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Standard Practice for Conducting Mixed Flowing Gas (MFG) Environmental Tests¹

This standard is issued under the fixed designation B827; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

^{ε1} NOTE—Note 3 and the notes in Table 1 were removed editorially in October 2009.

^{ε2} NOTE—Footnote 6 was added editorially in May 2010.

1. Scope

1.1 This practice provides procedures for conducting environmental tests involving exposures to controlled quantities of corrosive gas mixtures.

1.2 This practice provides for the required equipment and methods for gas, temperature, and humidity control which enable tests to be conducted in a reproducible manner. Reproducibility is measured through the use of control coupons whose corrosion films are evaluated by mass gain, coulometry, or by various electron and X-ray beam analysis techniques. Reproducibility can also be measured by in situ corrosion rate monitors using electrical resistance or mass/frequency change methods.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to become familiar with all hazards including those identified in the appropriate Material Safety Data Sheet (MSDS) for this product/material as provided by the manufacturer, to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use. See 5.1.2.4.*

2. Referenced Documents

2.1 *ASTM Standards:*²

B542 Terminology Relating to Electrical Contacts and Their Use

B765 Guide for Selection of Porosity and Gross Defect Tests for Electrodeposits and Related Metallic Coatings

B808 Test Method for Monitoring of Atmospheric Corrosion Chambers by Quartz Crystal Microbalances

B810 Test Method for Calibration of Atmospheric Corrosion Test Chambers by Change in Mass of Copper Coupons

B825 Test Method for Coulometric Reduction of Surface Films on Metallic Test Samples

B826 Test Method for Monitoring Atmospheric Corrosion Tests by Electrical Resistance Probes

B845 Guide for Mixed Flowing Gas (MFG) Tests for Electrical Contacts

D1193 Specification for Reagent Water

D2912 Test Method for Oxidant Content of the Atmosphere (Neutral Ki) (Withdrawn 1990)³

D2914 Test Methods for Sulfur Dioxide Content of the Atmosphere (West-Gaeke Method)

D3449 Test Method for Sulfur Dioxide in Workplace Atmospheres (Barium Perchlorate Method) (Withdrawn 1989)³

D3464 Test Method for Average Velocity in a Duct Using a Thermal Anemometer

D3609 Practice for Calibration Techniques Using Permeation Tubes

D3824 Test Methods for Continuous Measurement of Oxides of Nitrogen in the Ambient or Workplace Atmosphere by the Chemiluminescent Method

D4230 Test Method of Measuring Humidity with Cooled-Surface Condensation (Dew-Point) Hygrometer

E902 Practice for Checking the Operating Characteristics of X-Ray Photoelectron Spectrometers (Withdrawn 2011)³

G91 Practice for Monitoring Atmospheric SO₂ Deposition Rate for Atmospheric Corrosivity Evaluation

¹ This practice is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.11 on Electrical Contact Test Methods.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the [standard's Document Summary page](#) on the ASTM website.

³ The last approved version of this historical standard is referenced on www.astm.org.

3. Terminology

3.1 Definitions relating to electrical contacts are in accordance with Terminology **B542**.

4. Significance and Use

4.1 Mixed flowing gas (MFG) tests are used to simulate or amplify exposure to environmental conditions which electrical contacts or connectors can be expected to experience in various application environments (**1, 2**).⁴

4.2 Test samples which have been exposed to MFG tests have ranged from bare metal surfaces, to electrical connectors, and to complete assemblies.

4.3 The specific test conditions are usually chosen so as to simulate, in the test laboratory, the effects of certain representative field environments or environmental severity levels on standard metallic surfaces, such as copper and silver coupons or porous gold platings (**1, 2**).

4.4 Because MFG tests are simulations, both the test conditions and the degradation reactions (chemical reaction rate, composition of reaction products, etc.) may not always resemble those found in the service environment of the product being tested in the MFG test. A guide to the selection of simulation conditions suitable for a variety of environments is found in Guide **B845**.

4.5 The MFG exposures are generally used in conjunction with procedures which evaluate contact or connector electrical performance such as measurement of electrical contact resistance before and after MFG exposure.

