Designation: G24 – 13

Standard Practice for Conducting Exposures to Daylight Filtered Through Glass[1]

This standard is issued under the fixed designation G24; 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.

1. Scope*

1.1 This practice evaluates the resistance of nonmetallic materials to solar radiation filtered through glass in passively ventilated and non-vented enclosures. For exposures in under glass enclosures with forced air circulation, refer to Practice G201.

1.2 For direct exposures, refer to Practice G7.

1.3 This practice is limited to the method of conducting the exposures. The preparation of test specimens and evaluation of results are covered in various standards for the specific materials.

1.4 Exposure conducted according to this practice can use two types of exposure cabinets.

1.4.1 *Type A*—A cabinet that allows passive ventilation of specimens being exposed behind glass.

1.4.2 *Type B*—Enclosed cabinet with exterior painted black that does not provide for ventilation of specimens exposed behind glass. Exposures conducted using a Type B cabinet are typically referred to as "black box under glass exposures."

1.5 Type A exposures of this practice are technically similar to Method B of ISO 877-2.

1.6 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.

1.7 *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]

C1036 Specification for Flat Glass

D3424 Practice for Evaluating the Relative Lightfastness and Weatherability of Printed Matter

D4303 Test Methods for Lightfastness of Colorants Used in Artists' Materials

D6901 Specification for Artists' Colored Pencils

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

E903 Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres

E1084 Test Method for Solar Transmittance (Terrestrial) of Sheet Materials Using Sunlight

G7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials

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

G173 Tables for Reference Solar Spectral Irradiances: Direct Normal and Hemispherical on 37° Tilted Surface

G177 Tables for Reference Solar Ultraviolet Spectral Distributions: Hemispherical on 37° Tilted Surface

G201 Practice for Conducting Exposures in Outdoor Glass-Covered Exposure Apparatus with Air Circulation

2.2 *Other Documents:*

WMO Guide to Meteorological Instruments and Methods of Observation WMO No. 8, Seventh Edition.[3]

ISO 105 B01 Textiles—Tests for Colour Fastness, International Standards Organization, Geneva, Switzerland.[4]

ISO 877-1 Plastics – Methods of Exposure to Solar Radiation – Part 1: General Guidance[4]

ISO 877–2 Plastics – Methods of Exposure to Solar Radiation – Part 2: Direct Weathering and Exposure Behind Window Glas

AATCC TM 16, Option 6 Colorfastness to Light, Daylight[5]

AATCC Test Method 16.1-2012 Colorfastness to Light: Outdoor

3. Terminology

3.1 *Definitions:*

[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.

Current edition approved June 1, 2013. Published July 2013. Originally approved in 1973. Last previous edition approved in 2005 as G24 – 05. DOI: 10.1520/G0024-13.

[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] Available from World Meteorological Organization (WMO), 7bis, avenue de la Paix, Case Postale No. 2300, CH-1211 Geneva 2, Switzerland, http://www.wmo.int.

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

[5] Available from American Association of Textile Chemists and Colorists (AATCC), P.O. Box 12215, Research Triangle Park, NC 27709, http://www.aatcc.org.

***A Summary of Changes section appears at the end of this standard**

3.1.1 The definitions contained in Terminology G113 are applicable to this practice.

4. Significance and Use

4.1 Since solar radiation, air temperature, relative humidity, and the amount and kind of atmospheric contaminants vary continuously, results from exposures based on elapsed time may differ. The variations in the results may be minimized by timing the exposures in terms of:

4.1.1 One or more environmental parameters such as solar radiant exposure, or

4.1.2 A predefined property change of a weathering reference specimen with known performance.

4.2 Variations in temperature, moisture and atmospheric contaminants can have a significant effect on the degradation caused by solar radiation. In addition, exposures conducted at different times of the year can cause large differences in rate of degradation. Different materials may have different sensitivities to heat, moisture, and atmospheric contaminants, which may explain differences in rankings of specimens exposed to equivalent solar radiant exposure when other environmental conditions vary.

4.3 Since the method of mounting may influence the temperature and other parameters during exposure of the specimen, there should be a mutual understanding as to the method of mounting the specimen for the particular exposure test under consideration.

