Designation: G 177 – 03 (Reapproved 2008) $^{\epsilon 1}$ 

# Standard Tables for Reference Solar Ultraviolet Spectral Distributions: Hemispherical on 37° Tilted Surface<sup>1</sup>

This standard is issued under the fixed designation G 177; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\varepsilon$ ) indicates an editorial change since the last revision or reapproval.

 $\varepsilon^1$  Note—The title to Table 1 was corrected editorially in August 2008.

#### INTRODUCTION

These tables of solar ultraviolet (UV) spectral irradiance values have been developed to meet the need for a standard ultraviolet reference spectral energy distribution to be used as a reference for the upper limit of ultraviolet radiation in the outdoor weathering of materials and related indoor exposure studies. A wide variety of solar spectral energy distributions occur in the natural environment and are simulated by artificial sources during product, material, or component testing. To compare the relative optical performance of spectrally sensitive products, or to compare the performance of products before and after being subjected to weathering or other exposure conditions, a reference standard solar spectral distribution is required. These tables were prepared using version 2.9.2 of the Simple Model of the Atmospheric Radiative Transfer of Sunshine (SMARTS2) atmospheric transmission code (1,2).<sup>2</sup> SMARTS2 uses empirical parameterizations of version 4.0 of the Air Force Geophysical Laboratory (AFGL) Moderate Resolution Transmission model, MODTRAN (3,4). An extraterrestrial spectrum differing only slightly from the extraterrestrial spectrum in ASTM E 490 is used to calculate the resultant spectra. The hemispherical ( $2\pi$  steradian acceptance angle) spectral irradiance on a panel tilted 37° (average latitude of the contiguous United States) to the horizontal is tabulated. The wavelength range for the spectra extends from 280 to 400 nm, with uniform wavelength intervals. The input parameters used in conjunction with SMARTS2 for each set of conditions are tabulated. The SMARTS2 model and documentation are available as an adjunct (ADJG0173CD<sup>3</sup>)to this standard.

#### 1. Scope

1.1 The table provides a standard ultraviolet spectral irradiance distribution that maybe employed as a guide against which manufactured ultraviolet light sources may be judged when applied to indoor exposure testing. The table provides a reference for comparison with natural sunlight ultraviolet spectral data. The ultraviolet reference spectral irradiance is provided for the wavelength range from 280 to 400 nm. The wavelength region selected is comprised of the UV-A spectral region from 320 to 400 nm and the UV-B region from 280 to 320 nm.

- 1.2 The table defines a single ultraviolet solar spectral irradiance distribution:
- 1.2.1 Total hemispherical ultraviolet solar spectral irradiance (consisting of combined direct and diffuse components) incident on a sun-facing, 37° tilted surface in the wavelength region from 280 to 400 nm for air mass 1.05, at an elevation of 2 km (2000 m) above sea level for the United States Standard Atmosphere profile for 1976 (USSA 1976), excepting for the ozone content which is specified as 0.30 atmosphere-centimeters (atm-cm) equivalent thichkness.
- 1.3 The data contained in these tables were generated using the SMARTS2 Version 2.9.2 atmospheric transmission model developed by Gueymard (1,2).
- 1.4 The climatic, atmospheric and geometric parameters selected reflect the conditions to provide a realistic maximum ultraviolet exposure under representative clear sky conditions.
- 1.5 The availability of the SMARTS2 model (as an adjunct (ADJG0173CD³) to this standard) used to generate the standard spectra allows users to evaluate spectral differences relative to the spectra specified here.

<sup>&</sup>lt;sup>1</sup> These tables are under the jurisdiction of ASTM Committee G03 on Weathering and Durability and is the direct responsibility of Subcommittee G03.09 on Radiometry.

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<sup>&</sup>lt;sup>2</sup> The boldface numbers in parentheses refer to the list of references at the end of this standard

<sup>&</sup>lt;sup>3</sup> Available from ASTM International Headquarters. Order Adjunct No. ADJG173CD.