4.6 The MFG tests are useful for connector systems whose contact surfaces are plated or clad with gold or other precious metal finishes. For such surfaces, environmentally produced failures are often due to high resistance or intermittences caused by the formation of insulating contamination in the contact region. This contamination, in the form of films and hard particles, is generally the result of pore corrosion and corrosion product migration or tarnish creepage from pores in the precious metal coating and from unplated base metal boundaries, if present.

4.7 The MFG exposures can be used to evaluate novel electrical contact metallization for susceptibility to degradation due to environmental exposure to the test corrosive gases.

4.8 The MFG exposures can be used to evaluate the shielding capability of connector housings which may act as a barrier to the ingress of corrosive gases.

4.9 The MFG exposures can be used to evaluate the susceptibility of other connector materials such as plastic housings to degradation from the test corrosive gases.

4.10 The MFG tests are not normally used as porosity tests. For a guide to porosity testing, see Guide **B765**.

4.11 The MFG tests are generally not applicable where the failure mechanism is other than pollutant gas corrosion such as in tin-coated separable contacts.

5. Apparatus

5.1 Apparatus required to conduct MFG tests are divided into four major categories, corrosion test chamber, gas supply system, chamber monitoring system, and chamber operating system.

5.1.1 Corrosion Test Chamber:

5.1.1.1 The chamber shall consist of an enclosure made of nonreactive, low-absorbing, nonmetallic materials contained within a cabinet or oven capable of maintaining the temperature to a maximum tolerance of $\pm 1^\circ\text{C}$ with a preferred tolerance held to $\pm 0.5^\circ\text{C}$ within the usable chamber working space accordance with **7.3**, with a means to introduce and exhaust gases from the chamber.

5.1.1.2 The chamber isolates the reactive gases from the external environment. Chamber materials that are not low-absorbing can affect test conditions by absorbing or emitting reactive gases, leading to control and reproducibility problems. The chamber construction shall be such that the leak rate is less than 3 % of the volume exchange rate.

5.1.1.3 The chamber shall have provision for maintaining uniformity of the average gas flow velocity within $\pm 20\%$ of a specified value or of the chamber average when the chamber is empty. For chambers with a dimension of more than 0.5 m, measurement points shall be in accordance with Test Method **B810**. For chambers with all dimensions of less than 0.5 m, a minimum of five points shall be measured at locations in the plane of sample exposure (perpendicular to the expected flow direction) that are equidistant from each other and the walls of the chamber. After all five or more data values are recorded, all measurements shall be repeated a second time. After the two sets of measurements are recorded, a third complete set shall be recorded. The arithmetic average of the 15 or more measurements shall be the chamber average. See **7.5** and **7.6.8**. If a hot wire anemometer is used for gas velocity measurements, it shall be made in accordance with Test Method **D3464**, with the exception that sample sites shall be in accordance with Test Method **B810**.

⁴ The boldface numbers in parentheses refer to the list of references at the end of this standard.

5.1.1.4 A sample access port is desirable. This should be designed such that control coupons can be removed or replaced without interrupting the flow of gases. Corrosion test chamber corrosion rates have been shown to be a function of the presence or absence of light (3, 4). Provision for controlling the test illumination level in accordance with a test specification shall be made.

5.1.1.5 Examples of test chamber systems are diagrammed in Figs. 1-3. They are not to be considered exclusive examples.

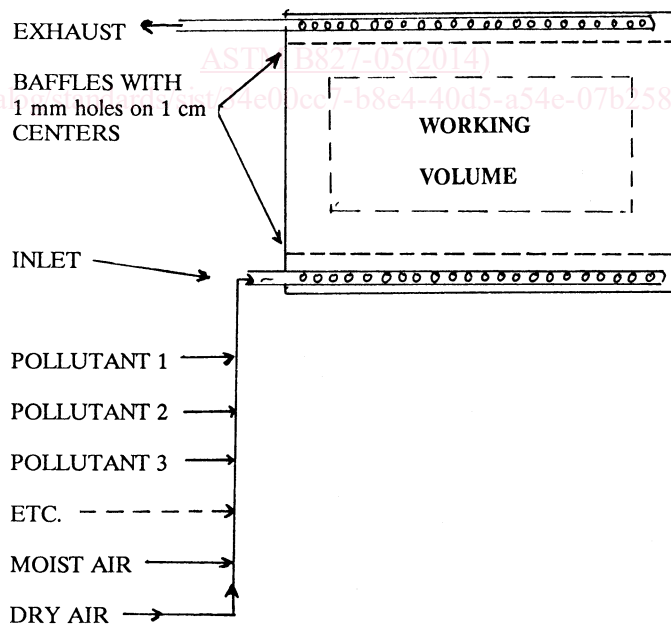
5.1.2 Gas Supply System:

5.1.2.1 Description and Requirements—The gas supply system consists of five main parts: a source of clean, dry, filtered air; a humidity source; corrosive gas source(s); gas delivery system; and corrosive gas concentration monitoring system(s). Total supply capacity must be such as to meet requirements for control of gas concentrations. The minimum number of volume changes is determined by the requirement that the concentration of corrosive gases be maintained within $\pm 15\%$ between gas inlet and outlet. This is verified by measurement of the gas concentrations near the gas inlet upstream of the usable chamber working volume and comparing with gas concentrations measured downstream of the usable chamber working volume just prior to the chamber exhaust; these values shall be within $\pm 15\%$ (see 7.6). Alternative methods of demonstrating compliance with the maximum allowable concentration gradient are acceptable. Normally, a conditioned chamber equilibrates within several hours after sample loading and start of the corrosive gas supply. Times longer than 2 h shall be reported in the test report; see Section 8. A guide to estimating supply requirements is provided in Appendix X1.

NOTE 1—Guidance: when inlet to outlet concentrations vary by more than $\pm 15\%$, it usually indicates an overloaded chamber.

5.1.2.2 Clean, Dry, Filtered Air Source—Gases other than oxygen and nitrogen that are present in the dry air source shall be less than or equal to those defined by OSHA Class D limits with the following additional constraint. Gases other than nitrogen, oxygen, carbon dioxide, noble gases, methane, nitrous oxide, and hydrogen shall be less than 0.005 (ppm) by volume total and shall be High Efficiency Particulate Arrestants (HEPA) filtered.

5.1.2.3 Humidity Source—The humidity source shall use distilled or deionized water, Specification D1193, Type 1 or better, and shall introduce no extraneous material. The humidity source shall be maintained equivalent to Specification D1193 Type II or better, with the exception that electrical resistivity shall be maintained equivalent to Specification D1193 Type IV. The time averaged value of humidity shall be within $\pm 1\%$ relative humidity of the specified value with absolute variations no greater than $\pm 3\%$ relative humidity from the specified value.



