Department of Commerce
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National Bureau of Standards

Certificate

Standard Reference Materials 2019 and 2020

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

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These Standard Reference Materials (SRM's) are intended for use in calibrating the reflectance scale of integrating sphere reflectometers, such as those used in the evaluation of solar energy materials. SRM 2019 is 5.1 x 5.1 cm in size and SRM 2020 is 3.8 x 7.6 cm in size.

The reflectance of each tile was measured at 375, 550 and 2000 nm with a high-precision instrument to guarantee the homogeneity of these SRM's. 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 these SRM's was 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 these SRM's were coordinated through the Office of Standard Reference Materials by R.K. Kirby.

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George A. Uriano, Chief
Office of Standard Reference Materials

(over)

Table 1

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

λ (nm)	R	λ (nm)	R	λ (nm)	R	λ (nm)	R	λ (nm)	R	λ (nm)	R
250	0.097	650	0.838*	1050	0.856	1450	0.863	1850	0.861	2250	0.856
260	(.094)[+]	660	.842	1060	.857	1460	.863	1860	.861	2260	.856
270	(.094)	670	.844	1070	.857	1470	.862	1870	.861	2270	.858
280	(.101)	680	.845	1080	.857	1480	.861	1880	.856	2280	.858
290	(.120)	690	.847	1090	.857	1490	.859	1890	.852	2290	.859
300	.147	700	.851*	1100	.857*	1500	.859*	1900	.852*	2300	.859*
310	(.190)	710	.853	1110	.857	1510	.864	1910	.854	2310	(.860)
320	(.238)	720	.854	1120	.860	1520	.866	1920	.856	2320	(.861)
330	(.303)	730	.854	1130	.862	1530	.866	1930	.858	2330	(.863)
340	(.377)	740	.855	1140	.864	1540	.866	1940	.859	2340	(.863)
350	.451*	750	.856*	1150	.865	1550	.867	1950	.859	2350	(.862)
360	.533	760	.856	1160	.867	1560	.867	1960	.861	2360	(.861)
370	.601	770	.857	1170	.867	1570	.867	1970	.862	2370	(.859)
380	.648	780	.856	1180	.866	1580	.867	1980	.863	2380	(.859)
390	.684	790	.855	1190	.867	1590	.868	1990	.864	2390	(.858)
400	.714*	800	.854*	1200	.867*	1600	.868*	2000	.863*	2400	.852*
410	.731	810	.856	1210	.867	1610	.868	2010	.864	2410	(.854)
420	.742	820	.854	1220	.867	1620	.868	2020	.865	2420	(.851)
430	.751	830	.853	1230	.867	1630	.867	2030	.866	2430	(.848)
440	.756	840	.852	1240	.867	1640	.867	2040	.866	2440	(.846)
450	.761*	850	.850	1250	.868	1650	.867	2050	.865	2450	(.843)
460	.765	860	.849	1260	.868	1660	.867	2060	.865	2460	(.842)
470	.770	870	.847	1270	.867	1670	.867	2070	.865	2470	(.840)
480	.774	880	.846	1280	.867	1680	.867	2080	.866	2480	(.839)
490	.781	890	.845	1290	.867	1690	.867	2090	.867	2490	(.838)
500	.787*	900	.845*	1300	.866*	1700	.867*	2100	.867*	2500	.838*
510	.793	910	.845	1310	.866	1710	.867	2110	.868		
520	.799	920	.846	1320	.866	1720	.866	2120	.868		
530	.805	930	.846	1330	.866	1730	.866	2130	.866		
540	.811	940	.846	1340	.866	1740	.865	2140	.864		
550	.815*	950	.846	1350	.865	1750	.865	2150	.863		
560	.819	960	.846	1360	.865	1760	.865	2160	.861		
570	.824	970	.847	1370	.865	1770	.865	2170	.858		
580	.826	980	.849	1380	.864	1780	.865	2180	.855		
590	.829	990	.849	1390	.862	1790	.864	2190	.852		
600	.833*	1000	.851*	1400	.862*	1800	.865*	2200	.851*		
610	.835	1010	.852	1410	.863	1810	.864	2210	.851		
620	.836	1020	.853	1420	.863	1820	.863	2220	.852		
630	.838	1030	.854	1430	.863	1830	.863	2230	.854		
640	.840	1040	.855	1440	.863	1840	.862	2240	.855		

[t]Relative to a perfect diffuser.

[+]The values in parentheses are not certified but are for information only.

*The uncertainty of this value (as expressed as one standard deviation) is less than 0.005. The uncertainties of all values not starred cannot be fully assessed.

Normalized directional/hemispherical reflectances at nine wavelengths and four angles of incidence are provided in Table 2 for information only. (These values are not certified.) These reflectances are the average values obtained on five tiles and normalized to the 6° / hemispherical reflectance factors given in Table 1 for radiant flux polarized in both the parallel (p) and perpendicular (s) directions as well as for unpolarized radiant flux.

These SRM's can be cleaned with a mild liquid soap and warm water followed by a rinse with distilled water. Ordinarily water will not penetrate the glazed front surface or the epoxy seal on the back and sides of the tile. If the tile is chipped or scratched, however, the clay substrate will absorb water and the infrared reflectance will be changed.

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