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 E 1918; 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:*

E 772 Terminology Relating to Solar Energy Conversion[2]

E 903 Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrated Spheres[2]

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 slop 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 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

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[2] *Annual Book of ASTM Standards*, Vol 12.02.

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

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 meters in diameter or squares four meters 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.

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

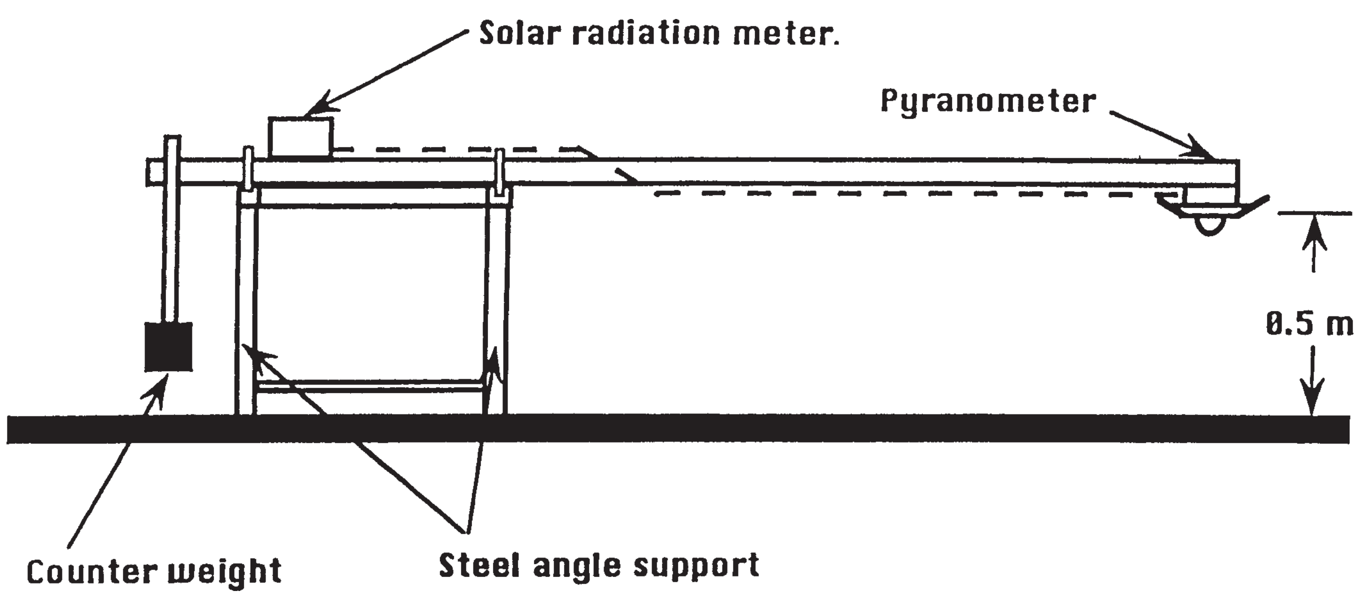

FIG. 1 A Schematic of the Pyranometer and its Stand

of acceptable measurements at each location. The solar reflectance is the average of the three acceptable values.

11. Precision and Bias

11.1 A precision and bias statement has not been established. However, most surfaces are non-uniform and their solar reflectances may vary both from one location to another and with time.

12. Keywords

12.1 pyranometer; solar energy; solar reflectance

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).

APPENDIX

(Nonmandatory Information)

X1. Bibliography

(1) Akbari, H., S. Bretz, H. Taha, D. Kurn, and J. Hanford. "Peak Power and Cooling Energy Savings of High-albedo Roofs," *Energy and Buildings*, Vol 25 (2), pp. 117–126, 1997.

(2) Rosenfeld A., H. Akbari, S. Bretz, B. Fishman, D. Kurn, D, Sailor, and H. Taha. "Mitigation of Urban Heat Islands: Material, Utility Programs, Updates," *Energy and Building*, 22 pp 255-265, 1995.

(3) Taha, H., D. Sailor, and H. Akbari. "High-Albedo Materials for Reducing Building Cooling Energy Use," Lawrence Berkley Laboratory Report LBL-31721, Berkeley, CA., 1992.

(4) Florida Solar Energy Center (FSEC)." Laboratory Testing of Reflective Properties of Roofing Materials," Contract Report FSEC-CR-670-93, August, 1993.

(5) Reagan, J. A. and D. M. A. Acklam. "Solar Reflectivity of Common Building Materials and its Influence of the Roof Heat Gain of Typical Southwestern USA Residences," *Energy and Buildings*, 2, pp 237-248, 1979.

(6) Yarbrough, D. W. and R. W. Anderson. "Use of Radiation Control Coatings to Reduce Building Air-Conditioning Loads," Energy Source, Vol 15, pp 59-66, 1992.