Designation: E1918 – 16

Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field[1]

This standard is issued under the fixed designation E1918; 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 test method covers the measurement of solar reflectance of various horizontal and low-sloped surfaces and materials in the field, using a pyranometer. The test method is intended for use when the sun angle to the normal from a surface is less than 45°.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions:*

3.1.1 *low-sloped surfaces*—surfaces with a slope smaller than 9.5°. The roofing industry has widely accepted a slope of 2:12 or less as a definition of low-sloped roofs. This corresponds to a slope of approximately 9.5° (16.7 %).

3.1.2 *pyranometer*—an instrument (radiometer) used to measure the total solar radiant energy incident upon a surface per unit time and unit surface area.

3.1.3 *solar energy*—the radiant energy originating from the sun. Approximately 99 % of solar energy lies between wavelengths of 0.3 to 3.5 µm.

3.1.4 *solar flux*—for these measurements, the direct and diffuse radiation from the sun received at ground level over the solar spectrum, expressed in watts per square metre.

3.1.5 *solar reflectance*—the fraction of solar flux reflected by a surface.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *solar spectrum*—the solar spectrum at ground level extending from wavelength 0.3 to 3.5 µm.

4. Summary of Test Method

4.1 A pyranometer is used to measure incoming and reflected solar radiation for a uniform horizontal or low-sloped surface. The solar reflectance is the ratio of the reflected radiation to the incoming radiation.

5. Significance and Use

5.1 Solar reflectance is an important factor affecting surface and near-surface ambient air temperature. Surfaces with low solar reflectance (typically 30 % or lower), absorb a high fraction of the incoming solar energy which is either conducted into buildings or convected to air (leading to higher air temperatures). Use of materials with high solar reflectance may result in lower air-conditioning energy use and cooler cities and communities. The test method described here measures the solar reflectance of surfaces in the field.

6. Apparatus

6.1 *Sensor*—A precision spectral pyranometer (PSP) sensitive to radiant energy in the 0.28–2.8 µm band is recommended. A typical pyranometer yields a linear output of ±0.5 % between 0 and 1400 $W \cdot m^{-2}$ and a response time of one s. Specific characteristics can be obtained based on calibration by the manufacturer of the pyranometer. Other suitable pyranometers are discussed in Zerlaut.[3] The double-dome design of the PSP minimizes the effects of internal convection resulting from tilting the pyranometer at different angles. For this reason, the PSP is especially suitable for this test, since measurement of solar reflectivity requires the apparatus to alternatively face up and down.

6.2 *Read-Out Instrument*—The analog output from the pyranometer is converted to digital output with a readout meter (such as EPLAB Model 455 Instantaneous Solar Radiation Meter) that has an accuracy of better than ±0.5 % and a resolution of 1 $W \cdot m^{-2}$. The meter shall be scaled to the

[1] This test method is under the jurisdiction of ASTM Committee D08 on Roofing and Waterproofing and is the direct responsibility of Subcommittee D08.18 on Nonbituminous Organic Roof Coverings.

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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] Zerlaut, G., "Solar Radiation Instrumentation," *Solar Resources*, R.L. Hulstrom, ed., MIT Press, Cambridge, MA, 1989, pp. 173–308.

sensitivity of the specific PSP by the manufacturer of the pyranometer. Alternatively, a precision voltmeter can be used.

6.3 *Pyranometer Stand*—The pyranometer shall be mounted on an arm and a stand that places the sensor at a height of 50 cm above the surface to minimize the effect of the shadow on measured reflected radiation. The arm and stand shall be strong, cast the smallest possible shadow, and allow the pyranometer to be turned upward and downward easily as shown in Fig. 1.

7. Sampling, Test Specimens, and Test Units

7.1 The test method described here applies to large (circles with at least four metres in diameter or squares four metres on a side), homogeneous, low-sloped surfaces, such as roofs, streets, and parking lots. The measurements shall be performed on dry surfaces.

8. Calibration and Standardization

8.1 The pyranometer shall be checked to ensure its accuracy. Most pyranometers are precalibrated by manufacturers. It is a good practice to recalibrate the pyranometer as specified by the manufacturer (typically once every year or two years). Recalibration is done by the manufacturer of the pyranometer.

9. Procedure

9.1 Cloud cover and haze significantly affect the measurements. The tests shall be conducted on a clear sunny day with no cloud cover or haze during the individual measurements. See Annex A1 for guidelines on determination of the suitability of the atmospheric conditions for conducting the tests.

9.2 The test shall be done in conditions where the angle of the sun to the normal from the surface of interest is less than 45°. For flat and low-sloped surfaces, this limits the test to between the hours of 9 a.m. and 3 p.m. local standard time; this is when solar radiation is at least 70 % of the value obtained at solar noon for that day. In winter months (when solar angle is low), perform the tests between hours 10 a.m. and 2 p.m.

