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Standard Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions From Indoor Materials/Products¹

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1. Scope

1.1 The use of small environmental test chambers to characterize the organic emissions of indoor materials and products is still evolving. Modifications and variations in equipment, testing procedures, and data analysis are made as the work in the area progresses. Until the interested parties agree upon standard testing protocols, differences in approach will occur. This guide will provide assistance by describing equipment and techniques suitable for determining organic emissions from indoor materials. Specific examples are provided to illustrate existing approaches; these examples are not intended to inhibit alternative approaches or techniques that will produce equivalent or superior results.

1.2 Small chambers have obvious limitations. Normally, only samples of larger materials (for example, carpet) are tested. Small chambers are not applicable for testing complete assemblages (for example, furniture). Small chambers are also inappropriate for testing combustion devices (for example, kerosene heaters) or activities (for example, use of aerosol spray products). For some products, small chamber testing may provide only a portion of the emission profile of interest. For example, the rate of emissions from the application of high solvent materials (for example, paints and waxes) via brushing, spraying, rolling, etc. are generally higher than the rate during the drying process. Small chamber testing can not be used to evaluate the application phase of the coating process.

1.3 The guide does not provide specific guidance for determining emissions of formaldehyde from pressed wood products, since large chamber testing methods for such emissions are well developed and widely used. For more information refer to Test Method E 1333. It is possible, however, that the guide could be used to support alternative testing methods.

1.4 The guide is applicable to the determination of emissions from products and materials that may be used indoors. The effects of the emissions (for example, toxicity) are not addressed and are beyond the scope of the guide.

1.5 As an ASTM guide, options are described, but specific courses of action are not recommended. The purpose of this guide is to increase the awareness of the user to available techniques for evaluating organic emissions from indoor materials/products via small chamber testing and to provide information from which subsequent evaluation and standardization can be derived.

1.6 Within the context of the limitations discussed in this section, the purpose of this guide is to describe the methods and procedures for determining organic emission rates from indoor materials/products using small environmental test chambers. The techniques described are useful for both routine product testing by manufacturers and testing laboratories and for more rigorous evaluation by indoor air quality (IAQ) researchers. Appendix X1 provides additional references for readers wishing to supplement the information contained in this guide.

1.7 The values stated in SI units are to be regarded as standard.

1.8 *This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- D 1193 Specification for Reagent Water²
- D 1356 Terminology Relating to Sampling and Analysis of Atmospheres³
- D 1914 Practice for Conversion Units and Factors Relating to Sampling and Analysis of Atmospheres³
- D 3195 Practice for Rotameter Calibration³
- D 3609 Practice for Calibration Techniques Using Permeation Tubes³
- D 3686 Practice for Sampling Atmospheres to Collect Organic Compound Vapors (Activated Charcoal Tube Adsorption Method)³

¹ This guide is under the jurisdiction of ASTM Committee D22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.05 on Indoor Air.

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² Annual Book of ASTM Standards, Vol 11.01.

³ Annual Book of ASTM Standards, Vol 11.03.

D 3687 Practice for Analysis of Organic Compound Vapors Collected by the Activated Charcoal Tube Adsorption Method³

E 355 Practice for Gas Chromatography Terms and Relationships⁴

E 1333 Test Method for Determining Formaldehyde Concentrations in Air and Emission Rates from Wood Products Using a Large Test Chamber⁵

3. Terminology

3.1 *Definitions*—For definitions and terms used in this guide, refer to Terminology D 1356. For an explanation of units, symbols, and conversion factors, refer to Practice D 1914.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *air change rate*—the flow rate of clean, conditioned air into the chamber divided by the chamber volume; usually expressed in units of h⁻¹.

3.2.2 *product loading*—the ratio of the test specimen area to the chamber volume.

4. Significance and Use

4.1 *Objectives*—The use of small chambers to evaluate organic emissions from indoor materials has several objectives:

4.1.1 Develop techniques for screening of products for organic emissions;

4.1.2 Determine the effect of environmental variables (that is, temperature, humidity, air exchange) on emission rates;

4.1.3 Rank various products and product types with respect to their emissions profiles (for example, emission factors, specific organic compounds emitted);

4.1.4 Provide compound-specific data on various organic sources to guide field studies and assist in evaluating indoor air quality in buildings;

4.1.5 Provide emissions data for the development and verification of models used to predict indoor concentrations of organic compounds; and

4.1.6 Develop data useful to manufacturers and builders for assessing product emissions and developing control options or improved products.

