**CCPR Key Comparison**

**Spectral Regular Transmittance (CCPR-K6.2010)**

**Report by:**

**NMISA Photometry & Radiometry**

**2016-02-18**

**Appendix A.1 Description of measurement facility and measurement method**

**Laboratory:** Photometry and Radiometry laboratory of NMISA.

**This table relates to Step 2.**

Table A-1 Details of Measurement Setup

|  |  |
| --- | --- |
| Make and Type of Spectrophotometer | Hitachi U-3400 Spectrophotometer. |
| Additional Stray Light Rejection | 0.0001% (maximum value claimed by manufacturer) |
| Source Drift Monitoring | The spectrophotometer was allowed to warm up and stabilise for 3 hours before measurements were started, reducing the source drift. |
| Source | Adjustment-free deuterium lamp and adjustment-free iodine tungsten lamp (50 W). |
| Detector | Photomultiplier R928 (UV-VIS) and PbS (NIR). |
| Temperature | The temperature was measured approximately every 15 minutes to 30 minutes with a calibrated platinum resistance thermometer in the sample compartment of the spectrophotometer within a distance of 50 mm from the filter. A calibrated probe thermometer was used to measure the environmental temperature in the laboratory.  The temperature in the sample compartment was found to be within the range of 27 °C to 30 °C with an average of 29 °C.  The environmental temperature in the laboratory was found to be within the range of 21 °C to 24 °C with an average of 22 °C. |
| Humidity | The relative humidity in the laboratory was measured approximately every 15 minutes to 30 minutes with a calibrated thermohygrograph and found to be within the range of 46 % to 52 % with an average of 48 %. |
| Beam Size | The beam size is approximately 5 mm × 10 mm. |
| Beam Collimation | Provision made by the optical layout of the instrument. |
| Measurement Sequence | Six spectral transmittance measurements were made for each filter. The filters were rotated 180 ° halfway through the six measurements. |
| Bandwidth | Bandwidths of 1 nm were used for all filters at the wavelengths of 380 nm, 400 nm, 500 nm, 600 nm, 700 nm and 800 nm and 2 nm at the wavelengths of 900 nm and 1 000 nm. |

**Description of measuring technique**

A baseline correction was performed in the wavelength region of 350 nm to 840 nm before measuring each filter. The spectral transmittance of the filters was measured with a parallel beam normal to the filters, over a bandwidth of 1 nm centred on the wavelengths 380 nm, 400 nm, 500 nm, 600 nm, 700 nm and 800 nm.

A spectral transmittance measurement was taken in the wavelength region of 375 nm to 805 nm in the centre of each filter. The filters were moved to the left and to the right of the centre with respect to the beam, taking a transmittance measurement in the same wavelength region every time. The filters were rotated 180° and three similar measurements were made at the centre of the filter, and to the left and to the right of the centre with respect to the beam.

Two background scans were performed in the wavelength region of 375 nm to 805 nm, for each filter. The background values were averaged and subtracted from the measured spectral transmittance values.

A baseline correction was performed in the wavelength region of 350 nm to 1 200 nm before measuring the spectral transmittance at 900 nm and 1 000 nm for each filter. The spectral transmittance of the filters was measured with a parallel beam normal to the filters, over a bandwidth of 2 nm centred on the wavelengths 900 nm and 1 000 nm. A correction was made for the bandwidth of 2 nm to 1 nm.

A spectral transmittance measurement was taken in the wavelength region of 895 nm to 1005 nm in the centre of each filter. The filters were moved to the left and to the right of the centre with respect to the beam, taking a transmittance measurement in the same wavelength region every time. The filters were rotated 180° and three similar measurements were made at the centre of the filter, and to the left and to the right of the centre with respect to the beam.

Two background scans were performed in the wavelength region of 895 nm to 1005 nm, for each filter. The background values were averaged and subtracted from the measured spectral transmittance values.

A total of six spectral transmittance measurements were taken for each filter. The average of the spectral transmittance at the specified wavelength, λ, λ + 0,2 nm and λ - 0,2 nm, was determined. This was done for each of the specified wavelengths, *i.e.* 380 nm, 400 nm, 500 nm, 600 nm, 700 nm, 800 nm, 900 nm and 1 000 nm. See Figure 1.

|  |
| --- |
|  |
| Figure 1: Schematic representation of the measurement sequence |

The relative humidity, the temperature inside the sample compartment and the environmental temperature in the laboratory were measured every 15 minutes to 30 minutes. The relative humidity in the laboratory was measured with a calibrated thermohygrograph (CT485B). The environmental temperature in the laboratory was measured with a calibrated probe thermometer (HMS-650). The temperature inside the sample compartment was measured with a calibrated platinum resistance thermometer (HSRTD-R) within a distance of 50 mm from the filter.