9.3 Align the stand such that the arm points toward the sun (this eliminates the shadow of the people conducting the test and minimizes the effect of the shadow from equipment). There shall be no other shadow on the measurement area other than the minimal shadow cast by the pyranometer and the stand. The pyranometer shall be parallel to the surface where measurement is conducted.

9.4 Face the pyranometer upward (that is, looking directly away from the surface) to read incoming solar radiation. Flip the pyranometer downward to read reflected solar radiation. Make sure the readings are constant for at least 10 s. The measurements of incoming and reflected radiation shall be performed in a time interval not to exceed 2 min. Solar reflectance is the ratio of the reflected radiation to incoming radiation. Repeat the pairs of incoming and reflected measurements at least three times. The calculated solar reflectance from all the measurements shall agree within 0.01 in a reflectivity scale of 0.00 to 1.00.

9.5 The solar reflectance of most exterior surfaces is inherently variable due to variations in the materials themselves, weathering conditions, and a broad range of environmental contaminants. To adequately represent the solar reflectance of these surfaces, a minimum of three measurements from widely spaced (locations separated by more that 10 times the height of the sensor above the surface being measured) areas must be collected, and the detailed condition (surface condition, location, and surrounding objects) of each sample are recorded. For each location repeat 9.1 – 9.3.

10. Report

10.1 The report shall include the following:

10.1.1 The place, date, and time of the test.

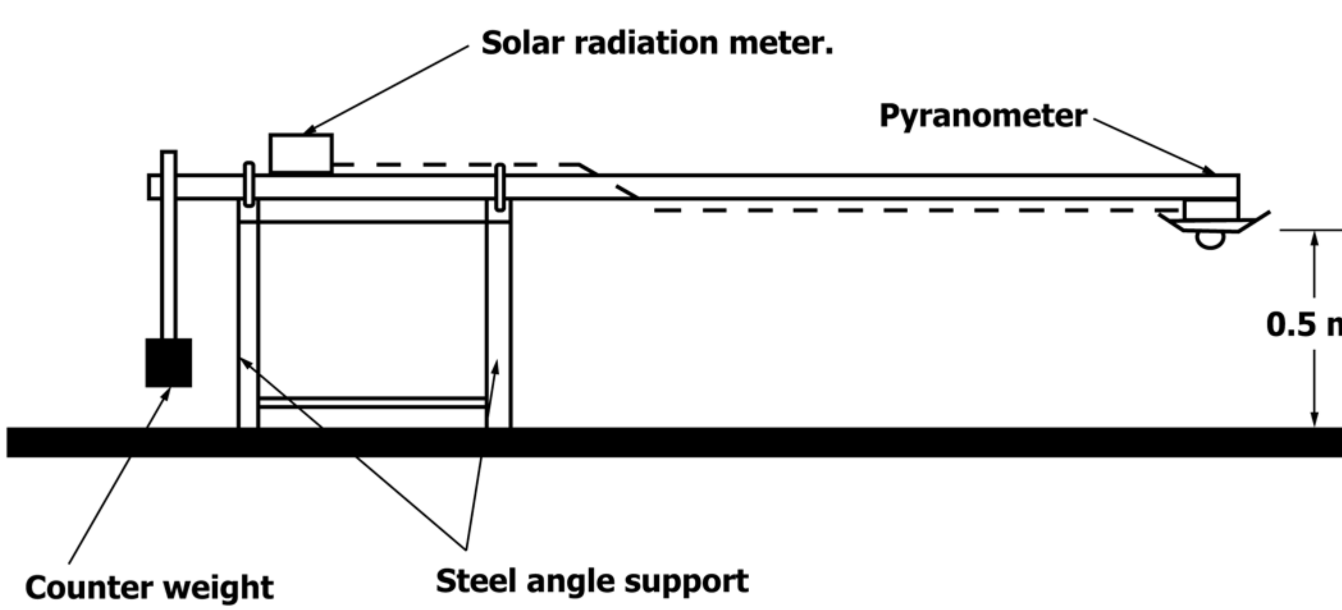

FIG. 1 Schematic of the Pyranometer and its Stand

10.1.2 General description of the surface (surface condition, dirt on surface, age, if available).

10.1.3 A qualitative assessment of cloud cover or haze. (The measurements may need to be repeated if taken under cloudy or hazy conditions.)

10.1.4 The incoming solar radiation, the reflected solar radiation, and the calculated solar reflectance for all three pairs of acceptable measurements at each location. The solar reflectance is the average of the three acceptable values.