4.2 *Mass Transfer Considerations*—Small chamber evaluation of emissions from indoor materials requires consideration of the relevant mass transfer processes. Three fundamental processes control the rate of emissions of organic vapors from indoor materials; evaporative mass transfer from the surface of the material to the overlying air, desorption of adsorbed compounds, and diffusion within the material. For more information, refer to Bird, Stewart, and Lightfoot (1960) and Bennett and Myers (1962) in X1.1.

4.2.1 The evaporative mass transfer of a given organic compound from the surface of the material to the overlying air can be expressed as:

$$E = km (VPs - VPa) \quad (1)$$

where:

E = emission rate,

km = mass transfer coefficient,

VPs = vapor pressure at the surface of the material, and

VPa = vapor pressure in the air above the surface.

Thus, the emission rate is proportional to the difference in vapor pressure between the surface and the overlying air. Since the vapor pressure is directly related to the concentration, the emission rate is proportional to the difference in concentration between the surface and the overlying air. The mass transfer coefficient is a function of the diffusion coefficient (in air) for the specific compound of interest, the level of turbulence in the bulk flow.

4.2.2 The desorption rate of compounds adsorbed on materials can be determined by the retention time (or average residence time) of an adsorbed molecule:

$$\tau = \tau_o e^{-Q/RT} \quad (2)$$

where:

τ = retention time, s,

τ_o = constant with a typical value from 10⁻¹² to 10⁻¹⁵ s,

Q = molar enthalpy change for adsorption (or adsorption energy), J/mol,

R = gas constant, 8.314 J/mol-K, and

T = temperature, K.

The larger the retention time, the slower the rate of desorption.

4.2.3 The diffusion mass transfer within the material is a function of the diffusion coefficient (or diffusivity) of the specific compound. The diffusion coefficient of a given compound within a given material is a function of the compound's physical and chemical properties (for example, molecular weight, size, and polarity), temperature, and the structure of the material within which the diffusion is occurring. The diffusivity of an individual compound in a mixture is also affected by the composition of the mixture.

4.2.4 *Variables Affecting Mass Transfer*—While a detailed discussion of mass transfer theory is beyond the scope of this guide, it is necessary to examine the critical variables affecting mass transfer within the context of small chamber testing:

4.2.4.1 Temperature affects the vapor pressure, desorption rate, and the diffusion coefficients of the organic compounds. Thus, temperature impacts both the mass transfer from the surface (whether by evaporation or desorption) and the diffusion mass transfer within the material. Increases in temperature cause increases in the emissions due to all three mass transfer processes.

4.2.4.2 Air change rate is flow of outdoor air entering the indoor environment divided by the volume of the indoor space, usually expressed in units of h⁻¹. The air exchange rate indicates the amount of dilution and flushing that occurs in indoor environments. The higher the air change rate the greater the dilution, assuming the indoor air is cleaner, and the lower the concentration. If the concentration at the surface is unchanged, a lower concentration in the air increases the evaporative mass transfer by increasing the difference in concentration between the surface and the overlying air.

4.2.4.3 *Air Velocity*—The mass transfer coefficient (km) is affected by the velocity in the boundary layer above the surface and the level of turbulence. Generally, the higher the velocity

⁴ Annual Book of ASTM Standards, Vol 14.02.

⁵ Annual Book of ASTM Standards, Vol 04.10.

and the higher the level of turbulence, the greater the mass transfer coefficient. In a practical sense, above a certain velocity and level of turbulence, the resistance to mass transfer through the boundary layer is minimized (that is, the mass transfer coefficient reaches its maximum value). In chamber testing, some investigators prefer to use velocities high enough to minimize the mass transfer resistance at the surface. For example, air velocities of 0.3 to 0.5 m/s have been used in evaluating formaldehyde emissions from wood products. Such velocities are higher than those observed in normal residential environments by Matthews et al.,⁶ where in six houses they observed velocities with a mean of 0.07 m/s and a median of 0.05 m/s. Thus, other investigators prefer to keep the velocities in the range normally found indoors. In either case, an understanding of the effect of velocity on the emission rate is needed in interpreting small chamber emissions data.