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MFG Corrosion Chamber with

Distributed Inlet and Exhaust

FIG. 1 Schematic Flow-Through Mixed Flowing Gas (MFG) Test System

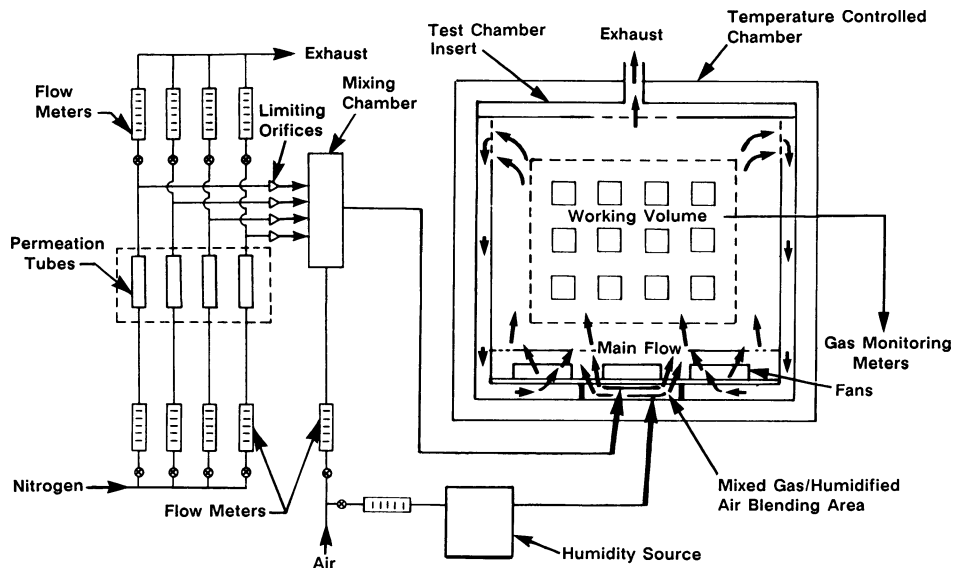


FIG. 2 Schematic Vertical Recirculating Mixed Flowing Gas (MFG) Test System

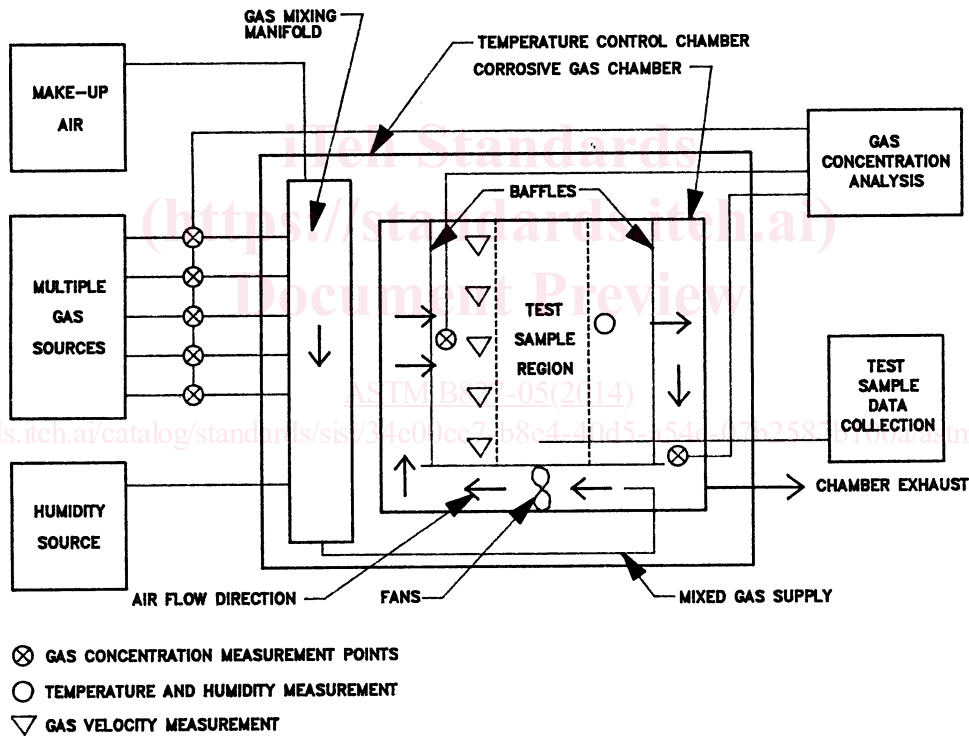


FIG. 3 Schematic Horizontal Recirculating Mixed Flowing Gas (MFG) Test System

5.1.2.4 *Corrosive Gas Sources*—Corrosive (test) gases, such as nitrogen dioxide, hydrogen sulfide, chlorine, sulfur dioxide, etc. shall be of chemically pure⁵ grade or better. Such gases are frequently supplied in dry carrier gas such as nitrogen or air. (**Warning**—This practice involves the use of hazardous materials, procedures, and equipment. The gas concentrations in the test chamber may be within permissible exposure limits (PEL). However, concentrations in the compressed gas cylinders or permeation devices are often above the PEL, and may exceed the immediately dangerous to life and health level (IDLH). This practice does not address safety issues associated with MFG testing.)

⁵ Chemically Pure and Pre-Purified are designations of Matheson Gas Co., East Rutherford, NJ, for specific grades of purity of gas. Other vendors such as AIRCO have equivalent gas purities available sold under different terminology.

5.1.2.5 *Gas Delivery System*—The gas delivery system is comprised of three main parts: gas supply lines, gas control valves and flow controllers,⁶ and a mixing chamber. The gas delivery system shall be capable of delivering gases at the required concentrations and rates within the test chamber.

(1) All materials used for the gas transport system must not interact with the gases to the extent that chamber gas concentrations are affected.

(2) Gases, make-up air, and water vapor must be thoroughly mixed before gas delivery to the samples under test in the chambers. Care must be taken to ensure absence of aerosol formation in the mixing chamber whereby gases are consumed in the formation of particulates which may interfere with gas concentration control and may introduce corrosion processes which are not representative of gaseous corrosion mechanisms. Aerosol formation may be detected by the presence of a visible film or deposit on the interior surface of the gas system where the gases are mixed.

