Devices & Services Co.
10024 MONROE DRIVE - DALLAS, TEXAS 75229 - (214) 902-8337

D&S TECHNICAL NOTE 87-1


# USING NATIONAL BUREAU OF STANDARDS REFERENCE MATERIALS AS STANDARDS FOR THE SSR-ER VERSION 5.0

With the introduction of Version 5.0 of the SSR Reflectometer, values for the reference standards are programmed into the electronics package read only memory. With this capability, it is possible to use NBS reference materials or other materials for which reflectance data is available as reference standards for the instrument. This allows the user to maintain reference standards traceable to the NBS, independent of the standards maintained at Devices & Services Company.

In order to program the standards into the electronics package, the reflectance value for each of the four detectors must be determined. The reflectance values are detemined by integration of the spectral reflectance data for the material for each of the four detectors. Reflectance data must be available for the wavelength range of 330 to 2500 nanometers. Along with this data a two digit identification code must be supplied to D&S for programming the data into read only memory. The code can use the digits 0 to 9 and the characters "H", "E", "L", "P" and "-".

## NBS Standard Reference Materials (SRM's)

Two SRM's are maintained at D&S, a highly specular aluminum second surface mirror and a diffuse white ceramic tile. These two standards are described here and are recommended for use with the SSR-ER.

SRM 2023 is a 2" x 2" second surface mirror that has aluminum vacuum deposited on a 2mm thick quartz plate. The mirror is protected by a second quartz plate bonded to the metallized surface. The specular reflectance is specified at an incidence angle of 6 degrees from normal. Correction factors for 30 degrees and 45 degrees were determined by measurements made on a master mirror. The certified reflectance values are assigned an uncertainty of $\pm$ 0.005.

SRM 2019 is a 2" x 2" white glazed ceramic tile. Reflectance values reported for the standard were established by measuring hemispherical reflectance values for each tile of a lot at 375, 550, and 2000nm with a highly precise instrument to guarantee homogeneity of the samples. A sample of tiles out of the lot was measured at closer wavelength spacings between 250 and 2500nm. Using the precise measurements to correct systematic errors in the measurements on the smaller sample, mean reflectance values were determined at each wavelength for the tiles. Additional reflectance data is provided for 15, 30, 45, and 60 degrees although this data is not certified. Note that the mean values are reported, therefore, the same values are applicable to any 2019 standard.

The standards can be obtained from:

National Bureau of Standards
Office of Standard Reference Materials
Chemistry Building, Room B311
Washington, DC 20234
Telephone: (301) 921-2045

**Calculation of Reflectance Values:**

The reflectance values for each detector are determined by numerical integration of the spectral reflectance of the standard over the range of spectral response of the detector.

$$R_{det} = \frac{\Sigma_n R_n * D_n}{\Sigma_n D_n}$$

Where:
- $R_{det}$ = the reflectance of the standard for a particular detector
- $R_n$ = the reflectance of the standard at wavelength n
- $D_n$ = the relative response of the detector at wavelength n
- n = designates the wavelength assuming equal intervals covering the range of wavelengths for which the detector response is non-zero

This is equivalent to the trapezoidal rule for numerical integration since the response of the detector is zero at both endpoints.

Tables of the detector response data and the spectral reflectance data for the 2019 and 2023 standards are included at the end of this note. For the 2023 specular standard, the reflectance values reported are specular rather than hemispherical values. Since the mirror is highly specular we assumed that the mirror is perfectly specular and the hemispherical and specular reflectance values are equal. Also, the difference between the reflectance at 6 degrees and 20 degrees is very small and was neglected. Values in the table for wavelengths that do not correspond to certified reflectance values were determined by interpolation with the aid of a continuous spectral reflectance curve provided with the data for the standard.

For the 2019 diffuse standard, the 6 degree incident values are given in the table. The correction to 20 degrees is small and varies somewhat with wavelength. An average correction factor of 1.002 was applied to the calculated reflectance values.