4.3 Other Factors Affecting Emissions—Most organic compounds emitted from indoor materials and products are non-reactive, and chambers are designed to reduce or eliminate reactions and adsorption on the chamber surfaces (see 5.2.1). In some cases, however, surface adsorption can occur. Some relatively high molecular weight, high boiling compounds can react (that is, with ozone) after being deposited on the surface. In such cases, the simultaneous degradation and buildup on and the ultimate re-emission from the chamber walls can affect the final chamber concentration and the time history of the emission profile. Unless such factors are properly accounted for, incorrect values for the emission rates will be calculated (see 9.4). The magnitude of chamber adsorption and reaction effects can be evaluated by way of mass balance calculations (see 9.5). For further information on these processes see Jayjock, et al. (X1.1).

4.4 Use of the Results—It is emphasized that small chamber evaluations are used to determine source emission rates. These rates are then used in IAQ models to predict indoor concentration of the compounds emitted from the tested material. Consultation with IAQ modelers may be required to ensure that the small chamber test regime is consistent with the IAQ model assumptions. The concentrations observed in the chambers themselves should not be used as a substitute for concentrations expected in full-scale indoor environments.

5. Facilities and Equipment

5.1 A facility designed and operated to determine organic emission rates from building materials and consumer products found indoors should contain the following: test chambers, clean air generation system, monitoring and control systems, sample collection and analysis equipment, and standards generation and calibration systems. Fig. 1 is a schematic showing an example system with two test chambers.

5.2 Environmental Test Chambers—Small environmental test chambers are designed to permit the testing of samples of various types of building materials and consumer products.

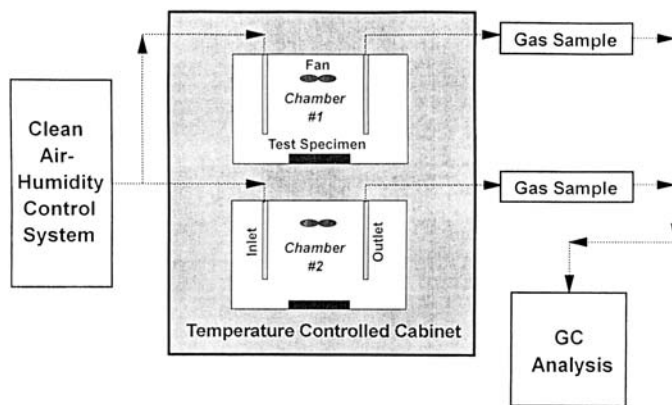


FIG. 1 Small Chamber Test Facility Schematic

They can range in size from a few litres to 5 m³. Generally, chambers of more than 5 m³ are considered “large.” Large chambers permit the testing of complete assemblages (for example, furniture); they may also be used to evaluate activities (for example, spray painting). For the purpose of this guide, small chambers are assumed to be used to test samples of larger materials and products, as opposed to full scale materials or processes.

5.2.1 Construction—Small environmental test chambers should have non-adsorbent, chemically inert, smooth interior surfaces so as not to adsorb or react with compounds of interest. Care must be taken in their construction to avoid the use of caulks and adhesives that emit or adsorb volatile organic compounds. Electropolished stainless steel and glass are common interior surfaces. The chamber must have an access door with air tight, non-adsorbent seals. The chambers must be fitted with inlet and outlet ports for air flow. Ports for temperature and humidity probes may also be required. Ports for sample collection are needed only if the sampling is not conducted in the outlet air (see 6.2).

5.2.2 Mixing—The chamber and its air moving components need to be designed to ensure good mixing of the incoming air with the chamber air. While contaminant concentration gradients are expected to exist in the chamber, particularly near the emissions source, the mixing issue concerns only the uniformity of the distribution of the air entering the chamber. Mixing fans and multi-port inlet and outlets are two techniques that have been used successfully to ensure adequate mixing of air in the chamber.

5.2.2.1 Assessment of Air Mixing—The adequacy of mixing in the chamber can be assessed using a tracer gas decay test, but other approaches may also be useful. Tests to determine the adequacy of mixing should be conducted not only in an empty chamber, but also with inert substrates of the types of samples to be tested to ensure that placement of the samples in the chamber will not result in inadequate mixing.

