National Bureau of Standards

Certificate

Standard Reference Material 2019a

White Ceramic Tile for Directional-Hemispherical Reflectance from 250 to 2500 nm

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This Standard Reference Material (SRM) is intended for use in calibrating the reflectance scale of integrating sphere reflectometers, such as those used in the evaluation of solar energy materials.

The reflectance of each tile was measured at 375, 550, and 2000 nm with a high-precision instrument to guarantee the homogeneity of this SRM. The certified values for incidence at 6° from normal were determined in the following way. The reflectance of each of 25 tiles was measured at 10-nm intervals from 250 to 2500 nm with a high-precision reflectometer. The reflectance of five of the 25 tiles was also measured at 25-nm intervals from 250 to 800 nm and at 100-nm intervals from 800 to 2500 nm with the highly accurate NBS Reference Reflectometer. These accurate measurements were used to correct for the systematic biases in the high-precision measurements, which after being corrected, provide the mean reflectance at each wavelength for this lot of tiles.

The mean values for 6° / hemispherical reflectance factor are given in Table 1. Starred values have an uncertainty of 0.005 or less, expressed as one standard deviation. This standard deviation applies to the difference between the value the NBS Reference Instrument would give for a single tile and the value given in this table. The errors for different wavelengths, however, are not independent. The uncertainties for unstarred values in the table cannot be fully assessed because they were obtained in part by interpolation of an additive correction. However, an indication of the maximum uncertainty is provided by the size of this correction, which ranged from 0.001 to 0.013. The research and development of this SRM were supported by the DOE Solar Thermal Program through the Solar Energy Research Institute.

The overall direction and coordination of the preparation and technical measurements leading to certification were performed under the chairmanship of J.C. Richmond.

The technical and support aspects involved in the certification and issuance of this SRM were coordinated through the Office of Standard Reference Materials by R.K. Kirby.

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(over)

George A. Uriano, Chief
Office of Standard Reference Materials

Table I

6°/Hemispherical Reflectance Factor[+] (R)

λ (nm)	F	λ (nm)	F	λ (nm)	F	λ (nm)	F	λ (nm)	F	λ (nm)	F
250	.097	650	.844*	1050	.861	1450	.867	1850	.866	2250	.860
260	.094	660	.848	1060	.861	1460	.867.	1860	.865	2260	.859
270	.094	670	.851	1070	.861	1470	.866	1870	.865	2270	.861
280	.101	680	.851	1080	.862	1480	.865	1880	.861	2280	.861
290	.120	690	.853	1090	.862	1490	.863	1890	.856	2290	.860
300	.147	700	.857*	1100	.861*	1500	.863*	1900	.854*	2300	.860*
310	.190	710	.858	1110	.862	1510	.867	1910	.856	2310	.860
320	.238	720	.859	1120	.865	1520	.869	1920	.860	2320	.861
330	.303	730	.860	1130	.868	1530	.871	1930	.862	2330	.863
340	.377	740	.861	1140	.869	1540	.871	1940	.863	2340	.863
350	.460*	750	.862*	1150	.870	1550	.871	1950	.863	2350	.862
360	.541	760	.862	1160	.871	1560	.871	1960	.865	2360	.861
370	.608	770	.863	1170	.871	1570	.871	1970	.867	2370	.859
380	.654	780	.863	1180	.871	1580	.872	1980	.867	2380	.859
390	.690	790	.861	1190	.871	1590	.872	1990	.868	2390	.858
400	.720*	800	.860*	1200	.872*	1600	.872*	2000	.869*	2400	.853*
410	.737	810	.862	1210	.872	1610	.872	2010	.869	2410	.854
420	.749	820	.860	1220	.872	1620	.872	2020	.870	2420	.851
430	.757	830	.859	1230	.872	1630	.871	2030	.870	2430	.846
440	.762	840	.857	1240	.871	1640	.872	2040	.870	2440	.846
450	.767*	850	.856	1250	.872	1650	.872	2050	.870	2450	.843
460	.772	860	.855	1260	.873	1660	.872	2060	.869	2460	.842
470	.776	870	.853	1270	.871	1670	.872	2070	.870	2470	.840
480	.780	880	.852	1280	.871	1680	.872	2080	.870	2480	.839
490	.787	890	.852	1290	.871	1690	.871	2090	.871	2490	.838
500	.793*	900	.852*	1300	.870*	1700	.871*	2100	.871*	2500	.839*
510	.799	910	.853	1310	.870	1710	.871	2110	.873		
520	.805	920	.853	1320	.870	1720	.871	2120	.872		
530	.811	930	.853	1330	.870	1730	.870	2130	.870		
540	.816	940	.853	1340	.869	1740	.870	2140	.869		
550	.820*	950	.853	1350	.869	1750	.870	2150	.867		
560	.825	960	.853	1360	.869	1760	.870	2160	.864		
570	.829	970	.853	1370	.869	1770	.870	2170	.863		
580	.831	980	.856	1380	.867	1780	.870	2180	.860		
590	.834	990	.856	1390	.866	1790	.870	2190	.856		
600	.837*	1000	.858*	1400	.866*	1800	.870*	2200	.856*		
610	.839	1010	.859	1410	.867	1810	.869	2210	.855		
620	.842	1020	.860	1420	.867	1820	.868	2220	.858		
630	.843	1030	.860	1430	.868	1830	.868	2230	.858		
640	.846	1040	.861	1440	.867	1840	.867	2240	.859		