(3) Any fogging of the tubing walls or mixing chamber walls can be taken to be an indication of a loss of corrosive gases from the atmosphere. Final mixing of the specified gases should occur inside a separate area of, or as close as possible to, the test chamber so as to ensure thermal equilibration with the test chamber.

(4) Flow measurement capability is required at the inlet of the chamber and also at the exhaust of negative pressure chambers to ensure the absence of uncalibrated gas streams.

5.1.2.6 *Corrosive Gas Concentration Monitoring System*—Standard measurement systems for very low level gas concentrations are listed in **Table 1**, which provides for gases in common use in present mixed flowing gas systems, for testing electrical contact performance.

(1) Each instrument must be characterized for interference with the gases specified, both individually and mixed.

(2) Depending on the exact equipment set used, it may not be possible to accurately measure the concentration of some gases, such as chlorine, in combination with any of the other gases.

(3) The analytic instruments shall be maintained and calibrated electronically in accordance with the manufacturers' recommendations. Standard gas sources shall also be calibrated in accordance with the manufacturers' specifications, or in accordance with Practice **D3609**. Gas concentration analyzers shall be calibrated to standard gas sources in accordance with the manufacturers' recommendations. They shall be calibrated before and after each test and whenever the indicated concentration changes exceed the allowed variation in the test specification.

(4) Control of the temperature and humidity within the test chamber itself is part of the chamber monitoring system which is described in **5.1.3**

NOTE 2—If the chlorine monitor is not being used during the test, it need not be calibrated during the test.

5.1.3 *Chamber Monitoring System*—Chamber monitoring systems are required to ensure test reproducibility from one test run to the next. Calibration of monitoring instruments is required periodically because the corrosive effects of mixed gas environments can affect instrument sensitivity and accuracy. The chamber monitoring system must address four test parameters: temperature, humidity, gas concentrations, and corrosivity.

5.1.3.1 *Temperature Monitoring*—Temperature monitoring is usually a simple thermocouple or other temperature measurement device capable of the required resolution of 0.2°C and accuracy of ±0.5°C within the temperature range required by the test specification. For test temperatures above 40°C, see **7.6.5**.

5.1.3.2 *Humidity Monitoring*—Humidity must be determined by an apparatus with a resolution of 0.5 % relative humidity and an accuracy of ±1 % relative humidity. Test Method **D4230** describes a dew point method which meets this requirement. For test temperatures above 40°C, see **7.6.5**.

5.1.3.3 *Corrosive Gas Monitoring*—Chamber corrosive gas concentration monitoring must be accomplished by provision of sampling lines from the test chamber to the gas concentration analyzers. These sampling lines must be maintained above the chamber dew point temperature. The interior of the gas concentration analyzers shall also be maintained above the chamber dew point temperature. For test temperatures above 40°C, see **7.6.5**.

5.1.3.4 *Chamber Corrosivity Monitoring*—Chamber corrosivity monitoring can be accomplished by a number of complementary techniques, none of which provide both a comprehensive analysis of the corrosion process and an instantaneous indication of the corrosion rate. Five acceptable techniques are as follows: metal coupon corrosion mass gain, corrosion film analysis by coulometric reduction, corrosion film analysis by electron or X-ray beam analysis, quartz crystal microbalance mass gain, and

⁶ Mass flow controllers are recommended for best results.

TABLE 1 Instrumental Methods for Gaseous Components

Gas	Suitable Instrumental Method	Suitable Procedure
H ₂ S	Photometric or luminescence	
SO ₂	Photometric or luminescence	Test Methods D2914 , G91 , D3449
NO ₂	Chemiluminescence	Method D3824
Cl ₂	Electrochemical or Reflectometric	Test Method D2912
The instrument manufacturer's instructions for delivering samples to the instruments should be followed.		

electrical resistance measurement of corroding metal conductors. The first three provide information subsequent to the test whereas the last two can be used in situ in the test chamber to provide information during the test itself. See [Appendix X2](#) for a discussion of these methods. It is recommended that the test requester specify chamber corrosivity monitoring methods to be used.

5.1.4 Chamber Operating System—The chamber operating system is comprised of equipment and software necessary to adequately control all of the variables of the test. This will include data logging and alert procedures for operation outside of desired bounds. Some form of computer control is highly recommended to assure satisfactory operation during unattended periods and for data tracking for failure analysis in case the test is disrupted.