5.2.2.2 Decay Test for Quantifying Mixing—The decay approach involves establishing a uniform tracer gas concentration within the chamber and monitoring the tracer gas concentration decay in the outlet air over time. A uniform concentration can be established by injecting tracer at a constant rate and waiting until the outlet air concentration has reached equilibrium. The monitoring of the decay should start as soon as the

⁶ Matthews, T. J., Thompson, C. V., Wilson, D. L., Hawthorne, A. R., and Mage, D. T., “Air Velocities inside Domestic Environments: An Important Parameter for Passive Monitoring,” *Indoor Air’87—Proceedings of the 4th International Conference on Indoor Air Quality and Climate*, Institute for Water, Soil and Air Hygiene, West Berlin, Vol 1, August 1987, pp. 154–158.

tracer gas injection is stopped and continue for at least one time constant t_n , where t_n equals the inverse of the chamber air change rate. In this analysis, the tracer gas concentration is assumed to equal zero in the inlet air during the decay. The degree of mixing is assessed by determining a mixing level η defined as follows:

$$n = \left\{ 1 - \frac{\sum_{i=1}^n [C_A(t_i) - C(t_i)](t_i - t_{i-1})}{\sum_{i=1}^n [C(t_i) (t_i - t_{i-1})]} \right\} \times 100 \% \quad (3)$$

where:

- η = mixing level,
- N = chamber air change rate in units of inverse time,
- t_n = time constant of chamber = N^{-1} ,
- $C_m(t_i)$ = tracer gas concentration in chamber exhaust,
- $C(t_i)$ = concentration for perfectly mixed system, calculated by $C(t) = C_{oe}^{-Nt}$,
- n = number of discrete concentration measurements, and
- t_i = time of i th concentration measurement, and
- C_o = tracer gas concentration at $t = 0$.

If the mixing level η , as determined using Eq 3, is above 80 %, then the air mixing within the chamber can be considered adequate.

5.2.3 Surface Velocity—As discussed in 4.2.4.3, the velocity near the surface of the material being tested can affect the mass transfer coefficient. Thus, sources with evaporative (gas-phase limited) emissions should be tested under typical indoor velocities (for example, 5 - 10 cm/s). A small fan can be used to achieve such velocities. Some investigators have had success with DC voltage computer fans (the ones used to cool the chips). The fan can be suspended above the source with wire. A diffuser should be used to eliminate the calm spot downstream of the fan hub. If the air stream is directed upward, the air will circulate and flow across the source. Velocity measurements can be made with hot wire or hot film anemometers. These devices typically have lower detection limits of 3 to 5 cm/s. Velocities should be measured close to the source; for example, a height of 1 cm above the surface of a horizontal source. An average velocity can be based on measurements at several locations. For example, a source area could be divided into grid sectors (for example, 2 by 3, 3 by 4, and so forth) and measurements made at the sector mid-points. Without a fan, velocities near the source surface will be below the detection limit of the anemometer. If the emissions from the source being tested are limited by diffusion within the source, a fan is not necessary. For example, multisorbent traps containing glass beads, Tenax, Ambersorb, and charcoal have been used for quantitative collection and thermal desorption of compounds with boiling points from 36 to 253°C. Multisorbent traps containing graphitized carbons and carbon molecular sieve are also useful for collection and thermal desorption of a broad range of analytes. Recoveries of analytes may vary dramatically from one medium to another as well as with desorption temperature or other factors.

5.2.4 Temperature Control—Temperature control can be achieved by placing the test chambers in incubator cabinets or other controllable constant temperature environments. The temperature of the inlet air can be controlled by using conditioning coils.

5.2.5 Lights—Small chambers are normally operated without lights. If the effect of lighting on emissions is to be determined, appropriate interior illumination should be provided. If lighting is used, care should be taken to avoid heating of the chamber interior.

