



Designation: E 781 – 86 (Reapproved 1996)

## Standard Practice for Evaluating Absorptive Solar Receiver Materials When Exposed to Conditions Simulating Stagnation in Solar Collectors With Cover Plates<sup>1</sup>

This standard is issued under the fixed designation E 781; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This practice covers a test procedure for evaluating absorptive solar receiver materials and coatings when exposed to sunlight under cover plate(s) for long durations. This practice is intended to evaluate the exposure resistance of absorber materials and coatings used in flat-plate collectors where maximum nonoperational stagnation temperatures will be approximately 200°C (392°F).

1.2 This practice shall not apply to receiver materials used in solar collectors without covers (unglazed) or in evacuated collectors, that is, those that use a vacuum to suppress convective and conductive thermal losses.

1.3 The values stated in SI units are to be regarded as the 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 establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

B 537 Practice for Rating of Electroplated Panels Subjected to Atmospheric Exposure<sup>2</sup>

D 1898 Practice for Sampling of Plastics<sup>3</sup>

E 408 Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques<sup>4</sup>

E 434 Test Method for Calorimetric Determination of Hemispherical Emittance and the Ratio of Solar Absorptance to Hemispherical Emittance Using Solar Simulation<sup>4</sup>

E 772 Terminology Relating to Solar Energy Conversion<sup>5</sup>

E 903 Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres<sup>5</sup>

<sup>1</sup> These test methods are under the jurisdiction of ASTM Committee E44 on Solar, Geothermal, and Other Alternative Energy Sources and is the direct responsibility of Subcommittee E44.05 on Solar Heating and Cooling Subsystems and Systems.

Current edition approved June 9, 1986. Published August 1986. Originally published as E 781 – 81. Last previous edition E 781 – 81.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 02.05.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 08.01.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 15.03.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 12.02.

E 962 Practice for Cleaning Cover Materials for Flat Plate Solar Collectors<sup>5</sup>

### 3. Terminology

3.1 *Definitions*—See Terminology E 772 for definitions.

### 4. Significance and Use

4.1 Although this practice is intended for evaluating solar absorber materials and coatings used in flat-plate collectors, no single procedure can duplicate the wide range of temperatures and environmental conditions to which these materials may be exposed during in-service conditions.

4.2 This practice is intended as a screening test for absorber materials and coatings. All conditions are chosen to be representative of those encountered in solar collectors with single cover plates and with no added means of limiting the temperature during stagnation conditions.

4.3 This practice uses exposure in a simulated collector with a single cover plate. Although collectors with additional cover plates will produce higher temperatures at stagnation, this procedure is considered to provide adequate thermal testing for most applications.

NOTE 1—Mathematical modelling has shown that a selective absorber, single glazed flat-plate solar collector can attain absorber plate stagnation temperatures as high as 226°C (437°F) with an ambient temperature of 37.8°C (100°F) and zero wind velocity; and a double glazed one as high as 245°C (482°F) under these conditions. The same configuration solar collector with a nonselective absorber can attain absorber stagnation temperatures as high as 146°C (284°F), if single glazed, and 185°C (360°F), if double glazed, with the same environmental conditions, (see “Performance Criteria for Solar Heating and Cooling Systems in Commercial Buildings,” NBS Technical Note 1187<sup>6</sup>).

4.4 This practice evaluates the thermal stability of absorber materials. It does not evaluate the moisture stability of absorber materials used in actual solar collectors exposed outdoors. Moisture intrusion into solar collectors is a frequent occurrence in addition to condensation caused by diurnal breathing.

4.5 This practice differentiates between the testing of spectrally selective absorbers and nonselective absorbers.

<sup>6</sup> Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

4.5.1 *Testing Spectrally Selective Absorber Coatings and Materials*—Spectrally selective solar absorptive coatings and materials require testing in a covered enclosure that contains a selectively coated sample mounting plate, such that the enclosure and mounting plate simulate the temperature conditions of a selective flat-plate collector exposed under stagnation conditions.

4.5.2 *Testing Nonselective Coatings and Materials*—Spectrally nonselective solar absorptive coatings and materials require testing in a covered enclosure that contains a nonselective coated sample mounting plate, such that the enclosure and mounting plate simulate the temperature conditions of a covered, nonselective flat-plate collector exposed under stagnation conditions.