Figure 2 shows a schematic representation of the measurement facility.

|  |
| --- |
|  |
| Figure 2: Schematic representation of the measurement facility |

No results were reported for the filter with the lowest transmittance, since the system cannot perform reliable measurements at this low transmittance level.

**If any damage, contamination or cleaning of the filters was carried out, please give details:**

Refer to appendices B.1 and B.2. An air duster was used to remove dust from the filters when it was necessary.

**Signature: Date:**

**A.2 Measurement Results**

**Laboratory:** Photometry and Radiometry laboratory of NMISA.

Table A-2i Measurement Results

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Spectral Transmittance (%) | 91.22 | 91.44 | 91.56 | 91.73 | 91.80 | 91.80 | 92.47 | 92.51 |
| Number of Measurements | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Temperature | 29.06 | 29.29 | 29.49 | 29.76 | 29.86 | 29.91 | 29.32 | 28.98 |
| Type A Uncertainty | 1.50E-03 | 1.62E-03 | 7.90E-04 | 5.10E-04 | 4.30E-04 | 4.70E-04 | 8.00E-04 | 7.90E-04 |
| Type B Uncertainty | 3.72E-03 | 4.42E-03 | 4.11E-03 | 4.07E-03 | 4.05E-03 | 5.00E-03 | 1.43E-02 | 2.14E-02 |
| Total Uncertainty | 4.02E-03 | 4.71E-03 | 4.19E-03 | 4.11E-03 | 4.08E-03 | 5.03E-03 | 1.44E-02 | 2.15E-02 |
| Degrees of Freedom | 237 | 346 | 3 863 | 19 709 | 39 032 | 1 635 | 441 | 277 |

Table A-2ii Type B Uncertainty Budget

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength  (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Nonlinearity | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 |
| Temperature | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Wavelength | 3.044E-04 | 3.302E-04 | 1.608E-04 | 1.045E-04 | 8.726E-05 | 9.635E-05 | 1.648E-04 | 1.616E-04 |
| Stray light | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 |
| Beam size & Position | 4.041E-04 | 4.041E-04 | 2.309E-04 | 1.155E-04 | 1.155E-04 | 1.155E-04 | 2.309E-04 | 1.732E-04 |
| Inter-reflection | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 |
| Obliquity | 5.307E-04 | 5.307E-04 | 5.715E-04 | 6.124E-04 | 3.674E-04 | 1.225E-04 | 9.553E-03 | 7.961E-03 |
| Polarization | 1.950E-03 | 1.600E-03 | 5.500E-04 | 1.500E-04 | 1.000E-04 | 2.950E-03 | 1.010E-02 | 1.955E-02 |
| Source Drift & Fluctuation | 4.041E-04 | 4.041E-04 | 2.309E-04 | 1.155E-04 | 1.155E-04 | 1.155E-04 | 2.309E-04 | 1.732E-04 |
| Bandwidth | 4.619E-04 | 3.464E-04 | 1.155E-04 | 5.774E-05 | 2.887E-04 | 4.041E-04 | 4.041E-04 | 9.238E-04 |
| Photometric accuracy of spectrophotometer | 3.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 3.000E-03 | 3.000E-03 |
| Total Type B Uncertainty | 3.72E-03 | 4.42E-03 | 4.11E-03 | 4.07E-03 | 4.05E-03 | 5.00E-03 | 1.43E-02 | 2.14E-02 |
| Degrees of Freedom | 2 593 | 11 279 | 271 810 | 374 306 | 1 801 566 | 1 647 | 438 | 277 |

**Signature: Date:**

Table A-2i Measurement Results

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Spectral Transmittance (%) | 40.85 | 60.80 | 62.17 | 60.93 | 63.65 | 57.67 | 51.85 | 47.01 |
| Number of Measurements | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Temperature | 29.60 | 29.60 | 29.89 | 30.27 | 29.24 | 30.01 | 29.76 | 30.30 |
| Type A Uncertainty | 1.51E-03 | 6.80E-04 | 6.00E-04 | 3.80E-04 | 6.30E-04 | 6.60E-04 | 7.70E-04 | 3.30E-04 |
| Type B Uncertainty | 3.72E-03 | 4.40E-03 | 4.10E-03 | 4.10E-03 | 4.06E-03 | 5.01E-03 | 1.43E-02 | 2.14E-02 |
| Total Uncertainty | 4.02E-03 | 4.46E-03 | 4.15E-03 | 4.12E-03 | 4.11E-03 | 5.06E-03 | 1.44E-02 | 2.15E-02 |
| Degrees of Freedom | 233 | 5 122 | 10 930 | 54 085 | 8 912 | 1 556 | 440 | 277 |

