Designation: G7/G7M – 13

Standard Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials[1]

This standard is issued under the fixed designation G7/G7M; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This practice covers procedures to be followed for direct exposure of nonmetallic materials to the environment. When originators of a weathering test have the actual exposure conducted by a separate agency, the specific conditions for the exposure of test and control specimens must be clearly defined and mutually agreed upon between all parties.

1.2 For exposures behind glass, refer to Practice G24.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 This practice is technically equivalent to the parts of ISO 877 that describe direct exposures of specimens to the environment.

1.5 *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 establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E41 Terminology Relating To Conditioning

E824 Test Method for Transfer of Calibration From Reference to Field Radiometers

E913 Method for Calibration of Reference Pyranometers With Axis Vertical by the Shading Method (Withdrawn 2005)[3]

E941 Test Method for Calibration of Reference Pyranometers With Axis Tilted by the Shading Method (Withdrawn 2005)[3]

G24 Practice for Conducting Exposures to Daylight Filtered Through Glass

G113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials

G130 Test Method for Calibration of Narrow- and Broad-Band Ultraviolet Radiometers Using a Spectroradiometer

2.2 *ISO Standards:*

ISO 877 Plastics—Methods of Exposure to Direct Weathering; to Weathering Using Glass-Filtered Daylight, and to Intensified Weathering by Daylight Using Fresnel Mirrors[4]

ISO 9370 Plastics—Instrumental Determination of Radiant Exposure in Weathering Tests—General Guidance and Basic Test Method[4]

2.3 *ASTM Adjuncts:*

A Test Rack[5]

3. Terminology

3.1 *Definitions*—The definitions given in Terminology E41 and Terminology G113 are applicable to this practice.

4. Significance and Use

4.1 The relative durability of materials in natural exposures can be very different depending on the location of the exposure because of differences in ultraviolet (UV) radiation, time of wetness, temperature, pollutants, and other factors. Therefore, it cannot be assumed that results from one exposure in a single location will be useful for determining relative durability in a different location. Exposures in several locations with different

[1] This practice is under the jurisdiction of ASTM Committee G03 on Weathering and Durabilityand is the direct responsibility of Subcommittee G03.02 on Natural and Environmental Exposure Tests.

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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.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Detailed drawings for an acceptable test rack may be obtained from ASTM International. Request ADJG0007.

climates which represent a broad range of anticipated service conditions are recommended.

4.2 Because of year-to-year climatological variations, results from a single exposure test cannot be used to predict the absolute rate at which a material degrades. Several years of repeat exposures are needed to get an "average" test result for a given location.

4.3 Solar ultraviolet radiation varies considerably as a function of time of year. This can cause large differences in the apparent rate of degradation in many polymers. Comparing results for materials exposed for short periods (less than one year) is not recommended unless materials are exposed at the same time in the same location.

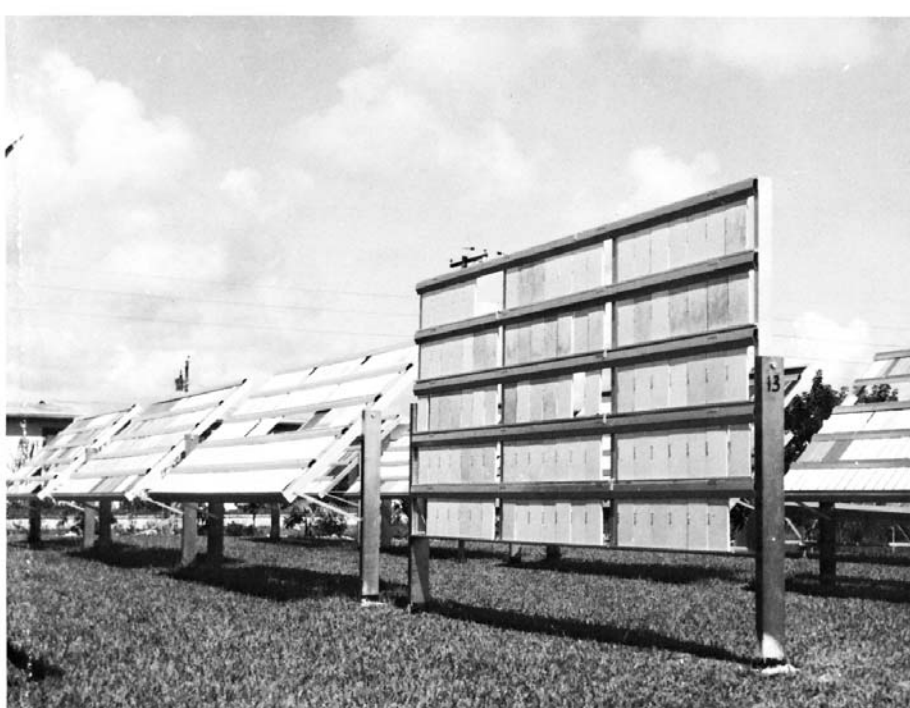
4.4 Defining exposure periods in terms of total solar or solar-ultraviolet radiant energy can reduce variability in results from separate exposures. Solar ultraviolet measurements are typically made using instruments which record broadband UV (for example, 295 to 385 nm) or narrow band UV, as described in 7.2.4 and 7.2.5. An inherent limitation in solar-radiation measurements is that they do not reflect the effects of temperature and moisture, which may also influence the rate or type of degradation.