## 5. Test Apparatus

5.1 *Test Enclosure* (Fig. 1), consisting of a box that approximates the dimensions of a typical flat-plate solar collector and shall have minimum dimensions of 0.75 by 1.5 by 0.1 m (29 by 60 by 4 in.) deep. The box should be constructed of materials that are impervious to moisture. Wood should not be used for construction of the box. Care shall be taken to prevent water leakage at joints, seams, and seals.

5.1.1 *Pre-Exposure of Test Box*—Prior to use, the test apparatus shall be placed in an operational environment where all components are allowed to equilibrate at the stagnation temperature for a sufficient length of time to allow for outgassing of the components. This procedure may aid in eliminating contamination of the cover plate and the samples during actual testing periods and is especially important where coatings employing organic components are used. If the cover plate is in place during this outgassing procedure, it shall be cleaned before the box is put into service in order to restore its original transmittance.

5.2 *Cover Plate*—The box shall have a single cover plate that is glazed and hinged to provide access.

5.2.1 Two types of cover plate materials may be used:

5.2.1.1 *Type I*—Tempered low-iron glass with spectral characteristics approximating those shown in Fig. 2.

5.2.1.2 *Type II*—Alternative types of solar transmitting glass or plastic materials might be used for the cover plate if the absorber is to be used under that material.

5.2.2 The solar-weighted transmittance values of the cover plate test patches (5.2.3 and 5.2.4) shall remain above the

indicated percentage of their initial values in the following wavelength regions:

300 to 400 nm – 90 %

400 to 2100 nm – 95 %

5.2.3 An easily removable test patch of the cover material measuring 50 by 50 mm (2 by 2 in.) shall be fastened onto the inner surface of the transparent cover plate in or near one lower corner. By periodically measuring the transmittance of this test patch, an indication of the effect of any condensable effluents on the cover material can be monitored.

5.2.4 An easily removable specimen of the cover plate material measuring 50 by 50 mm (2 by 2 in.) should also be mounted directly on an exterior upper corner of the cover plate to monitor the effects of atmospheric contamination and ultraviolet degradation. These effects are generally more severe for plastic materials than for glass.

5.3 *Seals*—A seal that does not outgas at the stagnation temperature should be used to make the box weather-resistant.

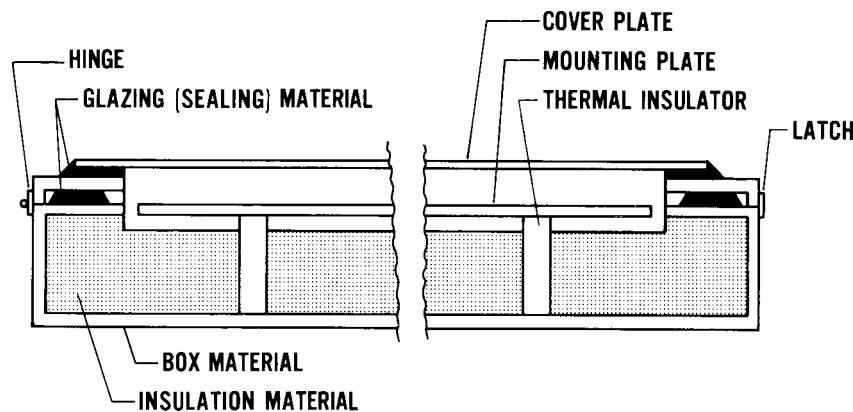
5.4 *Insulation*—The bottom and sides of the enclosure shall be insulated to have a thermal conductance of less than  $0.515 \text{ W}/(\text{m}^2 \cdot \text{K})(0.091 \text{ Btu}/(\text{h} \cdot \text{ft}^2 \cdot ^\circ\text{F}))$ , that is, an  $R$  value of 11 or greater with materials that do not outgas at the stagnation temperature.

5.5 *Sample Mounting Plate*—A metallic mounting plate with lateral dimensions approximately the same as the internal enclosure dimensions (less the thickness of the insulation on the sides of the box) shall be mounted approximately 10 mm (0.4 in.) above the bottom insulation by a thermally insulating material.

5.5.1 The mounting plate used to support selective specimens shall have a selective surface. The solar absorptance ( $\alpha$ ) of the selective coating shall be greater than 0.90, and the room temperature emittance ( $\epsilon$ ) shall be less than 0.15 at all times.

5.5.2 The mounting plate used to support nonselective specimens shall be coated with any nonselective black coating that is thermally resistant to temperatures up to approximately  $200^\circ\text{C}$  ( $392^\circ\text{F}$ ). The solar absorptance ( $\alpha$ ) of the coatings (solar-weighted average from 350 to 2500 nm) shall be greater than 0.90 at all times.