Table A-2ii Type B Uncertainty Budget

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength  (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Nonlinearity | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 |
| Temperature | 3.266E-04 | 4.491E-04 | 1.633E-04 | 5.307E-04 | 2.041E-04 | 1.225E-04 | 4.082E-05 | 2.041E-04 |
| Wavelength | 1.373E-04 | 9.177E-05 | 8.256E-05 | 5.130E-05 | 8.953E-05 | 8.504E-05 | 8.853E-05 | 3.464E-05 |
| Stray light | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 |
| Beam size & Position | 4.041E-04 | 1.732E-04 | 1.732E-04 | 1.155E-04 | 1.732E-04 | 1.732E-04 | 1.732E-04 | 5.774E-05 |
| Inter-reflection | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 |
| Obliquity | 5.307E-04 | 5.307E-04 | 5.715E-04 | 6.124E-04 | 3.674E-04 | 1.225E-04 | 9.553E-03 | 7.961E-03 |
| Polarization | 1.950E-03 | 1.600E-03 | 5.500E-04 | 1.500E-04 | 1.000E-04 | 2.950E-03 | 1.010E-02 | 1.955E-02 |
| Source Drift & Fluctuation | 4.041E-04 | 1.732E-04 | 1.732E-04 | 1.155E-04 | 1.732E-04 | 1.732E-04 | 1.732E-04 | 5.774E-05 |
| Bandwidth | 4.619E-04 | 3.464E-04 | 1.155E-04 | 5.774E-05 | 2.887E-04 | 4.041E-04 | 4.041E-04 | 9.238E-04 |
| Photometric accuracy of spectrophotometer | 3.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 3.000E-03 | 3.000E-03 |
| Total Type B Uncertainty | 3.72E-03 | 4.40E-03 | 4.10E-03 | 4.10E-03 | 4.06E-03 | 5.01E-03 | 1.43E-02 | 2.14E-02 |
| Degrees of Freedom | 2 605 | 11 126 | 275 570 | 250 462 | 1 641 489 | 1 654 | 438 | 277 |

**Signature: Date:**

Table A-2i Measurement Results

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Spectral Transmittance (%) | 2.11 | 9.44 | 9.11 | 7.61 | 15.92 | 14.89 | 10.82 | 8.10 |
| Number of Measurements | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Temperature | 26.72 | 26.82 | 27.33 | 28.16 | 27.87 | 27.57 | 29.24 | 30.40 |
| Type A Uncertainty | 4.98E-03 | 8.60E-04 | 9.90E-04 | 1.29E-03 | 6.90E-04 | 6.00E-04 | 1.25E-03 | 8.50E-04 |
| Type B Uncertainty | 4.15E-03 | 4.59E-03 | 4.16E-03 | 4.63E-03 | 4.13E-03 | 5.02E-03 | 1.43E-02 | 2.14E-02 |
| Total Uncertainty | 6.49E-03 | 4.67E-03 | 4.28E-03 | 4.81E-03 | 4.19E-03 | 5.06E-03 | 1.44E-02 | 2.15E-02 |
| Degrees of Freedom | 14 | 2 947 | 1 711 | 800 | 6 416 | 1 603 | 443 | 278 |

Table A-2ii Type B Uncertainty Budget

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength  (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Nonlinearity | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 |
| Temperature | 7.757E-04 | 1.388E-03 | 6.532E-04 | 2.164E-03 | 8.165E-04 | 3.266E-04 | 1.633E-04 | 7.757E-04 |
| Wavelength | 2.341E-05 | 1.790E-05 | 2.000E-05 | 2.198E-05 | 2.449E-05 | 1.967E-05 | 3.006E-05 | 1.521E-05 |
| Stray light | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 |
| Beam size & Position | 1.270E-03 | 2.309E-04 | 2.309E-04 | 3.464E-04 | 1.732E-04 | 1.732E-04 | 3.464E-04 | 2.309E-04 |
| Inter-reflection | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 |
| Obliquity | 5.307E-04 | 5.307E-04 | 5.715E-04 | 6.124E-04 | 3.674E-04 | 1.225E-04 | 9.553E-03 | 7.961E-03 |
| Polarization | 1.950E-03 | 1.600E-03 | 5.500E-04 | 1.500E-04 | 1.000E-04 | 2.950E-03 | 1.010E-02 | 1.955E-02 |
| Source Drift & Fluctuation | 1.270E-03 | 2.309E-04 | 2.309E-04 | 3.464E-04 | 1.732E-04 | 1.732E-04 | 3.464E-04 | 2.309E-04 |
| Bandwidth | 4.619E-04 | 3.464E-04 | 1.155E-04 | 5.774E-05 | 2.887E-04 | 4.041E-04 | 4.041E-04 | 9.238E-04 |
| Photometric accuracy of spectrophotometer | 3.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 3.000E-03 | 3.000E-03 |
| Total Type B Uncertainty | 4.15E-03 | 4.59E-03 | 4.16E-03 | 4.63E-03 | 4.13E-03 | 5.02E-03 | 1.43E-02 | 2.14E-02 |
| Degrees of Freedom | 2 933 | 8 555 | 152 425 | 4 141 | 121 870 | 1 665 | 439 | 277 |