The reflectance values for the four detectors are as follows:

| STANDARD | IR | RED | BLUE | UV |
|---|---|---|---|---|
| 2023, Specular | 0.937 | 0.848 | 0.881 | 0.890 |
| 2019, Diffuse | 0.864 | 0.845 | 0.788 | 0.636 |

The results for the 2019 standard will be identical for any other 2019 because the reflectance values for the entire lot were certified to the same values. For the 2023 specular standard, each sample is provided with certified reflectance values and the results will vary slightly from those given above.

The solar reflectance values for the two standards are as follows:

| Standard | AM0 | AM1 | AM1.5 | AM2 |
|---|---|---|---|---|
| 2023, Specular | 0.890 | 0.885 | 0.884 | 0.882 |
| 2019, Diffuse | 0.817 | 0.827 | 0.831 | 0.830 |

# TABLE 1
## 6° HEMISPHERICAL REFLECTANCE FOR SRM 2019 AND 2020

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

# TABLE 1 - PAGE 2
# 6° HEMISPHERICAL REFLECTANCE FOR SRM 2019 AND 2020

| WAVELENGTH | R |
|---|---|
| 2250 | 0.856 |
| 2260 | .856 |
| 2270 | .858 |
| 2280 | .858 |
| 2290 | .859 |
| 2300 | .859 |
| 2310 | .860 |
| 2320 | .861 |
| 2330 | .863 |
| 2340 | .863 |
| 2350 | .862 |
| 2360 | .861 |
| 2370 | .859 |
| 2380 | .859 |
| 2390 | .858 |
| 2400 | .852 |
| 2410 | .854 |
| 2420 | .851 |
| 2430 | .848 |
| 2440 | .846 |
| 2450 | .843 |
| 2460 | .842 |
| 2470 | .840 |
| 2480 | .839 |
| 2490 | .838 |
| 2500 | .838 |