4.4 There can be large differences among various single strength window glasses in their transmittance in the 300 to 350 nm region. For example, at 320 nm, the percent transmittance for seven different lots of single strength window glass ranged from 8.4 to 26.8 %. At 380 nm, the percent transmittance ranged from 84.9 % to 88.1 %.[6]

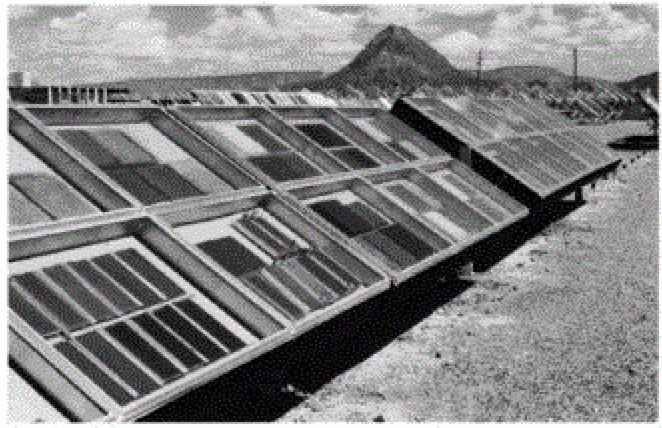

FIG. 2 Typical Non-Ventilated Enclosed Under Glass Exposure Cabinet, Type B (Black Box Under Glass)

4.5 Differences in UV transmittance between different lots of glass persist after solarization. The largest differences among window glasses in UV transmittance are in the spectral range of 300 to 320 nm.

4.6 This practice is best used to compare the relative performance of materials tested at the same time behind the same lot of glass. Because of variability between lots of glass and between exposures conducted at different times of the year, comparing the amount of degradation in materials exposed for the same duration or radiant exposure at separate times, or in separate fixtures using different lots of glass is not recommended.

4.7 It is strongly recommended that at least one control material be exposed with each test. The control material should be of similar composition and construction. and be chosen so that its failure modes are the same as that of the material being tested. It is preferable to use two control materials, one with relatively good durability, and one with relatively poor durability. If control materials are included as part of the test, they shall be used for the purpose of comparing the performance of the test materials relative to the controls.

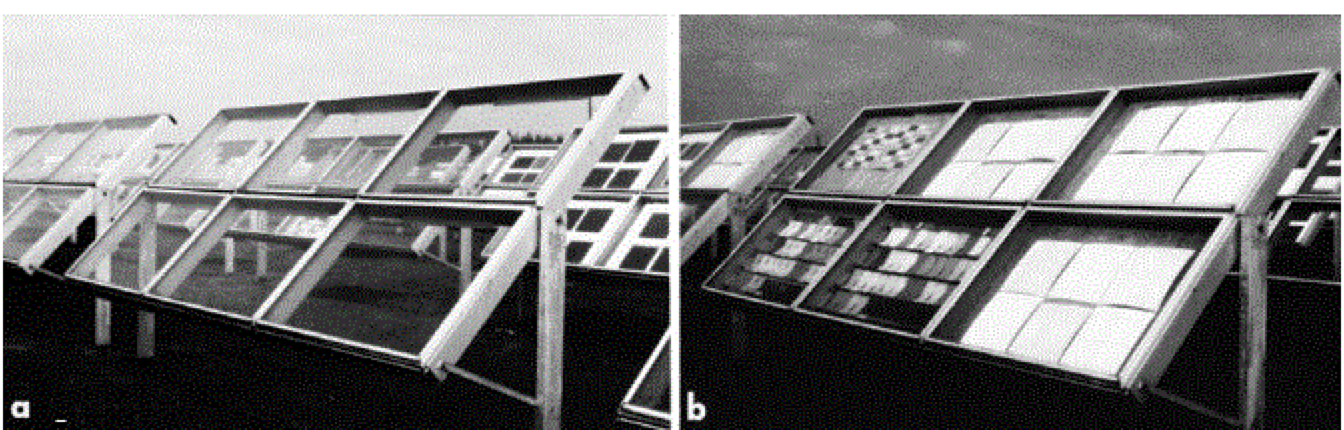

FIG. 1 a and 1b Typical Passively-Ventilated Under Glass Exposure Cabinet, Type A

[6] Ketola, W. D., and Robbins, J.S., III, "UV Transmission of Single Strength Window Glass," *Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202*, Warren D. Ketola and Douglas Grossman, Eds., American Society for Testing and Materials, Philadelphia, 1994.

4.8 There are other standards which describe exposures to glass filtered daylight. Six cited standards are D3424, D4303, D6901, ISO 105-B01, ISO 877-1, ISO-877-2, AATCC TM 16C.

4.9 Because of the possibility that certain materials may outgas during exposure, it is recommended that only similar materials be exposed in the same under glass cabinet at the same time.

5. Apparatus

5.1 *Exposure Cabinet:*

5.1.1 *Type A*—A glass-covered enclosure or cabinet of any convenient size, constructed to protect the specimens from rain. It typically is constructed of metal or wood, and shall be open on the back or sides to allow ambient air to passively circulate over the specimens (Fig. 1a and b).