**Signature: Date:**

Table A-2i Measurement Results

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Spectral Transmittance (%) | 0,03 | 0,51 | 0,83 | 0,82 | 2,60 | 3,19 | 2,39 | 1,76 |
| Number of Measurements | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Temperature | 27,90 | 27,90 | 27,77 | 27,77 | 29,73 | 29,73 | 29,91 | 29,94 |
| Type A Uncertainty | 0.00E+00 | 5.44E-03 | 0.00E+00 | 3.29E-03 | 1.56E-03 | 1.58E-03 | 4.10E-03 | 3.56E-03 |
| Type B Uncertainty | 4.25E-03 | 6.27E-03 | 4.35E-03 | 5.70E-03 | 4.66E-03 | 5.10E-03 | 1.44E-02 | 2.15E-02 |
| Total Uncertainty | 4.25E-03 | 8.31E-03 | 4.35E-03 | 6.59E-03 | 4.92E-03 | 5.34E-03 | 1.50E-02 | 2.18E-02 |
| Degrees of Freedom | 1 784 | 27 | 14 626 | 76 | 443 | 500 | 327 | 284 |

Table A-2ii Type B Uncertainty Budget

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength  (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Nonlinearity | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 |
| Temperature | 2.164E-03 | 4.042E-03 | 1.470E-03 | 3.797E-03 | 2.245E-03 | 8.573E-04 | 3.266E-04 | 1.143E-03 |
| Wavelength | 0.00E+00 | 6.086E-06 | 0.00E+00 | 6.086E-06 | 9.129E-06 | 1.122E-05 | 2.194E-05 | 1.394E-05 |
| Stray light | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 |
| Beam size & Position | 0.00E+00 | 1.386E-03 | 0.00E+00 | 8.660E-04 | 4.041E-04 | 4.041E-04 | 1.039E-03 | 9.238E-04 |
| Inter-reflection | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 |
| Obliquity | 5.307E-04 | 5.307E-04 | 5.715E-04 | 6.124E-04 | 3.674E-04 | 1.225E-04 | 9.553E-03 | 7.961E-03 |
| Polarization | 1.950E-03 | 1.600E-03 | 5.500E-04 | 1.500E-04 | 1.000E-04 | 2.950E-03 | 1.010E-02 | 1.955E-02 |
| Source Drift & Fluctuation | 0.00E+00 | 1.386E-03 | 0.00E+00 | 8.660E-04 | 4.041E-04 | 4.041E-04 | 1.039E-03 | 9.238E-04 |
| Bandwidth | 4.619E-04 | 3.464E-04 | 1.155E-04 | 5.774E-05 | 2.887E-04 | 4.041E-04 | 4.041E-04 | 9.238E-04 |
| Photometric accuracy of spectrophotometer | 3.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 3.000E-03 | 3.000E-03 |
| Total Type B Uncertainty | 4.25E-03 | 6.27E-03 | 4.35E-03 | 5.70E-03 | 4.66E-03 | 5.10E-03 | 1.44E-02 | 2.15E-02 |
| Degrees of Freedom | 1 784 | 1 094 | 14 626 | 1 003 | 3 680 | 1 772 | 448 | 280 |

