

National Bureau of Standards

Certificate

Standard Reference Material 2019b

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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Stanley D. Rasberry, Chief
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(over)

Table 1
6° / Hemispherical Reflectance Factor⁺ (R)

λ (nm)	R	λ (nm)	R	λ (nm)	R	λ (nm)	R	λ (nm)	R	λ (nm)	R
250	.097	650	.843*	1050	.857	1450	.865	1850	.863	2250	.857
260	.094	660	.847	1060	.858	1460	.865	1860	.863	2260	.858
270	.094	670	.850	1070	.858	1470	.864	1870	.862	2270	.859
280	.101	680	.851	1080	.858	1480	.864	1880	.859	2280	.859
290	.120	690	.852	1090	.858	1490	.861	1890	.854	2290	.860
300	.147	700	.857*	1100	.858*	1500	.861*	1900	.854*	2300	.859*
310	.190	710	.858	1110	.858	1510	.865	1910	.856	2310	.860
320	.238	720	.859	1120	.862	1520	.868	1920	.858	2320	.861
330	.303	730	.860	1130	.864	1530	.868	1930	.860	2330	.863
340	.377	740	.861	1140	.865	1540	.868	1940	.861	2340	.863
350	.456*	750	.861*	1150	.866	1550	.869	1950	.862	2350	.862
360	.536	760	.862	1160	.868	1560	.869	1960	.863	2360	.861
370	.605	770	.862	1170	.868	1570	.869	1970	.864	2370	.859
380	.651	780	.862	1180	.868	1580	.869	1980	.865	2380	.859
390	.687	790	.860	1190	.869	1590	.870	1990	.865	2390	.858
400	.717*	800	.858*	1200	.868*	1600	.870*	2000	.865*	2400	.851*
410	.734	810	.857	1210	.869	1610	.870	2010	.866	2410	.854
420	.745	820	.856	1220	.868	1620	.870	2020	.867	2420	.851
430	.754	830	.855	1230	.869	1630	.869	2030	.867	2430	.848
440	.759	840	.853	1240	.869	1640	.869	2040	.867	2440	.846
450	.764*	850	.852	1250	.869	1650	.869	2050	.867	2450	.843
460	.770	860	.851	1260	.869	1660	.869	2060	.867	2460	.842
470	.774	870	.849	1270	.869	1670	.869	2070	.867	2470	.840
480	.778	880	.849	1280	.869	1680	.869	2080	.868	2480	.839
490	.785	890	.847	1290	.869	1690	.868	2090	.869	2490	.838
500	.791*	900	.847*	1300	.868*	1700	.869*	2100	.868*	2500	.840*
510	.798	910	.848	1310	.868	1710	.868	2110	.870		
520	.804	920	.848	1320	.868	1720	.868	2120	.870		
530	.811	930	.848	1330	.868	1730	.868	2130	.868		
540	.815	940	.848	1340	.868	1740	.868	2140	.866		
550	.819*	950	.848	1350	.867	1750	.867	2150	.864		
560	.824	960	.849	1360	.867	1760	.867	2160	.861		
570	.829	970	.849	1370	.867	1770	.867	2170	.860		
580	.831	980	.851	1380	.866	1780	.867	2180	.856		
590	.833	990	.852	1390	.864	1790	.866	2190	.853		
600	.837*	1000	.853*	1400	.864*	1800	.867*	2200	.853*		
610	.839	1010	.854	1410	.865	1810	.866	2210	.853		
620	.840	1020	.855	1420	.865	1820	.865	2220	.854		
630	.843	1030	.856	1430	.865	1830	.865	2230	.856		
640	.845	1040	.857	1440	.865	1840	.864	2240	.856		

* 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*
<u>250 nm</u>				
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
<u>300 nm</u>				
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
<u>350 nm</u>				
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
<u>450 nm</u>				
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
<u>600 nm</u>				
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
<u>750 nm</u>				
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
<u>1000 nm</u>				
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
<u>1500 nm</u>				
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
<u>2000 nm</u>				
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