Designation: E744 – 07 (Reapproved 2022)

Standard Practice for Evaluating Solar Absorptive Materials for Thermal Applications[1]

This standard is issued under the fixed designation E744; 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 covers a testing methodology for evaluating absorptive materials used in flat plate or concentrating collectors, with concentrating ratios not to exceed five, for solar thermal applications. This practice is not intended to be used for the evaluation of absorptive surfaces that are (*1*) used in direct contact with, or suspended in, a heat-transfer liquid, (that is, trickle collectors, direct absorption fluids, etc.); (*2*) used in evacuated collectors; or (*3*) used in collectors without cover plate(s).

1.2 Test methods included in this practice are property measurement tests and aging tests. Property measurement tests provide for the determination of various properties of absorptive materials, for example, absorptance, emittance, and appearance. Aging tests provide for exposure of absorptive materials to environments that may induce changes in the properties of test specimens. Measuring properties before and after an aging test provides a means of determining the effect of the exposure.

1.3 The assumption is made that solar radiation, elevated temperature, temperature cycles, and moisture are the primary factors that cause degradation of absorptive materials. Aging tests are described for exposure of specimens to these factors.

NOTE 1—For some geographic locations, other factors, such as salt spray and dust erosion, may be important. They are not evaluated by this practice.

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

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B537 Practice for Rating of Electroplated Panels Subjected to Atmospheric Exposure

E408 Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques

E434 Test Method for Calorimetric Determination of Hemispherical Emittance and the Ratio of Solar Absorptance to Hemispherical Emittance Using Solar Simulation

E772 Terminology of Solar Energy Conversion

E781 Practice for Evaluating Absorptive Solar Receiver Materials When Exposed to Conditions Simulating Stagnation in Solar Collectors with Cover Plates

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

G26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials (Discontinued 2001) (Withdrawn 2000)[3]

G90 Practice for Performing Accelerated Outdoor Weathering of Materials Using Concentrated Natural Sunlight

G151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources

G155 Practice for Operating Xenon Arc Lamp Apparatus for Exposure of Materials

NOTE 2—In previous editions, Practice G26 was referenced for xenon arc exposure. It has been replaced with Practices G151 and G155, the performance-based standards, which cover the same apparatus used in Practice G26. The latter had described very specific designs used for xenon arc exposure.

[1] This practice is under the jurisdiction of ASTM Committee E44 on Solar, Geothermal and Other Alternative Energy Sources and is the direct responsibility of Subcommittee E44.20 on Optical Materials for Solar Applications.

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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 Refer to Teminology E772 for terminology relating to solar energy conversion.

4. Significance and Use

4.1 The methods in this practice are intended to aid in the assessment of long-term performance by comparative testing of absorptive materials. The results of the methods, however, have not been shown to correlate to actual in-service performance.

4.2 The testing methodology in this practice provides two testing methods, in accordance with Fig. 1.

4.2.1 Method A, which aims at decreasing the time required for evaluation, uses a series of individual tests to simulate various exposure conditions.

4.2.2 Method B utilizes a single test of actual outdoor exposure under conditions simulating thermal stagnation.

4.2.3 Equivalency of the two methods has not yet been established.

5. Test Specimens

5.1 Test specimens shall consist of the complete absorber material including coatings or layers and specific substrates where applicable.

5.2 The specimens shall be prepared in accordance with procedures and conditions used (or expected to be used) in commercial practice or in accordance with the recommendations of the coatings or material supplier.

NOTE 3—Results may vary due to coating substrate interactions.

NOTE 4—Some absorbers may not have discreet coatings or layers, for example, pigmented materials.

6. Conditioning

6.1 Specimens shall be measured and tested as received without additional processing or preconditioning.

7. Test Methods

7.1 *Property Measurement Tests*—Perform all property measurement tests at room temperature unless otherwise specified.

7.1.1 *Solar Absorptance*—Test in accordance with Test Method E903, unless otherwise specified.

NOTE 5—The spectral reflectance curves from which solar absorptance is calculated are often a more sensitive indicator of the onset of absorber material's degradation than integrated solar absorptance values. This is especially true for changes occurring in spectral regions where there is a limited amount of energy in the solar spectrum, for example, in the near infrared region.

7.1.2 *Emittance*—Test in accordance with Test Methods E434 or E408, unless otherwise specified.

7.1.3 *Appearance*—Test in accordance with Practice B537, unless otherwise specified.

7.2 *Environmental Exposure:*

7.2.1 *Outdoor Exposure Under Simulated Stagnation Conditions*—Expose test specimens for a minimum period of twelve months (Note 6) using Practice E781.