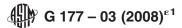


TABLE 1 Standard Ultraviolet Hemispherical Spectral Solar Irradiance for 37° Sun-Facing Tilted Surface

Num*/mm	Wavelength	Hemispherical								
1	nm	W/m²/nm								
280.0   2.300E-16   307.5   0.1277   335.0   0.6826   382.5   0.7823   380.0   0.9868   280.5   2.45E-15   306.5   0.1454   335.5   0.6862   383.0   0.7393   380.5   1.001   1.0046   281.5   2.45E-15   306.5   0.1454   336.5   0.6862   383.5   0.7799   381.0   1.0046   281.5   0.2865   381.0   0.0134   336.5   0.6863   380.5   0.7399   382.0   0.9823   282.5   0.0861   3.000.0   0.1304   337.0   0.5515   364.5   0.7379   382.0   0.9823   282.5   0.0861   3.000.0   0.1482   337.5   0.5914   365.0   0.8674   382.5   0.8682   283.0   2.4948-12   310.5   0.1867   338.0   0.6325   365.5   0.9094   383.0   0.5975   284.0   3.901E-11   311.5   0.2288   338.5   0.6867   366.0   0.9729   383.5   0.4747   284.0   3.901E-11   311.5   0.2283   339.0   0.6684   366.5   0.9732   394.0   0.6162   284.5   0.7798   383.5   0.6873   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8674   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   366.5   0.8673   367.0   0.8683   367.0   0.	λ								λ	
280.5	1		1	2	1	2	1	2	1	2
281.0 7.972E-15 300.5 0.1406 336.0 0.6063 393.5 0.7799 391.0 1.0546 281.5 9.229E-14 300.0 0.1334 336.5 0.6515 3864.0 8.0665 391.5 1.0788 282.0 4.085E-13 300.5 0.1310 337.0 0.5517 384.0 0.7379 382.0 0.9923 282.5 1.081E-12 310.5 0.1482 337.5 0.5914 365.0 0.8274 392.5 0.8262 283.0 2.948E-12 310.5 0.1867 338.0 0.6587 386.0 0.8729 393.0 0.5975 283.5 4.060E-12 310.5 0.2888 338.5 0.6587 386.0 0.8729 393.0 0.5975 283.5 1.0788 284.0 3.301E-11 311.5 0.2288 338.5 0.6587 386.0 0.9729 393.0 0.5975 283.5 1.0788 284.0 3.301E-11 311.5 0.2288 338.0 0.6684 386.0 0.9722 393.5 0.4747 382.5 0.8602 388.0 0.744E-10 312.0 0.2284 340.5 0.0681 387.5 0.3049 394.5 0.6163 382.5 0.6586 388.0 0.9722 393.5 0.6586 388.0 0.9722 393.5 0.6586 388.0 0.9722 393.5 0.6586 388.0 0.9722 393.5 0.6886 393.5 0.6887 386.0 0.8791 393.5 0.0886 393.5 0.6887 386.0 0.8791 393.5 0.6887 386.0 0.8791 393.5 0.0886 393.5 0.6887 386.0 0.9937 395.5 0.0887 386.0 0.9937 395.5 0.0887 386.0 0.9937 395.5 0.0887 386.0 0.9937 395.5 0.0887 386.0 0.9937 395.5 0.0888 395.5 0.0888 395.5 0.0888 395.5 0.0888 395.5 0.0888 395.5 0.0888 395.5 0.0888 395	280.0	2.320E-16	307.5		335.0	0.6826	362.5		390.0	0.9986