# TABLE 2
# $6^{O}$ SPECULAR REFLECTANCE FOR
# SRM 2023, #63

| WAVELENGTH | R | WAVELENGTH | R | WAVELENGTH | R | WAVELENGTH | R |
|---|---|---|---|---|---|---|---|
| | | 750 | .833* | 1250 | .95 | 1750 | .955* |
| | | 760 | .83 | 1260 | .95 | 1760 | .96 |
| 270 | 0.88 | 770 | .82 | 1270 | .95 | 1770 | .96 |
| 280 | .88 | 780 | .82 | 1280 | .95 | 1780 | .96 |
| 290 | .89 | 790 | .81 | 1290 | .95 | 1790 | .96 |
| 300 | .890* | 800 | .805* | 1300 | .947* | 1800 | .96 |
| 310 | .89 | 810 | .81 | 1310 | .95 | 1810 | .96 |
| 320 | .89 | 820 | .81 | 1320 | .95 | 1820 | .96 |
| 330 | .89 | 830 | .80 | 1330 | .95 | 1830 | .96 |
| 340 | .89 | 840 | .80 | 1340 | .95 | 1840 | .96 |
| 350 | .891* | 850 | .798* | 1350 | .95 | 1850 | .96 |
| 360 | .89 | 860 | .81 | 1360 | .94 | 1860 | .96 |
| 370 | .89 | 870 | .82 | 1370 | .94 | 1870 | .96 |
| 380 | .89 | 880 | .83 | 1380 | .94 | 1880 | .95 |
| 390 | .89 | 890 | .84 | 1390 | .94 | 1890 | .95 |
| 400 | .891* | 900 | .845* | 1400 | .95 | 1900 | .95 |
| 410 | .89 | 910 | .86 | 1410 | .95 | 1910 | .95 |
| 420 | .89 | 920 | .86 | 1420 | .95 | 1920 | .95 |
| 430 | .89 | 930 | .87 | 1430 | .95 | 1930 | .95 |
| 440 | .89 | 940 | .87 | 1440 | .95 | 1940 | .95 |
| 450 | .887* | 950 | .88 | 1450 | .95 | 1950 | .95 |
| 460 | .89 | 960 | .89 | 1460 | .95 | 1960 | .95 |
| 470 | .89 | 970 | .89 | 1470 | .95 | 1970 | .95 |
| 480 | .88 | 980 | .90 | 1480 | .95 | 1980 | .95 |
| 490 | .88 | 990 | .90 | 1490 | .95 | 1990 | .95 |
| 500 | .883* | 1000 | .909* | 1500 | .952* | 2000 | .954* |
| 510 | .88 | 1010 | .91 | 1510 | .95 | 2010 | .95 |
| 520 | .88 | 1020 | .91 | 1520 | .95 | 2020 | .95 |
| 530 | .88 | 1030 | .92 | 1530 | .95 | 2030 | .95 |
| 540 | .88 | 1040 | .92 | 1540 | .95 | 2040 | .95 |
| 550 | .877* | 1050 | .92 | 1550 | .95 | 2050 | .95 |
| 560 | .88 | 1060 | .924* | 1560 | .95 | 2060 | .95 |
| 570 | .88 | 1070 | .92 | 1570 | .95 | 2070 | .95 |
| 580 | .87 | 1080 | .93 | 1580 | .95 | 2080 | .95 |
| 590 | .87 | 1090 | .93 | 1590 | .95 | 2090 | .95 |
| 600 | .871* | 1100 | .931* | 1600 | .95 | 2100 | .95 |
| 610 | .87 | 1110 | .93 | 1610 | .95 | 2110 | .95 |
| 620 | .87 | 1120 | .93 | 1620 | .95 | 2120 | .95 |
| 630 | .87 | 1130 | .93 | 1630 | .96 | 2130 | .95 |
| 640 | .87 | 1140 | .93 | 1640 | .96 | 2140 | .94 |
| 650 | .863* | 1150 | .94 | 1650 | .96 | 2150 | .94 |
| 660 | .86 | 1160 | .94 | 1660 | .96 | 2160 | .94 |
| 670 | .86 | 1170 | .94 | 1670 | .96 | 2170 | .93 |
| 680 | .85 | 1180 | .94 | 1680 | .96 | 2180 | .93 |
| 690 | .85 | 1190 | .94 | 1690 | .96 | 2190 | .93 |
| 700 | .850* | 1200 | .941* | 1700 | .96 | 2200 | .93 |
| 710 | .85 | 1210 | .94 | 1710 | .96 | 2210 | .92 |
| 720 | .84 | 1220 | .94 | 1720 | .96 | 2220 | .92 |
| 730 | .84 | 1230 | .94 | 1730 | .96 | 2230 | .92 |
| 740 | .83 | 1240 | .94 | 1740 | .96 | 2240 | .91 |

TABLE 2 - PAGE 2
$6^{O}$ SPECULAR REFLECTANCE FOR
SRM 2023, #63

| WAVELENGTH | R |
|---|---|
| 2250 | .908* |
| 2260 | .91 |
| 2270 | .92 |
| 2280 | .92 |
| 2290 | .93 |
| 2300 | .93 |
| 2310 | .94 |
| 2320 | .94 |
| 2330 | .95 |
| 2340 | .95 |
| 2350 | .95 |
| 2360 | .95 |
| 2370 | .94 |
| 2380 | .94 |
| 2390 | .94 |
| 2400 | .94 |
| 2410 | .94 |
| 2420 | .94 |
| 2430 | .93 |
| 2440 | .93 |
| 2450 | .93 |
| 2460 | .93 |
| 2470 | .93 |
| 2480 | .92 |
| 2490 | .92 |
| 2500 | .922* |