5.3 Clean Air Generation System—Clean air must be generated and delivered to the chambers. A typical clean air system might use an oilless compressor drawing in ambient air followed by removal of moisture (for example, using a membrane dryer) and trace organics (for example, by catalytic oxidation units). Other options include gas cylinders or charcoal filtered outside or laboratory air. If granular media (for example, charcoal) are used for control of organics, a filter should be used downstream to remove particulate matter. Calculations should be conducted on the amount of air flow required before a decision is reached on the supply system. For most sources to be tested, extremely clean air is needed. Inlet concentrations should not exceed 2 $\mu\text{g}/\text{m}^3$ for any single compound or 10 $\mu\text{g}/\text{m}^3$ for the sum of all VOCs. The purity of the air should be verified by routine analysis of background air samples from a clean chamber.

5.3.1 Humidity Control—Humidity control of the chamber air is achieved by adding deionized water (see Specification D 1193) or HPLC grade distilled water to the air stream. Injection by syringe pumps followed by heating to vaporize the water can achieve desired humidity levels, although syringe pumps are prone to breakdown during prolonged, continuous use. Other types of pumps (for example, HPLC) might also provide sufficient accuracy. Humidification can also be accomplished by bubbling a portion of the airstream through deionized water at a controlled temperature (for example, in a water bath). The saturated air is then mixed with dry air to achieve the desired humidity. Steam humidification can also be used. Coiled lines inside the constant temperature environment can be used for inlet temperature equilibration before delivery to the test chambers.

5.4 Environmental Measurement and Control Systems—Measurement and control are required for air flow, temperature, and humidity. Air flow can be automatically monitored and controlled by electronic mass flow controllers, or manual flow control (for example, needle valve, orifice plate) and measurement (for example, bubble meter, rotameter) (see Practice D 3195) can be used. Some investigators recommend that the chamber be operated slightly above atmospheric pressure and that measurements be made of both atmospheric and chamber pressure. Temperature control is discussed in 5.2.4. Temperature measurement can be accomplished automatically via thermocouples or thermistors; manual dial or stem thermometers can also be used. Control of humidity depends on the humidification system employed. If liquid injection is used, water flow is controlled by the pump setting.

Control of humidity by saturated air requires temperature control of the water and flow control of the saturated air stream. Humidity measurement can be done by several types of sensors, including dew point detectors and thin-film capacitors. Temperature and humidity sensors should be located inside the chamber at least 5 cm from the inside wall and near the midpoint between the air inlet and outlet ports.

5.4.1 Automatic Systems—Microcomputer based measurement and control systems can be used to set air flow rates and monitor temperature, relative humidity and air flow during the course of experiments. Analog signals from temperature, relative humidity, and flow sensors are converted to digital units that can be stored by a microcomputer-based system, then processed to engineering units using appropriate calibration factors. In this way, chamber environmental data can be continuously monitored, then compiled and reduced for archival storage or display with minimal operator effort. Automatic systems are also capable of certain control functions. Digital signals can be output to control valves or converted to analog signals and sent out as set point signals to mass flow controllers. A graphics overlay program can be used to show current setpoints and measured values on a system schematic displayed on the microcomputer's monitor.

5.4.2 Manual Systems—While automatic systems provide enhanced data collection and control, they are also expensive and complex. The simplicity and low cost of manual systems may be preferable under many circumstances.

6. Sample Collection and Analysis

6.1 Indoor sources of organic emissions vary widely in both the strength of their emissions and the type and number of compounds emitted. Differences in emissions rates of several orders of magnitude among sources is not unusual. To characterize organic emissions fully, the sample collection/analysis system must be capable of quantitative collection and analysis of volatile, semivolatile, polar, and non-polar compounds. Any small chamber sampling and analysis technique or strategy developed must consider the emission characteristics of the specific source being evaluated. The design and operation of sample collection and analysis systems must be appropriate for the organic compounds (and their concentrations) being sampled. Such systems generally include sampling devices (for example, syringes, pumps), sample collectors (for example, syringes, adsorbent media, evacuated canisters), and instruments to analyze organic emissions (for example, gas chromatographs [GC], see Practice E 355). The remainder of this section provides a discussion of the alternatives available for small chamber sampling and analysis of organic emissions; technical details of specific systems are not included.