5.5.3 A specimen of the mounting plate material (50 by 50 mm (2 by 2 in.)) shall be securely fastened to and in contact with the mounting plate. The purpose of this specimen is to monitor the optical characteristics of the mounting plate.



**FIG. 1 Typical Cross Section of Exposure Test Apparatus**

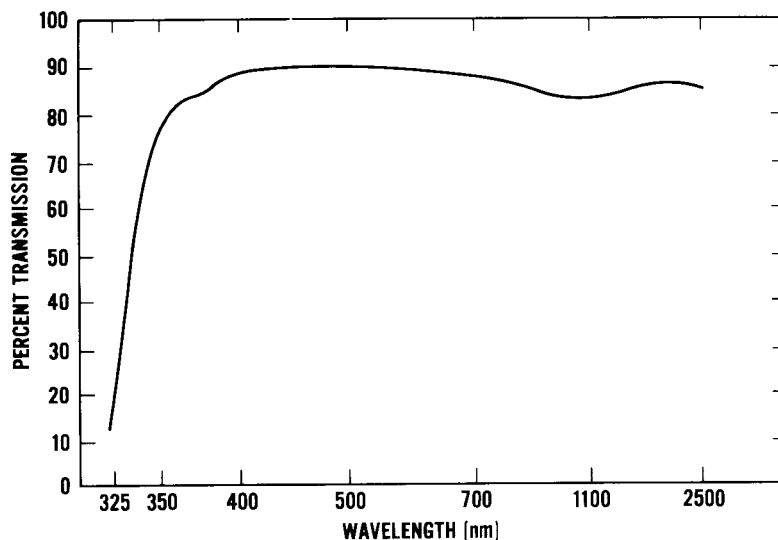


FIG. 2 Transmittance of Low-Iron Glass

5.6 *Condensation Control*—It is desirable to minimize or eliminate the presence of condensate on the inside of the cover plate and on the specimens during periods of solar irradiation to ensure uniform results. The use of a desiccant may aid in minimizing condensation. In some geographical locations, weep holes drilled at the lower corners of the test enclosure may be required to drain condensate and thereby preclude the condensation of moisture on the cover plate. Weep holes shall be limited in size and number so as not to disturb the equilibrium temperature of the test enclosure interior.

## 6. Test Specimens

6.1 Test specimens shall be defined to be either the coating applied to a specific substrate or the absorber material itself (for materials other than coatings).

6.2 The specimens shall be prepared in accordance with the procedures and conditions recommended by the coating or material supplier.

## 7. Procedure

7.1 *Number of Test Specimens* (see Note 2)—The number of test specimens shall be defined and selected based on the need for replication and the test plan option used as described in 7.1.1 and 7.1.2.

NOTE 2—Practice D 1898 provides guidance on statistical procedures for sampling.

NOTE 3—While replication is desirable whenever available and resources permit, a high level of experience with the weathering characteristics of any given product may permit single specimen testing with good reliability.

7.1.1 *Test Plan Option A*—Remove test specimens at preselected deadlines (or remove sections by cutting, stamping, or otherwise segmenting), measure nondestructively, and return to the test for continued exposure.

7.1.2 *Test Plan Option B*—Replicate specimens to permit withdrawals at preselected intervals without replacement.

7.1.3 Exercise caution with test specimens that may outgas or are subjected to rapid initial decomposition at elevated temperatures. Such outgassing may significantly alter the

transmittance of the cover plate. If this occurs, clean the cover plate (see 5.1.1) prior to resuming testing. The decomposing test specimens may be removed from the test apparatus. Note observations and actions taken in the test report.

7.2 *Mounting Test Specimens*—Mount the test specimens on the sample mounting plate. Perform mounting and handling while wearing gloves so as not to damage or contaminate the surface of either the test material or the backing plate (Note 4). The location and number of test specimens shall be consistent with thermal uniformity. Shading of specimens shall not occur, except just after sunrise and just before sunset.

NOTE 4—The potential for galvanic corrosion should be considered when mounting the specimens.

### 7.3 Orientation of Test Fixture and Duration of Exposure:

7.3.1 Mount the test fixture facing the equator with its major axis oriented east-west such that the angle between the normal to the plane of the test apparatus and the zenith is equal to the latitude of the testing site.