## TABLE 3
## IR DETECTOR RESPONSE

| WAVELENGTH | DATA | WAVELENGTH | DATA | WAVELENGTH | DATA | WAVELENGTH | DATA |
|---|---|---|---|---|---|---|---|
| 800 | 0.000 | 1300 | .698 | 1800 | .073 | 2300 | .037 |
| 810 | .006 | 1310 | .557 | 1810 | .065 | 2310 | .036 |
| 820 | .008 | 1320 | .445 | 1820 | .057 | 2320 | .035 |
| 830 | .010 | 1330 | .348 | 1830 | .052 | 2330 | .034 |
| 840 | .016 | 1340 | .269 | 1840 | .043 | 2340 | .030 |
| 850 | .026 | 1350 | .223 | 1850 | .034 | 2350 | .026 |
| 860 | .039 | 1360 | .194 | 1860 | .034 | 2360 | .024 |
| 870 | .053 | 1370 | .188 | 1870 | .036 | 2370 | .022 |
| 880 | .079 | 1380 | .186 | 1880 | .038 | 2380 | .020 |
| 890 | .109 | 1390 | .190 | 1890 | .039 | 2390 | .019 |
| 900 | .134 | 1400 | .198 | 1900 | .039 | 2400 | .018 |
| 910 | .166 | 1410 | .213 | 1910 | .040 | 2410 | .014 |
| 920 | .207 | 1420 | .247 | 1920 | .041 | 2420 | .012 |
| 930 | .251 | 1430 | .294 | 1930 | .042 | 2430 | .010 |
| 940 | .283 | 1440 | .352 | 1940 | .047 | 2440 | .008 |
| 950 | .326 | 1450 | .387 | 1950 | .049 | 2450 | .006 |
| 960 | .368 | 1460 | .421 | 1960 | .053 | 2460 | .004 |
| 970 | .405 | 1470 | .445 | 1970 | .057 | 2470 | .003 |
| 980 | .458 | 1480 | .468 | 1980 | .063 | 2480 | .002 |
| 990 | .496 | 1490 | .476 | 1990 | .067 | 2490 | .001 |
| 1000 | .530 | 1500 | .478 | 2000 | .073 | 2500 | 0.000 |
| 1010 | .569 | 1510 | .480 | 2010 | .077 | | |
| 1020 | .624 | 1520 | .474 | 2020 | .085 | | |
| 1030 | .672 | 1530 | .464 | 2030 | .091 | | |
| 1040 | .708 | 1540 | .453 | 2040 | .095 | | |
| 1050 | .749 | 1550 | .439 | 2050 | .099 | | |
| 1060 | .775 | 1560 | .421 | 2060 | .102 | | |
| 1070 | .816 | 1570 | .405 | 2070 | .107 | | |
| 1080 | .834 | 1580 | .393 | 2080 | .107 | | |
| 1090 | .862 | 1590 | .379 | 2090 | .106 | | |
| 1100 | .881 | 1600 | .358 | 2100 | .105 | | |
| 1110 | .901 | 1610 | .340 | 2110 | .103 | | |
| 1120 | .911 | 1620 | .324 | 2120 | .101 | | |
| 1130 | .931 | 1630 | .304 | 2130 | .100 | | |
| 1140 | .939 | 1640 | .287 | 2140 | .099 | | |
| 1150 | .949 | 1650 | .273 | 2150 | .097 | | |
| 1160 | .962 | 1660 | .263 | 2160 | .093 | | |
| 1170 | .972 | 1670 | .245 | 2170 | .091 | | |
| 1180 | .980 | 1680 | .227 | 2180 | .089 | | |
| 1190 | .988 | 1690 | .211 | 2190 | .081 | | |
| 1200 | .992 | 1700 | .198 | 2200 | .077 | | |
| 1210 | .994 | 1710 | .182 | 2210 | .073 | | |
| 1220 | 1.000 | 1720 | .168 | 2220 | .065 | | |
| 1230 | .996 | 1730 | .158 | 2230 | .065 | | |
| 1240 | .994 | 1740 | .142 | 2240 | .061 | | |
| 1250 | .992 | 1750 | .130 | 2250 | .059 | | |
| 1260 | .988 | 1760 | .113 | 2260 | .057 | | |
| 1270 | .968 | 1770 | .101 | 2270 | .051 | | |
| 1280 | .901 | 1780 | .093 | 2280 | .047 | | |
| 1290 | .810 | 1790 | .083 | 2290 | .042 | | |