6.2 Sampling Devices—The exhaust flow (for example, chamber outlet) is normally used as the sampling point, although separate sampling ports in the chamber can be used. A multipoint sampling manifold can provide flexibility for duplicate samples. A mixing chamber between the test chamber and the manifold can be used to permit addition and mixing of internal standard gases with the chamber air stream. Sampling ports with septums are needed if syringe sampling is to be conducted. The sampling system should be constructed of inert material (for example, glass, stainless steel), and the system

should be maintained at the same temperature as the test chambers. The exhaust from the sampling system should be ducted into a fume hood, ensuring that any hazardous chemicals emitted by the test materials are isolated from the laboratory environment.

6.2.1 Samples can be drawn into gas tight syringes, GC sampling loops, evacuated canisters, or through sorbent cartridges using sampling pumps. Gas tight syringes and closed-loops are frequently used when chamber concentrations are high and sample volumes must be small to prevent overloading of the analytical instrument. Larger volume samples can be pulled through sorbent cartridges using sampling pumps. Flow rate can be controlled by an electronic mass flow controller or other means. The sampling flow rate should be regulated to prevent instabilities in the chamber system flow. Generally, this will require that the sampling flow rate be limited to <50 % of the chamber flow rate. Valves and a vacuum gage may be incorporated into the system to permit verification of system integrity before samples are drawn. The entire system can be connected to a programmable electronic timer to permit unattended sample collection.

6.3 Sample Collection Media—Selection of appropriate sample collection technique(s) will depend upon factors such as boiling point, polarity, and concentration ranges of the compounds of interest, as well as the amount of water vapor in the sample airstream. No single sample collection, concentration, and delivery system will be adequate for all analytes of interest, and the user must understand the limitations of any system used to characterize source emissions. If the sample is collected by way of syringe or closed-loop sampling, it is injected directly into a GC or other instrument for analysis. Collection in a sampling bag (for example, Tedlar⁷) or vessel (for example, glass, stainless steel) allows for larger samples. For many small chamber evaluations of indoor materials, low concentrations of the compounds of interest require large volume samples, and collection on an appropriate adsorbent medium is required. Several sorbent materials are available for use, singly or in combination, including activated carbon (see Practice D 3686), glass beads, Amborsorb,⁸ Tenax⁹ (polyphe-nylene oxide), graphitized carbon, and XAD-2.¹⁰ The selection of the sorbent (or sorbent combination) depends on the compound(s) to be collected. XAD-2¹⁰ resin can be used to collect compounds considered to be semi- or non-volatile (for example, boiling points above 180°C). If sorbent collection is used, the laboratory must be equipped with appropriate storage capabilities. Air tight glass tubes or chemically inert bags are both appropriate. Flushing the storage containers with high purity nitrogen prior to use will help assure their cleanliness. Samples should be stored in a freezer at -20°C. If possible, sorbent samples should be desorbed and analyzed within 48 h of collection.

6.3.1 When sorbents are used for sample collection, desorption and concentration is necessary (see Practice D 3687). For

⁷ Tedlar is a registered trademark of Dupont.

⁸ Amborsorb is a registered trademark of Rohm and Haas.

⁹ Tenax is a registered trademark of Enka Research Institute.

¹⁰ XAD-2 is a registered trademark of Rohm and Haas.

example, a clamshell oven can be used to thermally desorb sorbent cartridges with the vapors fed to the concentrator column of a purge and trap concentrator that thermally desorbs the organic compounds to the GC column. Supercritical fluid or solvent extraction and liquid injection to the GC can also be employed. Other concentration techniques are also available, including cryotrapping.

6.4 Organic Analysis Instrumentation—A variety of analytical instruments is available for determining the concentration of the organics sampled from the chamber, with GCs being the most commonly used. GCs have a wide variety of columns available for separating organic compounds. Capillary columns are generally preferred. Several detectors can be used depending on the purpose of the test and the compounds of interest. Mass spectrometers (MS) are the most versatile and can be used in the scan mode to identify unknown compounds. When used in the scan mode, a conventional MS has a sensitivity of about 10^{-9} g. An ion trap may have a sensitivity approaching 10^{-12} g in the scan mode. If conventional MS is being used to analyze for known compounds, it is operated in the selected ion mode where its sensitivity increases to 10^{-12} g. MS can be made even more sensitive via negative ionization. Flame ionization detectors (FID) are also widely used. They respond to a wide variety of organic compounds and have a sensitivity of 10^{-11} g. Electron capture detectors (ECD) are used for analyzing electronegative compounds (for example, halogenated organics) and have a sensitivity of 10^{-13} g. Some compounds are not easily measured with GCs; for example, low molecular weight aldehydes require other instrumentation (for example, HPLC or wet chemical colorimetric).