281.5 9.229E-14 309.0 0.1334 338.5 0.5615 364.0 0.8065 391.5 1.0788 282.0 4.085E-13 309.5 0.1310 337.0 0.5517 364.5 0.7979 392.0 0.9923 282.5 1.081E-12 310.0 0.1482 337.5 0.5514 365.0 0.8274 392.5 0.8262 283.0 2.948E-12 310.0 0.1867 338.0 0.6325 365.5 0.0094 393.0 0.5575 283.5 4.660E-12 311.0 0.2288 338.5 0.6587 366.0 0.9729 393.5 0.4747 284.0 3.901E-11 311.5 0.2288 338.5 0.6587 366.0 0.9729 393.5 0.4747 284.0 3.901E-11 311.5 0.2289 338.5 0.6684 366.5 0.9732 394.0 0.6762 284.5 8.723E-11 312.0 0.2390 338.5 0.6684 366.5 0.9732 394.0 0.6762 285.5 5.618E-10 313.5 0.2460 340.0 0.7261 367.5 0.9349 395.0 1.0022 285.5 5.618E-10 313.0 0.2664 340.5 0.7261 367.5 0.9349 395.0 1.0022 285.5 5.618E-10 313.0 0.2664 340.5 0.7261 368.0 0.0731 395.5 0.10667 286.0 1.345E-08 314.5 0.2684 340.5 0.7261 368.0 0.0731 385.5 0.0673 386.0 0.0731 385.5 0.0683 385.0 0.07261 386.0 0.0731 385.5 0.0683 385.0 0.0727 386.0 0.0727 387.0 0.0869 387.0 0.0007 386.0 0.0007 386.0 0.0007 386.0 0.0007 386.0 0.0007 386.0 0.0007 386.0 0.0007 386.0 0.0007 386.0 0.0007 386.0 0.0007 386.0 0.0007 386.0 0.0007 386.0 0.0007 386.0 0.0007 386.0 0.00007 386.0 0.00007 386.0 0.00007 386.0 0.00007 386.0 0.00007 386.0 0.00007	280.5	2.453E-15	308.0	0.1334	335.5	0.6628	363.0		390.5	1.0061
282.0	281.0	7.972E-15	308.5	0.1406	336.0	0.6063	363.5	0.7799	391.0	1.0646
282.5   1.081E-12   310.0   0.1442   337.5   0.5914   365.0   0.8274   392.5   0.8262   283.0   2.948E-12   311.0   0.2288   338.5   0.6897   366.0   0.9729   393.5   0.4747   284.0   301.5   1.10   0.2288   338.5   0.6897   366.0   0.9729   393.5   0.4747   382.5   0.4747   382.5   0.6828   385.5   0.6836   367.0   0.9529   393.5   0.4747   382.5   0.6836   367.0   0.9529   394.5   0.6812   284.5   3.728E-11   311.2   0.2380   339.5   0.6836   367.0   0.9539   394.5   0.8493   285.0   1.794E-10   311.5   0.2420   340.0   0.7261   367.5   0.9349   395.0   1.0022   285.5   5.618E-10   313.0   0.2564   340.5   0.7226   368.0   0.8791   395.5   1.0667   286.5   5.474E-0.9   314.0   0.2768   341.5   0.6697   368.5   0.8720   396.0   0.9371   286.5   5.743E-0.9   314.0   0.2768   341.5   0.6697   369.0   0.9103   396.5   0.6807   287.0   1.536E-0.8   314.5   0.2842   342.0   0.6696   369.5   0.9767   397.0   0.5268   287.5   3.518E-0.8   315.5   0.2266   342.5   0.7212   370.0   0.9889   397.5   0.5268   287.5   3.518E-0.8   315.0   0.2668   342.5   0.7212   370.0   0.9889   397.5   0.5268   288.5   2.398E-0.7   316.5   0.3026   344.5   0.6903   371.0   0.9057   398.5   1.2416   288.5   2.398E-0.7   316.5   0.3026   344.5   0.6903   371.0   0.9057   398.5   1.2416   288.5   1.539E-0.6   317.5   0.3026   344.5   0.6903   371.0   0.9057   398.5   1.2416   288.5   1.539E-0.6   317.5   0.3683   344.5   0.6695   372.5   0.6724   399.5   1.3562   290.0   3.405E-0.6   317.5   0.3693   344.5   0.6695   377.5   0.6724   399.5   1.3562   290.0   3.405E-0.6   317.5   0.3490   344.5   0.6704   377.5   0.8935   379.0   0.8948   399.0   1.3769   399.5   1.3562   399.5   3.1562   