4.5 The design of the exposure rack, the location of the specimen on the exposure rack, and the type or color of adjacent specimens can affect specimen temperature and time of wetness. In order to minimize variability caused by these factors, it is recommended that test specimens, control specimens, and any applicable weathering reference material be placed on a single test panel or on test panels placed adjacent to each other during exposure.

4.6 It is strongly recommended that at least one control material be part of any exposure evaluation. When used, the control material shall meet the requirements of Terminology G113, and be of similar composition and construction compared to test specimens. It is preferable to use two control materials, one with relatively good durability and one with relatively poor durability. Unless otherwise specified, use at least two replicate specimens of each test and control material being exposed. Control materials included as part of a test shall be used for the purpose of comparing the performance of test materials relative to the controls.

5. Test Sites, Location of Test Fixtures, and Exposure Orientation

5.1 *Test Sites*—Exposures can be conducted in any type of climate. However, in order to get more rapid indications of outdoor durability, exposures are often conducted in locations that receive high levels of solar radiation, temperature, and moisture. Typically, these conditions are found in hot desert and subtropical or tropical climates. Known attributes of the use environment should be represented by the locations selected for outdoor durability evaluation. For example, if the use environment for the product being evaluated will include freeze/thaw cycling, specimen exposure in a northern temperature climate is recommended. In addition, exposures are often conducted in areas where specimens are subjected to salt air (seashore) or industrial pollutants.



NOTE 1—Detailed drawings of this test rack are available from ASTM International, 100 Barr Harbor Dr., W. Conshohocken, PA 19428. Request Adjunct ADJG0007.

FIG. 1 Typical Exposure Rack

FIG. 2 Backed Exposure Rack

5.1.1 Unless otherwise specified, test fixtures or racks shall be located in cleared areas. Unless otherwise specified, the area beneath and in the vicinity of the test fixtures shall have ground cover typical of the climatological area where the exposures are being conducted. In desert areas, the typical ground cover is often gravel to control dust and in most temperate areas, the typical ground cover is low-cut grass. The type of ground cover at the exposure site shall be indicated in the test report. If test fixtures are placed over ground covers not typical of the climatological area (for example, rooftops, concrete or asphalt), specimens may be subjected to different environmental conditions than if using typical ground cover or exposing at ground level. These differences may affect test results.

5.2 The lowest row of specimens on a test fixture or rack shall be positioned at least 0.45 m [18 in.] above the ground and shall not contact vegetation. This will also minimize damage that might occur during area maintenance.

5.3 Test fixtures shall be placed in a location so that there is no shadow on any specimen when the sun's angle of elevation is greater than 20°.

5.4 *Exposure Orientation*—Unless otherwise specified, exposure racks shall be oriented so that specimens face the equator. Specimens can be exposed at a number of different orientations or "exposure angles" in order to simulate end-use conditions of the material being evaluated. Typical exposure angles are as follows:

5.4.1 *Latitude Angle*—Exposure rack is positioned so that the exposed surface of specimens are at an angle from the horizontal that is equal to the geographical latitude of the exposure site.