**Signature: Date:**

**Appendix A.1 Description of measurement facility and measurement method**

**Laboratory:** Photometry and Radiometry laboratory of NMISA.

**This table relates to Step 4.**

Table A-1 Details of Measurement Setup

|  |  |
| --- | --- |
| Make and Type of Spectrophotometer | Hitachi U-3400 Spectrophotometer |
| Additional Stray Light Rejection | 0.0001% (maximum value claimed by manufacturer) |
| Source Drift Monitoring | The spectrophotometer was allowed to warm up and stabilise for 3 hours before measurements were started, reducing the source drift. |
| Source | Adjustment-free deuterium lamp and adjustment-free iodine tungsten lamp (50 W). |
| Detector | Photomultiplier R928 (UV-VIS) and PbS (NIR). |
| Temperature | The temperature was measured approximately every 10 minutes to 15 minutes with a calibrated platinum resistance thermometer in the sample compartment of the spectrophotometer within a distance of 50 mm from the filter. A calibrated thermohygrograph was used to measure the environmental temperature in the laboratory.  The temperature in the sample compartment was found to be within the range of 27 °C to 29 °C with an average of 28 °C.  The environmental temperature in the laboratory was found to be within the range of 19 °C to 20 °C with an average of 20 °C. |
| Humidity | The relative humidity in the laboratory was measured with a calibrated thermohygrograph and found to be within the range of 25 % to 33 % with an average of 29 %. |
| Beam Size | The beam size is approximately 5 mm × 10 mm. |
| Beam Collimation | Provision made by the optical layout of the instrument. |
| Measurement Sequence | Six spectral transmittance measurements were made for each filter. The filters were rotated 180 ° halfway through the six measurements. |
| Bandwidth | A bandwidth of 1 nm was used for all filters at the wavelengths of 380 nm, 400 nm, 500 nm, 600 nm, 700 nm, 800 nm, 900 nm and 1 000 nm. |

**Description of measuring technique**

A baseline correction was performed in the wavelength region of 350 nm to 1 030 nm before measuring each filter. The spectral transmittance of the filters was measured with a parallel beam normal to the filters, over a bandwidth of 1 nm centred on the wavelengths 380 nm, 400 nm, 500 nm, 600 nm, 700 nm, 800 nm, 900 nm and 1 000 nm.

A spectral transmittance measurement was taken in the centre of each filter in the wavelength ranges of 375 nm to 385 nm, 395 nm to 405 nm, 495 nm to 505 nm, 595 nm to 605 nm, 695 nm to 705 nm, 795 nm to 805 nm, 895 nm to 905 nm and 995 nm to 1 005 nm. The filters were moved to the left and to the right of the centre with respect to the beam, taking a transmittance measurement in the same wavelength regions every time. The filters were rotated 180° and three similar measurements were made at the centre of each filter, and to the left and to the right of the centre with respect to the beam.

Two background scans were performed for each filter, in the wavelength ranges of 375 nm to 385 nm, 395 nm to 405 nm, 495 nm to 505 nm, 595 nm to 605 nm, 695 nm to 705 nm, 795 nm to 805 nm, 895 nm to 905 nm and 995 nm to 1 005 nm. The background values were averaged and subtracted from the measured spectral transmittance values.

A total of six spectral transmittance measurements were taken for each filter. The average of the spectral transmittance at the specified wavelength, λ, λ + 0,2 nm and λ - 0,2 nm, was determined. This was done for each of the specified wavelengths, *i.e.* 380 nm, 400 nm, 500 nm, 600 nm, 700 nm, 800 nm, 900 nm and 1 000 nm. See Figure 1.

The relative humidity, the temperature inside the sample compartment and the environmental temperature in the laboratory were measured every 10 to 15 minutes. The environmental temperature and relative humidity in the laboratory were measured with a calibrated thermohygrograph (CT485B). The temperature inside the sample compartment of the spectrophotometer was measured with a calibrated platinum resistance thermometer (HSRTD-R) within a distance of 50 mm from the filter.

See Figure 2 for a schematic representation of the measurement facility.

No results were reported for filter with the lowest transmittance, since the system cannot perform reliable measurements at this low transmittance level.

**If any damage, contamination or cleaning of the filters was carried out, please give details:**

Refer to appendices B.1 and B.2. An air duster was used to remove dust from the filters when it was necessary.

**Signature: Date:**

**A.3 Measurement Results**

**Laboratory:** Spectrophotometry laboratory of NMISA.

Table A-3i Measurement Results

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Spectral Transmittance (%) | 91,19 | 91,40 | 91,45 | 91,68 | 91,71 | 91,92 | 90,38 | 92,47 |
| Number of Measurements | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Temperature | 27,05 | 27,15 | 27,31 | 27,44 | 27,54 | 27,57 | 27,54 | 27,62 |
| Type A Uncertainty | 1.53E-03 | 9.20E-04 | 1.24E-03 | 8.20E-04 | 1.01E-03 | 1.00E-03 | 1.51E-02 | 6.69E-03 |
| Type B Uncertainty | 3.72E-03 | 4.38E-03 | 4.13E-03 | 4.08E-03 | 4.07E-03 | 5.01E-03 | 1.56E-02 | 2.16E-02 |
| Total Uncertainty | 4.03E-03 | 4.48E-03 | 4.32E-03 | 4.17E-03 | 4.20E-03 | 5.11E-03 | 2.18E-02 | 2.27E-02 |
| Degrees of Freedom | 222 | 2 267 | 726 | 3 272 | 1 474 | 1 176 | 21 | 224 |