5.1.2 *Type B (Black Box Under Glass)*—A glass-covered enclosure or cabinet of any convenient size. It shall be constructed of corrosion resistant metal and be enclosed to prevent ambient air from circulating over specimens. Exterior non-glass surfaces shall be painted flat black. The interior shall remain unpainted (Fig. 2).

NOTE 1—For some exposures (for example Method B of D4303 or Method A of D6901), a small fan is inserted into the Type B enclosure to minimize condensation. For enclosures with forced air circulation, refer to Practice G201.

NOTE 2—The black box under glass enclosure is often used to simulate under glass exposures under conditions of high temperature, such as the interior of an automobile. However, because black box under glass cabinets are enclosed, air temperatures may exceed 80°C under conditions of high outside ambient air temperature and solar irradiance. In addition, significant differences in air and specimen temperatures can be experienced between upper and lower portions of the cabinet. Frequent temperature measurement and specimen repositioning may be required to properly use this enclosure.

5.1.3 Unless otherwise specified the glass cover shall be a piece of non-laminated, transparent flat glass, greenhouse quality Q4 or better as specified in section 4.1 of Specification C1036. Thickness shall be 2.0 to 3.2 mm.

5.1.3.1 In order to reduce variability due to changes in UV transmittance of glass, all new glass shall be exposed facing the equator, at any convenient exposure tilt angle within the range of 5 to 45°, according to Practice G7, or on an empty under glass exposure cabinet, for at least three months prior to installation in test cabinets.

5.1.3.2 After the three-month pre-exposure period, it is recommended that the spectral transmittance of representative samples from each lot of glass be measured. Typically, "single strength" glass will have a transmittance of 10 to 20 % at 320 nm and at least 85 % at wavelengths of 380 nm or higher after the three month pre-aging procedure. If transmittance of the glass is measured, report the average for at least three pieces of the lot of glass being tested. Follow the instructions for measurement of transmittance of solid samples recommended by the manufacturer of the UV-visible spectrophotometer used. If a spectrophotometer with an integrating sphere is used, the measurements shall be performed in accordance with Test Method E903.

NOTE 3—Other standards describing exposures behind glass have different requirements for glass transmittance and do not require pre-aging.

NOTE 4—After the initial pre-aging period, the UV transmittance of window glass is suitable for at least 60 months of use. UV transmittance differences between lots of glass persist during this time, however. Different lots of single-strength window glass can have different optical properties even if purchased from the same manufacturer.

5.1.3.3 Wash the exterior surface of the glass cover every month, and the interior surface of the glass cover every 3 months (or more frequently, if required) to remove dust particles and other undesirable deposits.

5.1.4 The enclosure or cabinet shall be equipped with a rack which supports the specimens in a plane parallel to the glass. Whenever possible, the specimens should be supported at a distance of 75 ± 25 mm (3 ± 1 in.) behind the glass cover. Formed specimens with irregular dimensions may require custom mounting with varying distances from the glass cover. In such cases, mount the test sample surface of major interest parallel to the glass cover at a distance of 75 ± 25 mm (3 ± 1 in.) behind the glass cover. The mounting frame or plate shall be constructed of a material that is compatible with the test specimens. In order to minimize shadowing from the top and sides of the cabinet, the usable exposure area under the glass shall be limited to that of the glass cover reduced by twice the distance from the cover to the specimens as shown in Fig. 3. The effective width of the specimen mounting area is L-4X and the effective height of the mounting area is W-4X, where L is the width of the glass cover, W is the height of the glass cover, and X is the distance between the glass cover and the specimens. For example, if the specimens are 75 mm below the

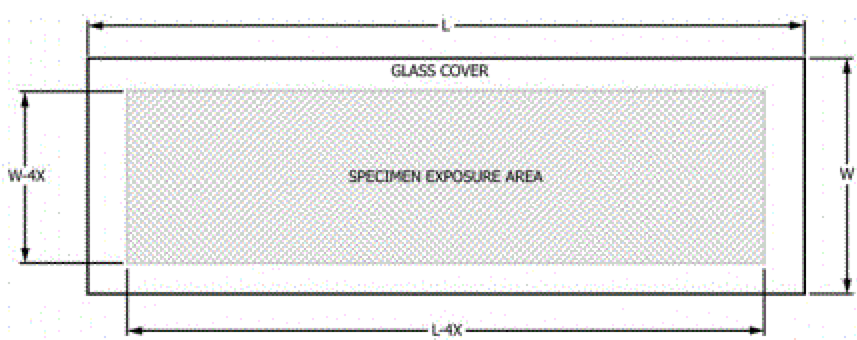

FIG. 3 Mounting Frame Dimensions

glass, then all specimens shall be at least 150 mm from the top or sides. Three types of mounting frames or backings may be used.