5.4.2 *45°*—Exposure rack is positioned so that the exposed specimens are at an angle of 45° from the horizontal. This is the most commonly used exposure orientation.

5.4.3 *90°*—Exposure rack is positioned so that the exposed specimens are at an angle of 90° from the horizontal.

5.4.4 *5°*—Exposure rack is positioned so that the exposed specimens are at an angle of 5° from the horizontal. This angle is preferred over horizontal exposure to avoid standing water on specimens being exposed. This exposure angle typically receives the highest levels of solar radiation during midsummer and is used to test materials that would normally be used in horizontal or nearly horizontal applications.

NOTE 1—Exposures conducted at less than the site latitude typically receive more ultraviolet radiation than exposures conducted at larger angles.

5.4.5 Any other angle that is mutually agreed on by all interested parties may be used. In some instances, exposures facing directly away from the equator or some other specific direction may be desired. The test report shall contain the exact angle and specimen orientation.

5.5 *Specimen Backing*—Three types of specimen backing can be used. Avoid comparisons between materials unless all exposures were conducted with the same specimen backing.

5.5.1 *Unbacked Exposures*—Specimens are exposed so that the portion of the test specimen being evaluated is subjected to the effects of the weather on all sides. For materials that deform easily during exposure, a wire mesh can be used to provide support and prevent deformation or distortion.

5.5.2 *Backed Exposures*—Specimens are attached to a solid substrate so that only the front surface is exposed. Surface temperatures of specimens in backed exposures will be higher than for specimens subjected to unbacked exposures. In some cases, the substrate is painted black, which produces significant differences in surface temperature compared to exposures

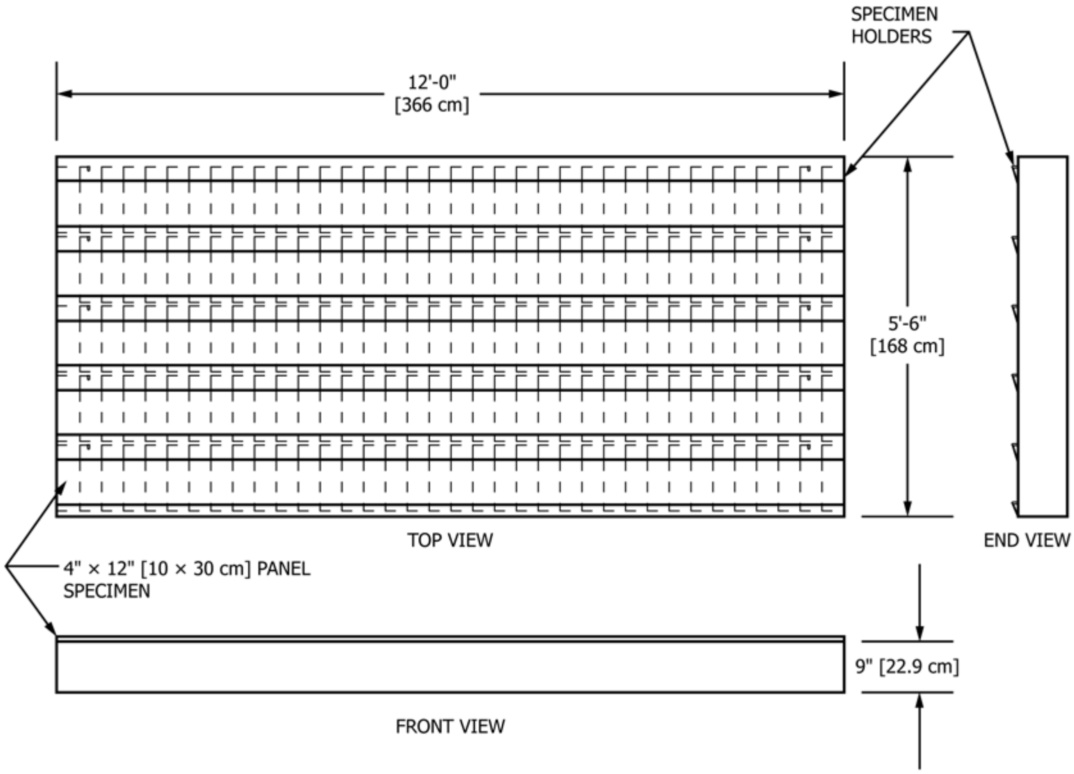


FIG. 3 Black Box

FIG. 4 Black Box in Use

conducted on unpainted substrate. This can cause large differences in degradation rates when compared to backed exposures conducted on unpainted substrates.