7.3.2 Expose the specimens to a minimum total solar irradiation of  $6.2 \times 10^9 \text{ J/m}^2$  ( $5.6 \times 10^5 \text{ Btu/ft}^2$ ) (see Note 5). In order to develop kinetic or rate information, it is recommended that the parameters chosen for studying these effects be measured at progressively longer exposure increments.

NOTE 5—This exposure value is based on the solar radiation received in a 12-month period assuming an average value of  $1.7 \times 10^7 \text{ J/m}^2$  per day ( $1500 \text{ Btu/ft}^2$  per day).

7.4 *Measurements of Test Specimen Properties*—Prior to exposure and at preselected exposure intervals, measure the properties of the test specimens as described in 7.4.1, 7.4.2, and 7.4.3.

7.4.1 *Solar Absorptance*—Measure the solar absorptance in accordance with Test Method E 903, unless otherwise specified.

NOTE 6—The spectral reflectance curves from which solar absorptance is calculated are often a more sensitive indicator of the onset of degradation of absorber materials than integrated solar absorptance values. This is especially true for changes occurring in spectral regions



## E 781

where there is a limited amount of energy in the solar spectrum, that is, in the near infrared region.

7.4.2 *Emittance*—Measure the total hemispherical or normal emittance, or both, in accordance with Test Methods E 434 or E 408, unless otherwise specified.

7.4.3 *General Appearance*—Assess the general appearance of the specimens in accordance with Practice B 537, where applicable.

7.5 *Temperature Measurements*—Daily measure and record the temperature of the absorber sample mounting plate near solar noon. Measure the temperature at two locations, one located 150 mm (6 in.) from the upper edge and the other at the same distance from the lower edge along the minor axis of the plate (see 7.3.1). Thermal sensors shall be in good thermal contact with the plate and shielded from direct solar radiation.

7.6 *Solar Radiation Measurements*—Measure total incident radiation on the plane containing the test fixture during the exposure period using a sensor meeting the requirements of a World Meteorological Organization second-class pyranometer.

### 7.7 *Other Measurements:*

7.7.1 *Spectral Transmittance*—Measure the spectral transmittance of the cover plate test patches periodically in the wavelength region 300 to 2100 nm in accordance with Test Method E 903 (see 5.2.2 and 5.2.3). Measure plastic cover materials every three months. Measure glass cover materials annually.

7.7.2 *Solar Absorptance*—Measure the solar absorptance of the test patch of the mounting plate absorber coating every three months (see 5.5.3). If a selective absorber is used, measure the infrared emittance every three months. Methods of measurement shall be as specified in 7.4.

7.7.3 *Appearance*—Visually inspect test specimens at least once per month, noting any changes in their appearance.

7.8 *Maintenance of Test Fixture*—Inspect the test fixture periodically and replace defective components whose characteristics have degraded beyond the stated limits.

7.8.1 Clean the cover plate in accordance with Practice E 962 as needed to maintain its spectral transmittance above the stated limits.

## 8. Report

8.1 The report shall include the following:

8.1.1 Complete identification of the absorber material tested.

8.1.2 Complete identification of the substrate(s) used for absorber coatings, including composition and thickness.

8.1.3 Method of preparing the test specimens and any conditioning treatment.

8.1.4 Complete description of the test apparatus.

8.1.5 Location and dates of exposure.

8.1.6 Total incident solar irradiation received by the test apparatus and documentation of the instrumentation and measurement procedure.

8.1.7 Type of cover plate material used, the spectral transmittance measured initially and periodically throughout exposure, and documentation of the instrumentation and measurement procedure. Any cleaning or replacement of the cover plate shall be noted.

8.1.8 Maximum weekly temperature as recorded in 7.5.

8.1.9 Number and size of specimens tested.

8.1.10 Test specimen properties as measured in 7.4 and test patch properties as measured in 7.7.

8.1.11 Documentation of the instrument and the procedures used for measuring the reflectance and emittance of the test specimens and the solar spectral distribution used for computation of the optical properties.

8.1.12 Other observations such as those described in 7.1.3 and 7.7.3.

8.1.13 Any change in the appearance or condition (fading, blistering, rusting, etc.) of individual specimens or group of specimens and identification of specimens that caused visible fogging of the cover plate and time intervals during which fogging occurred.

## 9. Keywords

9.1 absorber; absorptance; aging; cover plates; emittance; outdoor weathering; selective absorber; solar collectors; stagnation; thermal testing; weathering

*ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

*This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).*