Table A-3ii Type B Uncertainty Budget

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength  (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 | Correlation Coefficient |
| Nonlinearity | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 1.0000 |
| Temperature | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.0000 |
| Wavelength | 3.101E-04 | 1.864E-04 | 2.523E-04 | 1.664E-04 | 2.070E-04 | 2.044E-04 | 3.045E-03 | 1.382E-03 | -0.0559 |
| Stray light | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.0000 |
| Beam size & Position | 4.041E-04 | 2.309E-04 | 3.464E-04 | 2.309E-04 | 2.887E-04 | 2.309E-04 | 3.868E-03 | 1.732E-03 | -0.0217 |
| Inter-reflection | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 1.0000 |
| Obliquity | 5.307E-04 | 5.307E-04 | 5.715E-04 | 6.124E-04 | 3.674E-04 | 1.225E-04 | 9.553E-03 | 7.961E-03 | 1.0000 |
| Polarization | 1.950E-03 | 1.600E-03 | 5.500E-04 | 1.500E-04 | 1.000E-04 | 2.950E-03 | 1.010E-02 | 1.955E-02 | 1.0000 |
| Source Drift & Fluctuation | 4.041E-04 | 2.309E-04 | 3.464E-04 | 2.309E-04 | 2.887E-04 | 2.309E-04 | 3.868E-03 | 1.732E-03 | -0.0217 |
| Bandwidth | 4.619E-04 | 3.464E-04 | 1.155E-04 | 5.774E-05 | 2.887E-04 | 4.041E-04 | 4.041E-04 | 9.238E-04 | 1.0000 |
| Photometric accuracy of spectrophoto-meter | 3.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 3.000E-03 | 3.000E-03 | 1.0000 |
| Total Type B Uncertainty | 3.72E-03 | 4.38E-03 | 4.13E-03 | 4.08E-03 | 4.07E-03 | 5.01E-03 | 1.56E-02 | 2.16E-02 | 0.9984 |
| Degrees of Freedom | 2 594 | 11 037 | 246 111 | 363 758 | 1 212 902 | 1 662 | 606 | 286 | 0.9992 |

**Signature: Date:**

Table A-3i Measurement Results

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Spectral Transmittance (%) | 41,05 | 60,74 | 62,05 | 60,94 | 63,65 | 57,65 | 51,51 | 45,66 |
| Number of Measurements | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Temperature | 28,13 | 28,42 | 28,52 | 28,65 | 28,44 | 28,62 | 28,42 | 28,44 |
| Type A Uncertainty | 1.91E-03 | 1.07E-03 | 1.27E-03 | 8.70E-04 | 3.10E-04 | 4.80E-04 | 1.10E-02 | 4.10E-03 |
| Type B Uncertainty | 3.75E-03 | 4.40E-03 | 4.13E-03 | 4.10E-03 | 4.05E-03 | 5.00E-03 | 1.49E-02 | 2.14E-02 |
| Total Uncertainty | 4.21E-03 | 4.53E-03 | 4.33E-03 | 4.20E-03 | 4.07E-03 | 5.03E-03 | 1.86E-02 | 2.18E-02 |
| Degrees of Freedom | 114 | 1 421 | 665 | 2 655 | 135 013 | 1 633 | 38 | 279 |