6.5 Standards Generation and System Calibration—Calibration gas may be added to the test chamber or sampling manifold from permeation ovens (see Practice D 3609), gas cylinders, or dilution bottles. Calibration (or tracer) gas is added through the test chamber in tests to determine chamber mixing, check for leaks, or to evaluate chamber “sink” effects. Internal standards for quality control may be added at the head of the sampling system. The internal standard should not be added to the chamber due to the potential for adsorption on the material being tested. Quality control can also be achieved by spiked samples.

7. Experimental Design

7.1 Test Objectives—The first step in designing an experiment for chamber tests of indoor materials/products is to determine the test objectives. For example, a builder or architect would be interested in emissions from a variety of materials to be used under a given set of conditions for a specific building. In this case, the experiment would be designed to handle many materials with one set of environmental conditions. A manufacturer might want to know the emissions characteristics of a single product under both normal and extreme conditions and would design a test to cover the appropriate range of environmental variables. IAQ researchers interested in the interactions among variables would use a more complex design involving ranges of several variables.

7.2 Critical Parameters—A basic experimental design for small chamber tests should include consideration of the effects of various parameters on the emission characteristics of the

materials to be tested. Six variables are generally considered to be critical parameters: temperature [T], humidity [H], air exchange rate [N], product loading [L], time [t], and air velocity [v].

7.2.1 Temperature ($^{\circ}\text{C}$), [T] affects the vapor pressure, diffusion coefficient (diffusivity), and desorption rates of the organic compounds in the materials/products and can have a major impact on emission rates.

7.2.2 Humidity, [H] has been shown to affect the emission rate of formaldehyde from particleboard and may have similar effects for other water-soluble gases. Humidity can be expressed in relative (% of saturation) or absolute (g water/ m^3 air) terms.

7.2.3 Air Exchange Rate (h^{-1}), [N] is determined by the flow rate of clean air to the chamber divided by the chamber volume. The air exchange rate indicates the amount of dilution and flushing that occurs in indoor environments and can have a major impact on chamber concentrations.

7.2.4 Product Loading (m^2/m^3), [L] is the ratio of the test specimen area to the chamber volume. This variable allows product usage in the test chambers to correspond to normal use patterns for the same product in “full scale” environments. Studies of formaldehyde emissions have shown that the ratio of air change rate (N) to product loading (L) is proportional to the emission rate. Thus, (N/L) is often selected as a parameter in designing chamber experiments. In some cases, the configuration of the source makes product loading an inappropriate parameter. For example, studies of sealants often employ elongated beads. In this case, the configuration and length of the bead are appropriate experimental design parameters.

7.2.5 Age (hours, days, etc.), [t] is a critical parameter, since most materials have emission rates that vary with time. Fresh, wet solvent-containing products can have emission rates that vary several orders of magnitude in a few hours; other materials such as pressed wood products may have emission rates that take several years to decay.

7.2.6 Air Velocity (cm/s or m/s), [v] is a critical parameter, because the air velocity over the surface of the emitting source can affect the emission rate, especially for wet, evaporative sources (see 4.2.4.3 and 5.2.3).

7.3 Product History—Information on the history of the material/product to be tested is useful in designing the testing program. Details of manufacture, production, or assembly may be useful in determining compounds to be emitted. Information on product age, treatment (for example, coatings, cleaning), storage conditions (that is, time, temperature, humidity, ventilation), and handling/transportation may provide additional insight. For example, older materials may emit at a lower rate than new materials; materials stored at high temperatures may also have lower emission rates when tested; storage or transportation with other materials may cause adsorption of organics that will be emitted during the chamber tests.

7.4 Selection of Sample to be Tested—The method used to select samples of materials for evaluation in small chambers depends on the purpose of the proposed testing.

7.4.1 If the purpose is to develop emission rates that are representative of a given product or material (or class of products or materials), a statistically based sampling strategy