5.5.3 *Black Box Exposure*—Specimens are attached to the front face of a black painted aluminum box (see 6.2.3). The specimens form the top surface of the box. If there are not enough test specimens to completely cover the top surface, open areas shall be filled with black painted sheet metal panels so that the box is completely closed.

6. Construction of Test Fixtures (Exposure Racks)

6.1 *Materials of Construction*—All materials used for test fixtures shall be noncorrodible without surface treatment. Aluminum Alloys 6061T6 or 6063T6 have been found suitable for use in most locations. Properly primed and coated steel is suitable for use in desert areas. Monel has been found suitable in highly corrosive areas. Untreated wood is acceptable in desert areas but may pose maintenance problems in other areas. (See Fig. 1.)

6.1.1 For backed exposures (see 6.2.2 and Fig. 2), use exterior-grade plywood to form a solid surface to which specimens are directly attached. Replace the plywood when there is any warping or distortion that changes the orientation of the specimens, or when there are visible signs of delamination or fiber separation. Medium-density overlay (MDO) or high-density overlay (HDO) plywood are satisfactory substrates and require less frequent replacement than plywood with no overlay. The edges of the plywood should be sealed with a durable paint to prevent delamination.

6.2 *Test Fixture Design*—Test racks shall be constructed to hold specimens or specimen holders of any convenient width and length. Racks shall be constructed so that any contamination from specimens higher on the fixture cannot directly run down onto specimens in lower positions.[5]

6.2.1 *Unbacked Exposures*—Test racks shall be constructed so that most of the test specimen is exposed to the effects of the weather on all sides. Specimens are attached to the test fixture at the top or bottom, or both, using clamping devices, properly spaced slots, or mechanical fasteners. The method of attachment shall not prevent expansion and contraction of specimens caused by temperature or moisture. Use fastening devices for attaching specimens to the test fixture that will not corrode or degrade and contaminate the specimens. Aluminum, properly galvanized steel, or stainless steel fasteners are recommended.

6.2.2 *Backed Exposures*—Test racks shall be constructed so that specimens are attached to a plywood substrate. The thickness of the plywood and type of coating used, if any, shall be agreed upon by all interested parties and must be reported.

NOTE 2—Backed exposures as described in this standard are not insulated exposures. For some applications such as outdoor exposure tests for roofing products, a layer of insulation material is attached behind the solid substrate to which specimens are attached. Insulated exposures of this type produce higher specimen temperatures than those that would be seen on backed exposures conducted according to this practice.

6.2.3 *Black Box Exposures*—An aluminum box 0.23 m [9 in.] deep with the outside surface painted black. The top surface is open and fitted with mounting strips to hold specimens firmly in place. Two types of black boxes are in common usage. One measures approximately 1.7 m [5.5 ft] high and 3.7 m [12 ft] wide and the other measures 1.5 m [5 ft] high and 1.8 m [6 ft] wide. Fig. 3 shows the design and dimensions for an acceptable black box. Fig. 4 shows a black box in use. All exposure positions on a black box shall be filled with either test or control specimens or blank panels.

7. Instrumentation[6,7,8]

7.1 Unless otherwise specified, instruments for determining climatological data during the exposure period shall be operated within 1000 m of the test racks. Data obtained shall be reported if requested as part of the results of a test.

7.2 Instruments for recording the following are recommended:

7.2.1 *Ambient Temperature (Daily Maximum and Minimum)*—Instruments used for recording ambient temperature shall be a thermocouple (Type T or J), a thermistor, or a resistance temperature device (RTD). Any instrument used shall have a calibration traceable to the National Institute for Standards and Technology (NIST) and must be calibrated no less often than every twelve months. Instruments shall be mounted inside a white ventilated enclosure.