Table A-3ii Type B Uncertainty Budget

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength  (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 | Correlation Coefficient |
| Nonlinearity | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 1.0000 |
| Temperature | 2.449E-04 | 3.674E-04 | 1.633E-04 | 4.082E-04 | 2.041E-04 | 1.225E-04 | 4.082E-05 | 1.633E-04 | 0.9898 |
| Wavelength | 1.750E-04 | 1.440E-04 | 1.762E-04 | 1.183E-04 | 4.407E-05 | 6.136E-05 | 1.267E-03 | 4.176E-04 | -0.0560 |
| Stray light | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.0000 |
| Beam size & Position | 5.196E-04 | 2.887E-04 | 3.464E-04 | 2.309E-04 | 5.774E-05 | 1.155E-04 | 2.829E-03 | 1.039E-03 | -0.0816 |
| Inter-reflection | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 1.0000 |
| Obliquity | 5.307E-04 | 5.307E-04 | 5.715E-04 | 6.124E-04 | 3.674E-04 | 1.225E-04 | 9.553E-03 | 7.961E-03 | 1.0000 |
| Polarization | 1.950E-03 | 1.600E-03 | 5.500E-04 | 1.500E-04 | 1.000E-04 | 2.950E-03 | 1.010E-02 | 1.955E-02 | 1.0000 |
| Source Drift & Fluctuation | 5.196E-04 | 2.887E-04 | 3.464E-04 | 2.309E-04 | 5.774E-05 | 1.155E-04 | 2.829E-03 | 1.039E-03 | -0.0816 |
| Bandwidth | 4.619E-04 | 3.464E-04 | 1.155E-04 | 5.774E-05 | 2.887E-04 | 4.041E-04 | 4.041E-04 | 9.238E-04 | 1.0000 |
| Photometric accuracy of spectrophoto-meter | 3.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 3.000E-03 | 3.000E-03 | 1.0000 |
| Total Type B Uncertainty | 3.75E-03 | 4.40E-03 | 4.13E-03 | 4.10E-03 | 4.05E-03 | 5.00E-03 | 1.49E-02 | 2.14E-02 | 0.9996 |
| Degrees of Freedom | 2 657 | 11 203 | 248 452 | 314 092 | 1 726 429 | 1 649 | 514 | 279 | 0.9809 |

**Signature: Date:**

Table A-3i Measurement Results

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Spectral Transmittance (%) | 2,17 | 9,47 | 9,09 | 7,63 | 15,96 | 14,88 | 10,85 | 7,72 |
| Number of Measurements | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Temperature | 27,13 | 27,54 | 27,75 | 27,98 | 28,16 | 28,21 | 28,16 | 28,13 |
| Type A Uncertainty | 4.42E-03 | 4.90E-04 | 1.14E-03 | 5.60E-04 | 5.10E-04 | 8.20E-04 | 5.99E-02 | 5.38E-02 |
| Type B Uncertainty | 4.11E-03 | 4.68E-03 | 4.18E-03 | 4.57E-03 | 4.13E-03 | 5.02E-03 | 2.62E-02 | 2.91E-02 |
| Total Uncertainty | 6.04E-03 | 4.71E-03 | 4.34E-03 | 4.61E-03 | 4.17E-03 | 5.09E-03 | 6.54E-02 | 6.12E-02 |
| Degrees of Freedom | 17 | 5 810 | 1 029 | 3 908 | 18 305 | 1 425 | 7 | 8 |

Table A-3ii Type B Uncertainty Budget

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength  (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 | Correlation Coefficient |
| Nonlinearity | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 1.0000 |
| Temperature | 8.981E-04 | 1.674E-03 | 7.348E-04 | 2.082E-03 | 8.573E-04 | 3.674E-04 | 1.633E-04 | 5.307E-04 | 0.9718 |
| Wavelength | 2.143E-05 | 1.018E-05 | 2.309E-05 | 9.428E-06 | 1.805E-05 | 2.725E-05 | 1.453E-03 | 9.269E-04 | 0.3574 |
| Stray light | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.0000 |
| Beam size & Position | 1.155E-03 | 1.155E-04 | 2.887E-04 | 1.155E-04 | 1.155E-04 | 2.309E-04 | 1.547E-02 | 1.391E-02 | -0.0905 |
| Inter-reflection | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 1.0000 |
| Obliquity | 5.307E-04 | 5.307E-04 | 5.715E-04 | 6.124E-04 | 3.674E-04 | 1.225E-04 | 9.553E-03 | 7.961E-03 | 1.0000 |
| Polarization | 1.950E-03 | 1.600E-03 | 5.500E-04 | 1.500E-04 | 1.000E-04 | 2.950E-03 | 1.010E-02 | 1.955E-02 | 1.0000 |
| Source Drift & Fluctuation | 1.155E-03 | 1.155E-04 | 2.887E-04 | 1.155E-04 | 1.155E-04 | 2.309E-04 | 1.547E-02 | 1.391E-02 | -0.0905 |
| Bandwidth | 4.619E-04 | 3.464E-04 | 1.155E-04 | 5.774E-05 | 2.887E-04 | 4.041E-04 | 4.041E-04 | 9.238E-04 | 1.0000 |
| Photometric accuracy of spectrophoto-meter | 3.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 3.000E-03 | 3.000E-03 | 1.0000 |
| Total Type B Uncertainty | 4.11E-03 | 4.68E-03 | 4.18E-03 | 4.57E-03 | 4.13E-03 | 5.02E-03 | 2.62E-02 | 2.91E-02 | 0.9747 |
| Degrees of Freedom | 3 017 | 6 588 | 119 446 | 4 581 | 102 107 | 1 674 | 700 | 633 | 0.9992 |