5.1.4.1 *Unbacked or Open Mounting*—Specimens are attached only at edges.

5.1.4.2 *Expanded Aluminum Mounting*—Specimens are attached to an expanded aluminum backing.

5.1.4.3 *Solid Mounting*—Specimens are attached to a solid backing such as plywood.

NOTE 5—The method used to mount specimens shall be related to their end-use. In evaluating the specimens, the edges of these specimens that are used to secure the specimen to the framework should be disregarded.

5.1.5 The cabinet shall be located where it will receive direct sunlight throughout the day and where shadows of objects in the vicinity will not fall upon it. When the cabinet is installed over grass, the distance between the bottom of the cabinet and the ground shall be sufficient to prevent contact with plant growth, or to minimize damage that might occur during maintenance.

5.1.6 The glass cover and the test specimens shall be oriented in a manner mutually agreed upon between interested parties. The angle shall be reported in the results of the test. Possible exposure orientations are listed as follows:

5.1.6.1 Fixed tilt angle equal to the latitude of the exposure site with cabinet facing equator,

5.1.6.2 Tilt angle of 45° facing the equator,

5.1.6.3 Tilt angle of 5° facing the equator,

5.1.6.4 Tracking azimuth and tilt angle in order to maintain the exposure plane normal to the sun's direct beam.

5.1.6.5 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.

5.2 *Climatological Instruments:*

5.2.1 Instruments suitable for determining maximum, minimum, and average daily ambient air temperature, cabinet air temperature (optional), and specimen temperature (optional). Ambient air temperature will be measured in a shielded, elevated location in the general vicinity of the under glass exposure cabinet.

5.2.2 Instruments suitable for determining the maximum, minimum, and average daily ambient air humidity, and cabinet humidity (optional).

5.2.3 Instruments for recording solar radiant exposure.

5.2.3.1 Instrumental means of measuring full-spectrum solar radiant exposure shall consist of a pyranometer connected to an integrating device to indicate the total energy received over a given period. The pyranometer shall be sensitive to solar irradiance received at a geometry similar to that over which solar irradiance is received by the test specimens. The pyranometer shall be a World Meteorological Organization (WMO) Good Quality instrument or better as defined by the WMO Guide to Meteorological Instruments. The pyranometer shall be calibrated in accordance with Method E824 no less often than annually against a WMO Good Quality pyranometer whose calibration is traceable to the World Radiometric Reference (WRR).

5.2.3.2 Instrumental means of measuring solar radiant exposure in specific wavelength regions (such as all or a portion of the ultraviolet spectrum) shall consist of a wavelength-band specific global irradiance radiometer connected to an integrating device to indicate the energy received in a specified wavelength band over a given period (optional). The spectral response of the narrow-band radiometer shall be known and shall be as flat as possible throughout the spectral region utilized.

NOTE 6—Solar radiant exposure should be measured and expressed in SI units of joules per square metre. One langley is equivalent to 4.184×10^4 J/m^2.

6. Procedure

6.1 Unless otherwise specified, or agreed to by all interested parties, it is recommended that a minimum of three replicates of each material being tested be exposed. The simultaneous exposure of a similar number of specimens of a control is also strongly recommended.

6.2 Expose the test specimens, control specimens, and/or specimens of an applicable weathering reference material, (for example, blue wool) in the glass-covered exposure cabinet continuously 24 hours a day and remove from the cabinet only for inspection, return to customer, or to protect specimens from possible damage during severe weather events.

6.3 Measure and record daily the maximum, minimum, and average air temperature and relative humidity in the vicinity of the test cabinet. It is also recommended that cabinet air temperature and humidity as well as specimen temperature be recorded.

NOTE 7—While these conditions cannot be controlled, a record of them is desirable to indicate the general conditions that prevailed during the exposure.

6.4 Remove the test specimens, control specimens, and/or specimens of applicable weathering reference material from the cabinet based on one of the following:

6.4.1 *Amount of Solar Radiant Exposure*—Expose the test specimens for a specified solar radiant exposure dose, either total (all wavelengths) or a selected wavelength band.

6.4.2 *Predetermined Property Change*—Expose the test specimens (and any specified control or weathering reference specimen if desired) until a specified amount of property change has occurred in either the candidate materials or standard samples.

6.4.3 *Duration of Exposure*—Expose the test specimens for a specified time period.