NOTE 6—It may be desirable to continue exposures of test specimens beyond the time period recommended to obtain additional rate data or to obtain data on mechanisms of degradation.

7.2.2 *Outdoor Exposure Using Fresnel Concentration*—Expose test specimens to direct sunlight reflected from the Fresnel concentrators described in Practice G90. Test specimens shall be mounted in a manner similar to that shown in Fig. 2. The cooling of the test specimens shall be adjusted to maintain the absorber specimens at stagnation temperatures. Refer to Cycle 3 of Practice G90 for details of the water spray operating procedure.

NOTE 7—The spectral transmission characteristics of the cover(s) used in a solar collector will control the amount and spectral distribution of the solar radiation reaching the absorber surface. For this reason, testing should be performed with the glazings to be used in the actual collector

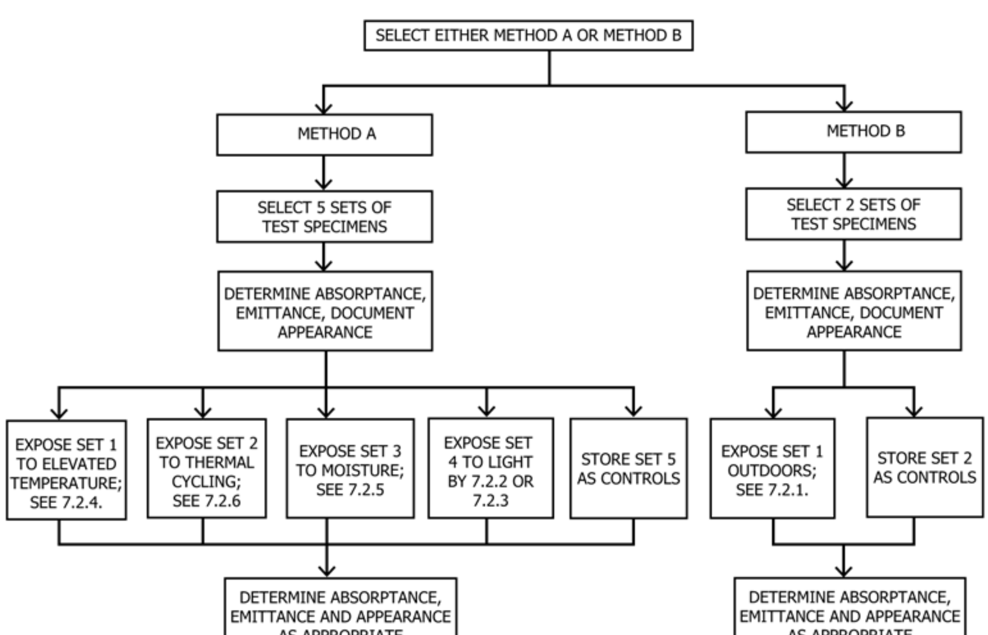
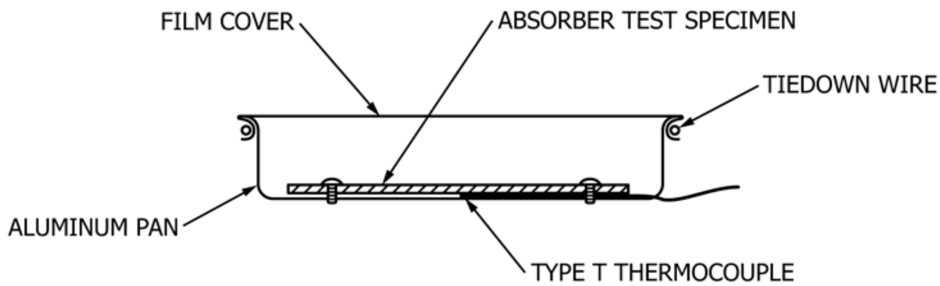


FIG. 1 Outline of Test Method Options



NOTE 1—*Film Cover:* Polytetrafluoroethylene.
NOTE 2—*Absorber Test Specimen:* 7.5 × 6.1 cm.
NOTE 3—*Aluminum Pan:* 11.5 × 6.5 × 2 cm. Interior painted black and baked at 230 °C for 24 h.

FIG. 2 Accelerated Exposure Absorber Mini-Box

installed between the light source and the absorber surface, or with the worst-case configuration possible. When solar simulators are used, the light source should be filtered to match the solar spectrum.

7.2.3 *Xenon Arc Exposure*—Expose test specimens to radiation from a filtered xenon arc lamp in accordance with the conditions stipulated in Table 1.