6. Reagents and Materials

6.1 Materials required to conduct flowing mixed gas tests are as follows:

6.1.1 *Purity of Water*—Water for humidity generation shall be equivalent to Type 1 or better of Specification [D1193](#).

6.1.2 *Carrier Gas*—Carrier gas such as nitrogen shall not introduce reactive constituents into the test atmosphere to an amount of more than 5 % of any specified corrosive test atmosphere constituent.

6.1.3 *Clean Filtered Air*—Clean filtered air as required for makeup to support the necessary exchange rate, in accordance with [7.6.7.1 \(2\)](#) is specified in [5.1.2.2](#).

6.1.4 *Corrosive Gases*—Corrosive gases shall be chemically pure⁴ grade or equivalent.

6.1.5 *Corrosivity Monitor Materials (CMM)*—CMM are comprised of the coupons that are exposed to the test atmosphere for mass gain or coulometric reduction in accordance with Test Methods [B810](#) and [B825](#), respectively, the coated quartz crystals used for microbalance measurements in accordance with Test Method [B808](#), resistance monitor materials in accordance with Test Method [B826](#), or other coupons for analytical techniques described in [Appendix X2.3](#).

7. Procedure

7.1 The following procedure is comprised of requirements and other comments provided as a general guide to achieving reproducible results with MFG testing. This procedure is compatible with most test facilities; however, differences in apparatus, test conditions, or local safety requirements may necessitate alternative procedures. Any deviations shall be reported with all test results (see [Section 8](#)).

7.2 The procedure is comprised of the following major activities: test chamber calibration, sample preparation, test chamber set-up, test chamber start-up, test chamber operation during test duration, test chamber shut-down, and reporting requirements.

7.3 *Test Chamber Calibration*—The spatial uniformity of the corrosivity of test chambers larger than 0.5 m on a side shall be measured in accordance with Test Method [B810](#), which describes the required placement scheme for calibration samples which are used to determine corrosion rate uniformity over the entire chamber volume. For chambers smaller than 0.5 m on a side or chambers of unusual geometry, use sufficient samples for corrosivity characterization so as to clearly delineate the usable chamber working volume as defined in this paragraph. This profiling shall be done when the chamber is initially built and after any structural change to the chamber that may affect the flow of test gas over the test samples. Test Method [B810](#) describes a procedure using mass gain. Alternative means to characterize corrosion rates such as Test Method [B825](#), Coulometric Reduction, or Test Method [B808](#), Quartz Crystal Microbalance, in accordance with [5.1.3.4](#) are also acceptable. A minimum of three corrosivity monitors of a given type must be used, if possible, in each chamber location. The average corrosivity for that location must be within 15 % of the average for the entire chamber. When a single monitor has to be used at a location, due to chamber size limitations or monitor geometry, the average corrosivity for that location must be based upon three consecutive calibration runs. These requirements define the usable chamber working space.

NOTE 3—Profiling does not remove the necessity to provide and evaluate CMM for each test run of the test chamber.

7.4 *Sample Preparation*—Two types of samples are used for these tests, CMM and the test samples being evaluated. Prepare CMM in accordance with their respective standards, such as Test Method [B810](#).

7.4.1 Prepare the test samples in accordance with any agreement between vendor and user of the samples being tested. Such preparation shall be consistent with normal preparations expected when test samples would be exposed to normal application environments in their intended applications except when evaluation of preparation methods is the object of the test.

7.5 *Test Chamber Set-Up*—Place test samples and CMM in the chamber in a manner that is representative of the way the test samples would be used in the application environment, if known. This should be done in a consistent manner, such that the test results will be reproducible over time.

7.5.1 In general, the samples shall be suspended or held with their long dimension parallel to the flow of air and a minimum of 5 cm away from any surface to avoid boundary layer effects. It is particularly important that no test samples or CMM be shielded from the source of the pollutant gases by any control coupon, test fixture, test samples, test rack, or other obstruction placed upstream.

7.5.2 In general, when larger systems under test are being expressed to a MFG environment, the interior of the system under test will be underexposed due to the gettering or reaction of pollutant gases by the surrounding system surfaces. Under these circumstances, the system should be placed in the exposure chamber in a configuration that is consistent with exposure in actual field configuration. CMMs should be placed around the system under test.