399.5   3.1562   399.5   3.1562   399.5   3.1562   399.5   3.1562   3.250.0   3.2606   3.250.0   3.2606   3.250.0   3.2606   3.250.0   3.2606   3.250.0   3.2606   3.250.0   3.2606   3.250.0   3.2606   3.250.0   3.2606   3.250.0   3.2606   3.250.0   3.2606   3.250.0   3.2606   3.250.0   3.2606   3.250.0   3.2606   3.250.0   3.2606   3.250.0   3.2606   3.25	281.5	9.229E-14	309.0	0.1334	336.5	0.5615	364.0	0.8065	391.5	1.0788
283.0	282.0	4.085E-13	309.5	0.1310	337.0	0.5517	364.5	0.7979	392.0	0.9923
283.5	282.5	1.081E-12	310.0	0.1482	337.5	0.5914	365.0	0.8274	392.5	0.8262
284.0 3.901E-11 311.5 0.2283 339.0 0.6684 366.5 0.9732 394.0 0.6162 284.5 367.0 0.9559 394.5 0.8396 285.5 0.7291E-10 312.5 0.2420 340.0 0.7261 367.5 0.9349 394.5 0.8493 285.5 6.18E-10 312.5 0.2420 340.0 0.7261 367.5 0.9349 395.0 1.0022 285.5 6.18E-10 313.0 0.2564 340.5 0.7226 368.0 0.8791 395.5 1.0667 286.0 1.452E-09 313.5 0.2508 341.0 0.6754 368.5 0.8720 396.0 0.9371 286.5 5.743E-09 314.0 0.2768 341.5 0.6697 369.0 0.9103 395.5 1.0667 287.0 1.345E-08 314.5 0.2242 342.0 0.6568 368.5 0.9767 397.0 0.5268 287.5 3.518E-08 314.5 0.2242 342.0 0.6568 368.5 0.9767 397.0 0.5268 287.5 3.518E-08 315.5 0.2504 343.0 0.7314 370.5 0.8928 399.5 1.0521 288.5 2.398E-07 316.5 0.2504 343.0 0.7314 370.5 0.8928 399.0 1.0521 288.5 2.398E-07 316.5 0.3026 344.0 0.5971 371.5 0.9402 399.0 1.3516 289.0 3.1537E-07 316.5 0.3026 344.0 0.5971 371.5 0.9402 399.0 1.3169 289.5 1.539E-06 317.0 0.3446 344.5 0.5718 372.0 0.8696 379.5 0.7242 290.0 3.403E-06 317.5 0.39693 345.0 0.6476 372.5 0.8365 400.0 1.3701 292.0 4.777E-05 318.5 0.3460 346.0 0.6704 373.5 0.7244 291.5 2.602E-05 318.5 0.3463 345.5 0.6883 373.0 0.6846 291.0 1.192E-05 318.5 0.3463 346.0 0.6704 373.5 0.7247 292.0 4.777E-05 319.5 0.3699 347.5 0.68915 374.5 0.7715 292.0 4.777E-05 320.5 0.3689 347.5 0.68915 375.5 0.8425 293.5 0.6802 320.0 0.3889 347.0 0.6815 375.5 0.8425 293.5 0.8662 320.0 0.3889 347.0 0.6815 375.5 0.8425 293.5 0.8662 320.0 0.3863 350.0 0.7307 377.5 1.0232 295.5 0.402E-04 320.5 0.4423 348.0 0.6623 375.5 0.8425 293.5 0.8425 293.5 0.0600-4 321.5 0.4991 349.0 0.6464 376.5 0.8568 293.0 1.052E-04 320.5 0.4423 348.0 0.6623 375.5 0.8425 293.5 0.8660 323.5 0.4065 351.0 0.7307 377.5 1.0232 295.5 0.8660 322.5 0.3663 350.0 0.7307 377.5 1.0232 295.5 0.8660 322.5 0.3663 350.0 0.7307 377.5 1.0232 295.5 0.8660 322.5 0.3663 350.0 0.7307 377.5 1.0232 295.5 0.8660 322.5 0.3666 332.0 0.4483 351.5 0.7326 383.5 0.6991 325.5 0.6466 322.5 0.3666 331.0 0.4483 351.5 0.7326 383.5 0.6991 325.5 0.6466 322.5 0.6466 322.5 0.6466 322.5 0.6466 322.5 0.6466 322.5 0.6466 322.5 0.6466 322.5 0.6466 322.5 0.6	283.0	2.948E-12	310.5	0.1867	338.0	0.6325	365.5	0.9094	393.0	0.5975