7.2.4 *Effect of Elevated Temperatures*—Expose test specimens to heat aging for a period of 500 h at the stagnation temperature to which they will be exposed in actual service.

NOTE 8—The maximum service temperature will normally be obtained when the collector is receiving its maximum level of solar radiation and the heat transfer fluid is not flowing through the collector. Data on stagnation temperatures are normally available from collector manufacturers. Stagnation temperature data for flat plate collectors are included in the National Bureau of Standards (NBS) Technical Note 1187.[4]

TABLE 1 Exposure Test Conditions

NOTE 1—1330 ± 12 h = 55–56 day,
0.52 W/(m^2·nm) at 340 nm for 1330 h = 2490 kJ/(m^2·nm) at 340 nm,
0.49 W/(m^2·nm) at 340 nm for 1330 h = 2298 kJ/(m^2·nm) at 340 nm,
0.50 W/(m^2·nm) at 340 nm for 1330 h = 2394 kJ/(m^2·nm) at 340 nm.
Total UV irradiance from xenon controlled at 0.5 W/(m^2·nm) at 340 nm is 55.5 W/m^2. Hourly TUV exposure is 198 kJ/m^2
1330 h × 198 kJ/m^2·h = 263 MJ/m^2.

Radiation source	Xenon Arc
ASTM Practice	G151 and G155
Filters	Daylight
Irradiance at 340 nm, W/(m^2·nm)	0.50 ± 0.02^A
Uninsulated black panel temperature	90 ± 2.5 °C^A
Chamber air temperature	62 ± 2 °C^A
Relative humidity, %	50 ± 5/saturation^{A,B}
Radiant Exposure at 340 nm, kJ/(m^2·nm)	2394 ± 30^C
Exposure interval, h	1330 ± 12
Exposure program, min	40 light, 20 light and water spray on front of specimen, 40 light, 60 dark with water spray on back of specimen

[A] The operational fluctuations are allowable deviations from the specified set points for irradiance, temperature, and relative humidity during equilibrium operation. They do not imply that the user is allowed to program a set point higher or lower than that specified. If the operational fluctuations are greater than the maximum allowable after the equipment has stabilized, discontinue the test and correct the cause of the problem before continuing.
[B] Light on condition without water spray/light off (dark) conditions with back panel rack spray.
[C] Provides total UV (300 to 400 nm) radiant exposure equal to approximately 50 % of the average yearly amount available at Miami, FL. Previous versions of the standard stated that 1330 h exposure in the xenon arc device is equivalent to a year in Miami, FL. It was based on an incorrect assumption of exposure to radiation 100 % of the time due to neglect of the dark time and it also neglected adjustment for differences in the spectral regions measured in the xenon arc device and Miami. Test results cannot be extrapolated to simulate a full year exposure in Miami because of nonlinearity of degradation with exposure for many materials.

7.2.5 *Effect of Moisture*—Expose test specimens for 30 days at 90 ± 5 °C and 95 + 5 % relative humidity.

NOTE 9—Research has indicated that the degradation caused by this test can be considerably more severe than the degradation occurring in three years of outdoor exposure in full-size solar collectors for some absorber materials.

7.2.6 *Effect of Thermal Cycling*—Expose test specimens to 30 cycles of heating and cooling with each cycle consisting of the following steps:

7.2.6.1 Heat for 7 h at the stagnation temperature to which they will be exposed in actual service (see Note 5).

7.2.6.2 Cool to room temperature over a 30-min period.

7.2.6.3 Cool at −10 °C for 16 h.

7.2.6.4 Warm to room temperature over a 30-min period.

NOTE 10—The humidity maintained during this warming process shall be such that moisture condenses on the surfaces of the test specimens.

7.2.7 *Offgassing*—Release of volatiles from the absorber material, in some cases, may be a significant factor that can affect the transmittance of a cover plate, or the properties of the absorber itself, or both. A generally applicable procedure is not presently available to evaluate effects of offgassing products. It is essential, however, that this factor be recognized.

8. Test Procedure

8.1 Select either Method A (see 8.2) or Method B (see 8.3), in accordance with Fig. 1.

8.2 *Method A (Laboratory Exposure):*

8.2.1 Select five sets of test specimens for each absorber material to be evaluated. Each set shall consist of at least three identical test specimens.

8.2.2 Determine the absorptance and emittance of the specimens in accordance with 7.1.1 and 7.1.2. Also document the appearance of the specimens in accordance with 7.1.3.

8.2.3 Store *Set 5* specimens (controls) at ambient laboratory conditions.

[4] NBS Technical Note 1187, "Performance Criteria for Solar Heating and Cooling Systems in Commercial Buildings," available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.