7.2.2 *Relative Humidity (Daily Maximum and Minimum)*—Instruments used for recording relative humidity must have a calibration traceable to NIST. Instruments shall be mounted inside a white ventilated enclosure.

7.2.3 *Total Solar Radiation*—For measurement of total solar radiation, use a pyranometer meeting either WMO (World Meteorological Organization) High Quality or Good Quality specification. Calibrate the pyranometer at the tilt-angle at which it will be used in suitable radiometric units. Calibrate the pyranometer against an instrument traceable to the WRR (World Radiometric Reference) at least annually. Perform this comparison either by comparison to a suitable reference pyranometer in accordance with Test Method E824 or by the direct shading disk calibration in accordance with Test Method E941 (for axis vertical and tilted respectively). If at tilt calibrations are not available, correct for tilt angle effects in accordance with the instructions provided by the radiometer manufacturer. If requested, a certificate of calibration shall be provided with all total solar irradiance measurements.

NOTE 3—Most radiometers are calibrated and sold as systems, complete with read out means which show appropriate units. In such cases radiometers are calibrated in Wm^{-2}. For radiometers without direct ready-out, calibration units are typically $Wm^{-2}V^{-1}$.

NOTE 4—ISO 9370 also provides procedures for calibrating radiometers used for measuring total solar or solar ultraviolet radiation.

7.2.4 *Total Solar Ultraviolet Radiation*—For measurement of total solar ultraviolet radiation, use a radiometer that measures ultraviolet radiation in the wavelength region from at least 295 to 385 nm. The total solar ultraviolet radiometer shall be calibrated against a standard source of spectral irradiance traceable to NIST, or other national standards laboratory, at least annually. Test Method G130 describes calibration of narrow and broad-band ultraviolet radiometers using a spectroradiometer. The calibration shall be in suitable radiometric units, preferably in watts per square metre per volt ($Wm^{-2}V^{-1}$).

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[6] For further information on instrumentation, see either *Symposium on Weathering Conditioning, ASTM STP 133*, or Sereda, P. J., "Measurement of Surface Moisture," *ASTM Bulletin, No. 228*, 1959, pp. 61–63.

[7] *Guide to Meteorological Instruments and Methods of Observation*, 7th ed., WMO-No. 8, Secretariat of the World Meteorological Organization, Geneva, 1983.

[8] Suitable calibrations can usually be obtained from the manufacturer of the instrument.

If requested, a certificate of calibration shall be provided with all total solar ultraviolet irradiance measurements.

NOTE 5—Traditionally, UV radiometers measuring 295 to 385 nm have been used. Use of radiometers with different wavelength response (for example, those that respond to 400 nm) can result in recorded UV radiant exposures that are up to 10 to 15 % higher.

7.2.5 *Narrow-Band Solar Ultraviolet Radiation*—Narrowband radiometers can be used to measure specific wavelength bands of solar ultraviolet radiation in the UVB or UVA regions. Unless otherwise specified, the narrow-band radiometers shall be calibrated against a standard source of spectral irradiance at least annually. The calibration shall be in suitable radiometric units, preferably in watts per square metre per volt ($Wm^{-2}V^{-1}$). If requested, a certificate of calibration shall be provided with all narrow band solar ultraviolet irradiance measurements.

NOTE 6—Subcommittee G3.09 is developing standard practices describing procedures for determination of radiant exposure.

7.2.6 *Time of Wetness*—Practice G84 describes a procedure for determination of time of wetness. Other procedures may be used if mutually agreed upon by interested parties.

8. Procedure

8.1 Prepare test specimens according to standards or procedures relevant to the materials being evaluated. Identify each specimen with a unique mark that will not be destroyed or become illegible during the exposure.

8.2 If nondestructive testing is used, measure the desired properties on all test and reference and control specimens prior to exposure. If destructive testing is done, measure the level of the desired property on a separate set of specimens. When destructive tests are used, separate sets of specimens are needed for each exposure period desired.