**Signature: Date:**

Table A-3i Measurement Results

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| Spectral Transmittance (%) | 0,04 | 0,51 | 0,83 | 0,82 | 2,62 | 3,19 | 2,48 | 1,52 |
| Number of Measurements | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Temperature | 28,21 | 28,54 | 28,52 | 28,49 | 28,60 | 28,62 | 28,52 | 28,44 |
| Type A Uncertainty | 6.46E-02 | 1.16E-02 | 6.07E-03 | 5.55E-03 | 2.03E-03 | 4.50E-03 | 3.73E-01 | 1.62E-01 |
| Type B Uncertainty | 2.40E-02 | 7.62E-03 | 4.96E-03 | 6.34E-03 | 4.52E-03 | 5.31E-03 | 1.37E-01 | 6.27E-02 |
| Total Uncertainty | 6.90E-02 | 1.39E-02 | 7.84E-03 | 8.43E-03 | 4.96E-03 | 6.97E-03 | 3.98E-01 | 1.74E-01 |
| Degrees of Freedom | 6 | 10 | 14 | 26 | 173 | 28 | 6 | 7 |

Table A-3ii Type B Uncertainty Budget

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wavelength  (nm) | 380 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 | Correlation Coefficient |
| Nonlinearity | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 2.500E-04 | 1.0000 |
| Temperature | 2.286E-03 | 4.572E-03 | 1.715E-03 | 4.409E-03 | 1.878E-03 | 7.348E-04 | 2.449E-04 | 8.981E-04 | 0.9890 |
| Wavelength | 5.611E-06 | 1.305E-05 | 1.130E-05 | 1.027E-05 | 1.194E-05 | 3.212E-05 | 2.067E-03 | 5.473E-04 | 0.8243 |
| Stray light | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.000E-06 | 1.0000 |
| Beam size & Position | 1.669E-02 | 3.002E-03 | 1.559E-03 | 1.443E-03 | 5.196E-04 | 1.155E-03 | 9.613E-02 | 4.163E-02 | 0.3580 |
| Inter-reflection | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 5.000E-05 | 1.0000 |
| Obliquity | 5.307E-04 | 5.307E-04 | 5.715E-04 | 6.124E-04 | 3.674E-04 | 1.225E-04 | 9.553E-03 | 7.961E-03 | 1.0000 |
| Polarization | 1.950E-03 | 1.600E-03 | 5.500E-04 | 1.500E-04 | 1.000E-04 | 2.950E-03 | 1.010E-02 | 1.955E-02 | 1.0000 |
| Source Drift & Fluctuation | 1.669E-02 | 3.002E-03 | 1.559E-03 | 1.443E-03 | 5.196E-04 | 1.155E-03 | 9.613E-02 | 4.163E-02 | 0.3580 |
| Bandwidth | 4.619E-04 | 3.464E-04 | 1.155E-04 | 5.774E-05 | 2.887E-04 | 4.041E-04 | 4.041E-04 | 9.238E-04 | 1.0000 |
| Photometric accuracy of spectrophoto-meter | 3.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 4.000E-03 | 3.000E-03 | 3.000E-03 | 1.0000 |
| Total Type B Uncertainty | 2.40E-02 | 7.62E-03 | 4.96E-03 | 6.34E-03 | 4.52E-03 | 5.31E-03 | 1.37E-01 | 6.27E-02 | 0.7168 |
| Degrees of Freedom | 427 | 1 108 | 5 816 | 830 | 6 573 | 1 991 | 409 | 500 | 0.7274 |

**Signature: Date:**

**Appendix B.1 Receipt of Standards**

To Laboratory: NMISA

From Laboratory: MSL New Zealand

Has the filter transportation package been opened during transit? e.g. Customs.

No.

Is there any damage to the transportation package?

No.

Are there any visible signs of damage or contamination to the filters?

Yes,

Filter A21: Two small specs of dust or scratch marks, but not in the centre of the filter, i.e. not in the primary measurement area.

Filter B22: Small marks on the edges of the filter, i.e. not in the primary measurement area.

Filter E15: Small specs of dust or scratch marks across the filter.

We confirmed having received the standards of the BIPM Key comparison “regular spectral transmittance”.

**Signature: Date:**

**Appendix B.2 Condition of the transfer standards on departure**

Laboratory: NMISA

Were the filters contaminated or damaged in any way while at your laboratory?

Yes,

Filter D17: Small mark near the centre of the filter.

Was any cleaning of the filter undertaken while at your laboratory?

No.

Has the filter container been flushed with dry nitrogen and sealed?

Yes.

**Signature: Date:**