6.4.4 *Any Other Specified Environmental Parameter.*

6.4.5 Report the results in terms of any specified method of measuring changes in test specimens.

6.5 Two methods can be used to determine solar radiant exposure under glass. Only record solar radiation while the samples are on exposure.

6.5.1 *Under Glass Measurement Method*—Mounting the pyranometer under the glass produces a direct measurement of solar radiant exposure under glass, R_{UG}. The pyranometer or UV-radiometer shall be mounted under glass having the characteristics specified in 5.1.3. The glass shall be mounted parallel to the surface of the pyranometer or UV-radiometer sensor, 75 10 mm above it, and at the same orientation (tilt angle) as the glass cover and test specimens as specified in 5.1.6. The glass shall be at least 600 by 600 mm in size. For tracking exposures, the glass cover shall be at least 375 mm × 375 mm in size.

6.5.2 *Under lass Calclation Method*—Mounting the pyranometer outside the enclosure produces a measurement of solar radiant exposure without glass (unfiltered), $_S$. The transmittance of the glass is applied after measurement to obtain $_U$. The pyranometer or UV-radiometer shall be mounted outside the enclosure at the same orientation as specimens being tested. The radiant exposure shall be calculated using the following equation:

$$_{g} \quad _{s}3\ ! \qquad (1)$$

Where:

$_U$ = solar radiant exposure under glass,
$_S$ = solar radiant exposure outside the enclosure
! = glass solar transmittance.

6.5.2.1 The glass solar transmittance shall be determined using Test Method E903 or E1084. Test Method E903 is a method for calculating the solar transmittance of the glass based on spectrophotometer measurements. Test Method E1084 is a method for directly measuring the solar transmittance of the glass using the sun as the source and a pyranometer as the sensor. Regardless of the method chosen, it shall be performed on at least three pieces of glass representative of the glass used in the exposure test field. If Test Method E903 is used, the calculated solar transmittance for the above equation shall be based on the spectral irradiance distributions in Tables G177 for UV only or Tables G173 for total solar. If E1084 is used, the pyranometer or UV-radiometer used to determine the glass solar transmittance must be of the same type and wavelength sensitivity as the pyranometer or UV-radiometer used to determine radiant exposure. The glass used for glass solar transmittance measurements, whether the latter is based on E903 or E1084, shall be pre-exposed for three months under the same conditions as the glass used for the exposures.

NOTE 8—The two methods of determining solar radiation under glass in 6.5.1 and 6.5.2, i.e., by measurement and by calculation, may not provide identical results.

7. Report

7.1 The report shall include the following:

7.1.1 Type of exposure cabinet used (Type A or B). Note in the report if a small fan is used in a Type B enclosure to minimize condensation. Report the transmittance characteristics of the glass, if measured, and thickness. All interested parties should agree upon the wavelengths at which transmittance is reported,

7.1.2 Dates and location of exposure, including the latitude of the exposure site, and

7.1.3 Tilt and Azimuth Angles or Compass Orientations at which the exposure cabinet was oriented during the test.

7.2 The report may optionally contain the following information:

7.2.1 Applicable physical property or appearance data for each specimen obtained prior to exposure and after each exposure increment, if measured. If replicate specimens are used, report the mean and standard deviation of each property measured,

7.2.2 Methods used for measuring physical or appearance properties of test and control specimens,

7.2.3 Solar radiant exposure data expressed in SI units and the method of measurement (Under Glass Measurement Method or Under Glass Calculation Method), if measured,

7.2.4 Maximum, minimum, and average daily temperatures, as well as cabinet air and specimen temperatures, if recorded,

7.2.5 Maximum, minimum, and average daily relative humidity, as well as cabinet humidity, if recorded,

7.2.6 Any other specified environmental parameter,

7.2.7 Any variations from the specified conditions, and

7.2.8 Type of specimen rack and mounting employed.

8. Keywords

8.1 aging; exposure; glass; ultraviolet; weathering; lightfastness; fading; solar radiation

SUMMARY OF CHANGES

Committee G03 has identified the location of selected changes to this standard since the last issue (G24 – 05) that may impact the use of this standard. (Approved June 1, 2013.)

1 Section 1.1 – The scope was modified restricting the use of this standard to passively-ventilated enclosures. For actively-ventilated enclosures, a reference to ASTM G201 was added.
2 Section 5.1.4 – Detail was added describing how to determine the effective exposure area.
Section 6.5 – This section was changed to allow two methods to be used for measuring solar radiation – Under Glass Measurement Method, and Under Glass Calculation Method.
4 Section 7 – This section was changed to require noting the measurement technique used to determine solar radiation, and to note if a small fan is used in a Type B enclosure to minimize condensation.