8.3 Select one of the following methods for defining the duration of exposure:

8.3.1 *Calendar Basis*—Expose specimens for a specified number of days, months, or years. The report shall indicate the exact dates of the exposure.

8.3.2 *Radiant Exposure Basis*—Expose specimens until a specified level of solar radiant exposure has been achieved. Use hemispherical radiation measurements (direct plus scattered solar radiation) as the basis for determining the radiant exposure. The wavelength region in which the solar energy is measured must be specified. The instruments used to measure radiant energy shall meet the requirements of 7.2.3 – 7.2.5. The report shall indicate the radiant energy, wavelength in which it was measured, and exact dates, if appropriate, of the exposure.

8.3.3 *Deterioration Basis*—Expose specimens until a specified physical change has occurred. Examples are degree of shrinkage, color change, blistering, gloss loss, or loss of strength. The report shall indicate the property used as a basis for defining the exposure, the method used to measure the property, the initial and final values of the desired property, and the exact dates of the exposure.

8.3.4 *Based on Property Change in Weathering Reference Material*—With this procedure, a weathering reference material shall be exposed with the test specimens. Expose until a specified change has occurred in the weathering reference material. The report shall describe the weathering reference material used, the property used as a basis for defining the exposure, the method used to measure the property, the initial and final values of the measured property of the weathering reference material, and the exact dates of the exposure.

9. Report

9.1 Report the following information with reference to exposures conducted according to this practice:

9.1.1 Complete description of the test specimens and any control and weathering materials used, including:

9.1.1.1 Composition, including description of substrate to which specimens such as paints, coatings, graphic tapes, and so forth, are applied. In some cases, exposures are conducted by a third party contract lab, but formulation and property testing is done by the producer. In these cases, the contract lab that performs the exposure is unable to report formulation information or the results of property tests that the contract lab did not perform.

9.1.1.2 Method of preparation (reference applicable standards here),

9.1.2 Location of exposure (including whether specimens were exposed at ground level, on a rooftop, and so forth),

9.1.3 Ground cover in area of test racks,

9.1.4 Angle at which exposure conducted, and the facing direction such as N, S, E, W

9.1.5 Type of exposure (unbacked, backed, or black box). If backed exposure is used, include thickness and type of backing and, if painted, the color of paint used,

9.1.6 Method of mounting, including description of supports if needed

9.1.7 Date exposure started and date exposure completed,

9.1.8 If required, solar radiant exposure determined according to 7.2.3 – 7.2.5, including wavelength range in which radiant energy measured. If required, include a certificate of calibration for the radiometer used, with this information, and

9.1.9 If used, details of any specimen treatment such as washing conducted during the exposure. This shall include description of the treatment used and the frequency of treatment.

9.1.10 Report any deviations from this Practice

9.1.11 If required, the following climate information:

9.1.11.1 Ambient temperature (daily maximum and minimum),

9.1.11.2 Relative humidity (daily maximum and minimum),

9.1.11.3 Total hours of wetness and method used to measure,

9.1.11.4 Rainfall in millimeters,

9.1.11.5 Concentration of pollutants such as NO_2, SO_2, O_3, and method used to measure the concentration, and

9.1.12 Results of property measurements if required or conducted before and after exposure. This shall include a description of the method used to measure the property.

10. Precision and Bias

10.1 *Precision:*

10.1.1 Repeatability and reproducibility of results obtained by this practice will vary depending on the materials being tested, the material property being measured, the climate in which the exposures are conducted, and year-to-year differences in climate at a single location. Therefore, no specific statement about the absolute precision of the results obtained by this practice can be made.

10.1.2 Because of the potentially high absolute variability in results obtained by this practice, it is best that performance requirements be specified in terms of comparison with a control material. This control material shall be exposed simultaneously with the test specimen. The specific control material used must be agreed upon by all interested parties.

10.2 *Bias*—Bias in results obtained according to this practice will vary with the materials being tested, the material property being measured, the climate in which the exposures are conducted, and year-to-year differences in climate at a single location. In addition, no acceptable standard reference materials are available for the myriad of material weathering property responses.

11. Keywords

11.1 durability; exposure; weathering