## TABLE 4
## RED DETECTOR RESPONSE

| WAVELENGTH | DATA | WAVELENGTH | DATA |
|---|---|---|---|
| 440 | 0.000 | | |
| 450 | .004 | 900 | .215 |
| 460 | .006 | 910 | .168 |
| 470 | .014 | 920 | .121 |
| 480 | .021 | 930 | .074 |
| 490 | .031 | 940 | .059 |
| 500 | .053 | 950 | .053 |
| 510 | .090 | 960 | .055 |
| 520 | .159 | 970 | .053 |
| 530 | .307 | 980 | .053 |
| 540 | .496 | 990 | .053 |
| 550 | .674 | 1000 | .051 |
| 560 | .768 | 1010 | .051 |
| 570 | .842 | 1020 | .051 |
| 580 | .881 | 1030 | .049 |
| 590 | .922 | 1040 | .047 |
| 600 | .959 | 1050 | .045 |
| 610 | .969 | 1060 | .044 |
| 620 | .988 | 1070 | .041 |
| 630 | .990 | 1080 | .040 |
| 640 | 1.000 | 1090 | .039 |
| 650 | 1.000 | 1100 | .035 |
| 660 | 1.000 | 1110 | .031 |
| 670 | .996 | 1120 | .024 |
| 680 | .994 | 1130 | .021 |
| 690 | .982 | 1140 | .014 |
| 700 | .980 | 1150 | .006 |
| 710 | .959 | 1160 | 0.000 |
| 720 | .943 | | |
| 730 | .928 | | |
| 740 | .912 | | |
| 750 | .898 | | |
| 760 | .871 | | |
| 770 | .861 | | |
| 780 | .832 | | |
| 790 | .809 | | |
| 800 | .783 | | |
| 810 | .742 | | |
| 820 | .693 | | |
| 830 | .668 | | |
| 840 | .617 | | |
| 850 | .562 | | |
| 860 | .518 | | |
| 870 | .455 | | |
| 880 | .359 | | |
| 890 | .281 | | |

# TABLE 5
# BLUE DETECTOR RESPONSE

| WAVELENGTH | DATA |
|---|---|
| 370 | 0.000 |
| 380 | .040 |
| 390 | .116 |
| 400 | .164 |
| 410 | .218 |
| 420 | .282 |
| 430 | .360 |
| 440 | .458 |
| 450 | .574 |
| 460 | .710 |
| 470 | .824 |
| 480 | .912 |
| 490 | .964 |
| 500 | 1.000 |
| 510 | .897 |
| 520 | .722 |
| 530 | .620 |
| 540 | .578 |
| 550 | .506 |
| 560 | .358 |
| 570 | .270 |
| 580 | .206 |
| 590 | .160 |
| 600 | .132 |
| 610 | .103 |
| 620 | .086 |
| 630 | .070 |
| 640 | .057 |
| 650 | .045 |
| 660 | .036 |
| 670 | .032 |
| 680 | .026 |
| 690 | .020 |
| 700 | .019 |
| 710 | .018 |
| 720 | .017 |
| 730 | .016 |
| 740 | .020 |
| 750 | .021 |
| 760 | .024 |
| 770 | .025 |
| 780 | .026 |
| 790 | .025 |
| 800 | .020 |
| 810 | 0.000 |

TABLE 6
UV DETECTOR RESPONSE

| WAVELENGTH | DATA |
|---|---|
| 330 | 0.000 |
| 340 | .044 |
| 350 | .131 |
| 360 | .263 |
| 370 | .526 |
| 380 | .999 |
| 390 | .800 |
| 400 | .242 |
| 410 | .095 |
| 420 | .011 |
| 430 | 0.000 |