[+]Relative to a perfect diffuser.

*Standard Deviation is less than 0.005 (All other values in the table are interpolated and the uncertainty for these values cannot be assessed.)

Table 2

Directional/Hemispherical Reflectances Normalized to the 6° Angle of Incidence

(These values are not certified)

Wavelength Angle of Incidence	Parallel (p) Polarized	Perpendicular (s) Polarized	Unpolarized (Ordinary)	STDM*
250 nm				
15°	(0.970)	(1.032)	(1.001)	0.06%
30°	(.860)	(1.176)	(1.019)	.08
45°	(.691)	(1.503)	(1.100)	.19
60°	(.602)	(2.290)	(1.453)	.34
300 nm				
15°	(.983)	(1.026)	(1.004)	.04
30°	(.923)	(1.134)	(1.029)	.12
45°	(.825)	(1.373)	(1.101)	.23
60°	(.790)	(1.926)	(1.361)	.43
350 nm				
15°	(.997)	(1.007)	(1.002)	.05
30°	(.987)	(1.034)	(1.011)	.24
45°	(.979)	(1.088)	(1.034)	.09
60°	(.980)	(1.207)	(1.093)	.13
450 nm				
15°	(1.000)	(1.002)	(1.001)	.00
30°	(.999)	(1.010)	(1.005)	.01
45°	(.998)	(1.025)	(1.012)	.02
60°	(1.001)	(1.057)	(1.029)	.05
600 nm				
15°	(1.000)	(1.001)	(1.001)	.02
30°	(1.000)	(1.007)	(1.003)	.02
45°	(1.000)	(1.017)	(1.008)	.02
60°	(1.001)	(1.037)	(1.019)	.03
750 nm				
15°	(1.000)	(1.001)	(1.001)	.01
30°	(1.000)	(1.006)	(1.003)	.00
45°	(1.000)	(1.014)	(1.007)	.01
60°	(1.002)	(1.031)	(1.016)	.02
1000 nm				
15°	(1.008)	(1.002)	(1.005)	.28
30°	(1.003)	(1.007)	(1.005)	.22
45°	(1.009)	(1.019)	(1.014)	.26
60°	(1.008)	(1.037)	(1.022)	.31
1500 nm				
15°	(0.999)	(0.999)	(0.999)	.20
30°	(.998)	(1.005)	(1.002)	.24
45°	(.998)	(1.011)	(1.005)	.23
60°	(1.001)	(1.029)	(1.015)	.18
2000 nm				
15°	(0.997)	(1.007)	(1.002)	1.14
30°	(1.005)	(1.001)	(1.003)	1.19
45°	(1.006)	(1.008)	(1.007)	1.04
60°	(1.007)	(1.029)	(1.018)	0.88

*Percent Standard Deviation of the Mean