11. Precision and Bias

11.1 *Precision*—The precision of this test method is based on an interlaboratory study of Practice E1918 conducted in 2012. Each of seven laboratories tested three different smooth surfaced materials. Every "test result" represents the average of three determinations, and all participants were instructed to report four replicate test results. Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report No. RR:D08-1018.[4] This precision statement is not applicable to materials which surface is covered with mineral granules such as modified bitumen cap sheets. A new interlaboratory study is under way to determine the precision of this test method with such materials.

11.1.1 *Repeatability (r)*—The difference between repetitive results obtained by the same operator in a given laboratory applying the same test method with the same apparatus under constant operating conditions on identical test material within short intervals of time would in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

11.1.1.1 Repeatability can be interpreted as maximum difference between two results, obtained under repeatability conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

11.1.1.2 Repeatability limits are listed in Tables 1-3.

11.1.2 *Reproducibility (R)*—The difference between two single and independent results obtained by different operators applying the same test method in different laboratories using different apparatus on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

11.1.2.1 Reproducibility can be interpreted as maximum difference between two results, obtained under reproducibility conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

11.1.2.2 Reproducibility limits are listed in Tables 1-3.

11.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

11.1.4 Any judgment in accordance with statements 11.1.1 and 11.1.2 would have an approximate 95 % probability of being correct.

11.2 The precision statement was determined through statistical examination of 208 results, from seven laboratories, on three smooth surfaced materials, using three different instrument types (described below).

(1) Instrument A: second-class pyranometer (CMP3)

(2) Instrument B: first-class pyranometer (upper CMP6 pyranometer on CMA6 albedometer)

(3) Instrument C: first-class albedometer (CMA6)

11.3 To judge the equivalency of two test results, it is recommended to choose the material closest in characteristics to the test material.

11.4 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for the test method, therefore no statement on bias is being made.

12. Keywords

12.1 pyranometer; solar energy; solar reflectance

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D08-1018. Contact ASTM Customer Service at service@astm.org.

TABLE 1 Solar Reflectance – Instrument A[A]

Material[B]	Average[C] $\bar{x}$	Repeatability Standard Deviation S_r	Reproducibility Standard Deviation S_R	Repeatability Limit r	Reproducibility Limit R
Black EPDM	0.0653	0.0039	0.0102	0.0108	0.0286
White TPO	0.7125	0.0065	0.0159	0.0182	0.0446
Beige Metal	0.3822	0.0049	0.0084	0.0139	0.0236

[A] Please note that measurements from Instrument A have been included only as supplementary information since Instrument A (second-class pryanometer) does not meet the hardware requirements of Test Method E1918.
[B] This precision statement is not applicable to materials which surface is covered with mineral granules such as modified bitumen cap sheets.
[C] The average of the laboratories' calculated averages.

TABLE 2 Solar Reflectance – Instrument B

Material[A]	Average[B] $\bar{x}$	Repeatability Standard Deviation S_r	Reproducibility Standard Deviation S_R	Repeatability Limit r	Reproducibility Limit R
Black EPDM	0.0694	0.0033	0.0088	0.0091	0.0246
White TPO	0.7021	0.0056	0.0192	0.0157	0.0536
Beige Metal	0.3884	0.0020	0.0112	0.0057	0.0313

[A]This precision statement is not applicable to materials which surface is covered with mineral granules such as modified bitumen cap sheets.
[B]The average of the laboratories' calculated averages.

TABLE 3 Solar Reflectance – Instrument C

Material[A]	Average[B] $\bar{x}$	Repeatability Standard Deviation S_r	Reproducibility Standard Deviation S_R	Repeatability Limit r	Reproducibility Limit R
Black EPDM	0.0735	0.0023	0.0138	0.0063	0.0387
White TPO	0.6873	0.0056	0.0125	0.0156	0.0349
Beige Metal	0.3794	0.0040	0.0080	0.0112	0.0224

[A]This precision statement is not applicable to materials which surface is covered with mineral granules such as modified bitumen cap sheets.
[B]The average of the laboratories' calculated averages.

ANNEX

(Mandatory Information)

A1. GUIDELINES ON DETERMINATION OF THE SUITABILITY OF THE ATMOSPHERIC CONDITIONS FOR CONDUCTING THE TESTS

A1.1 The following criteria shall be used to establish the suitability of the measurement conditions:

A1.1.1 *Haze*—As long as the solar disk is visible and solar flux is not changing rapidly during the test, the measurements can be performed with reasonable accuracy.

A1.1.2 *Clouds*—The impact of clouds close to the sun is larger than clouds in the horizon. It is important to make the measurements in a stable solar condition. The best way of determining stability is to make several measurements (each performed within a two-minute period), and make sure that the calculated solar reflectance is repeatable within the period of the measurement (see 9.4).

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