of the manikin. Additional information on how the hood is performing can be obtained by traversing the face of the hood with the probe or locating the probe, detector, and manikin independently.

In the event that the sash is not vertical, the position of the probe and ejector is to be determined from a vertical plane starting at the intersection of the sash and the work surfaces. The probe and ejector distances from this plane should be as described in 7.5

**A-7.7 (Detector Readings)** A preferable method of collecting the data is with direct input into a computer or datalogger. Such data collection should be at least every second.

**A-7.11** The peripheral traverse data can be used as a diagnostic tool to determine potential leakage points. There is significant potential for variation in the traverse results due to variation in hand held probe positions and speed of traverse.

**A-7.12 (Sash Movement Effects)** Since hood performance depends considerably on the way a vortex is formed and shed by the manikin, the effect of moving the sash could depend on the status of the vortex formation. The result of each test should be recorded. The resulting rating should be clearly distinguished from the hood performance rating since a VAV hood functions as a constant-volume hood most of the time.

**(This appendix is not a part of this standard but is included for information purposes only.)**

## APPENDIX B—BIBLIOGRAPHY


Adams, John B., Jr. 1989. Synthesis—Laboratory fumehoods: Easy, reliable performance evaluation and importance of sash design. *Journal of Chemical Education* 66(12): A389-A391.

ANSI/AIHA Z9.5-1992, *Laboratory ventilation*, 1992.

ASHRAE. 1991. *1991 ASHRAE handbook—HVAC applications*, chapter 14, "Laboratories." Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Caplan, K.J., and G.W. Knutson. 1977. The effect of room air challenge on the efficiency of laboratory fume hoods. *ASHRAE Transactions* 83(1): 141-156.

Caplan, K.J., and G.W. Knutson. 1978. Laboratory fume hoods: Influence of room air supply. *ASHRAE Transactions* 84(1): 552-557.

Caplan, K.J., and G.W. Knutson. 1978. Laboratory fume hoods: A performance test. *ASHRAE Transactions* 84(1): 511-521.

## POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effects on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the standards and guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive technical committee structure, continue to generate up-to-date standards and guidelines where appropriate and adopt, recommend, and promote those new and revised standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating standards and guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.