284.5 8.723E-11 312.0 0.2380 339.5 0.6836 367.0 0.9539 394.5 0.8493 285.0 1.794E-10 312.5 0.2420 340.0 0.7261 367.5 0.9349 395.0 1.0022 285.5 5.618E-10 313.0 0.2564 340.5 0.7226 368.0 0.8791 395.5 1.0667 286.0 1.452E-09 314.0 0.2768 341.5 0.6697 368.0 0.8720 395.5 1.0667 368.5 5.743E-09 314.0 0.2768 341.5 0.6697 360.0 0.9103 396.0 0.9371 286.5 5.743E-09 314.0 0.2768 341.5 0.6697 360.0 0.9767 397.0 0.5268 287.5 3.518E-08 315.0 0.2926 342.5 0.7212 370.0 0.9889 397.5 0.7774 288.0 1.168E-07 315.5 0.2604 343.0 0.7314 370.5 0.8928 390.0 1.0521 288.5 2.398E-07 315.0 0.2526 342.5 0.7212 370.0 0.9889 397.5 0.7774 288.5 1.539E-06 317.0 0.3268 344.0 0.5971 371.5 0.9057 398.5 1.2416 289.0 1.358E-06 317.0 0.3466 344.5 0.5718 372.0 0.9057 398.5 1.2416 289.0 1.358E-06 317.0 0.3463 344.5 0.5718 372.0 0.8791 399.0 1.3169 289.0 1.122E-05 318.0 0.3480 345.5 0.6803 371.0 0.9057 399.0 1.3769 290.0 3.403E-06 317.0 0.3463 345.5 0.6803 373.0 0.8066 400.0 1.3701 290.5 6.192E-06 318.0 0.3480 345.5 0.6803 373.0 0.8066 400.0 1.3701 290.5 6.192E-06 318.0 0.3480 345.5 0.6803 373.0 0.8046 400.0 1.3701 291.0 1.192E-05 318.5 0.3480 345.5 0.6803 373.0 0.8046 400.0 1.3701 292.0 4.777E-05 318.5 0.3480 345.5 0.6803 373.0 0.8046 400.0 1.3701 292.0 1.052E-04 320.0 0.3899 347.0 0.6915 374.5 0.6825 375.0 0.7244 291.5 2.602E-05 319.0 0.3893 347.5 0.6665 376.0 0.7244 291.5 2.602E-05 319.0 0.3893 347.5 0.6665 376.0 0.7217 292.0 0.8046 322.5 0.3680 335.0 0.7307 377.5 1.0232 293.0 1.052E-04 320.5 0.4023 346.5 0.6827 375.0 0.8025 377.0 0.9181 320.0 0.3889 347.5 0.6665 375.0 0.7224 375.5 0.8025 320.0 0.3889 347.5 0.6665 375.0 0.7225 292.5 6.402E-05 320.0 0.3889 347.5 0.6665 375.0 0.7227 292.0 0.8026 322.5 0.3663 350.0 0.7307 377.5 1.0232 293.0 1.052E-04 320.5 0.4023 346.5 0.6721 370.0 0.8025 377.5 0.8026 320.0 0.3899 347.5 0.6665 375.0 0.7528 377.5 0.8026 320.0 0.3895 322.0 0.7130 322.5 0.4005 322.5 0.4005 322.5 0.4005 322.5 0.4005 322.5 0.4005 322.5 0.4005 322.5 0.4005 322.5 0.4005 322.5 0.4005 322.5 0.4005 322.5 0.4005 322.5 0.4005 322.5 0.4005 322.5 0.400	283.5	4.660E-12	311.0	0.2288	338.5	0.6587	366.0		393.5	0.4747
285.0 1.794E-10 312.5 0.2420 340.0 0.7261 367.5 0.9349 395.0 1.0022 285.5 6.18E-10 313.0 0.2564 340.5 0.7226 388.0 0.8791 395.5 1.0667 286.0 1.452E-09 313.5 0.2568 341.0 0.6754 388.5 0.8720 396.0 0.9371 286.5 5.743E-09 314.0 0.2788 341.5 0.6867 389.5 0.9767 397.0 0.5268 287.5 3.518E-08 314.5 0.2926 342.5 0.7212 370.0 0.9103 396.5 0.8007 287.0 1.354E-08 314.5 0.2926 342.5 0.7212 370.0 0.9889 397.5 0.5268 287.5 3.518E-08 315.5 0.2926 342.5 0.7212 370.0 0.9889 397.5 0.7774 288.0 1.168E-07 315.5 0.2926 342.5 0.7212 370.0 0.9852 389.0 1.0521 288.5 2.398E-07 316.5 0.2026 342.5 0.7314 370.5 0.8928 389.0 1.0521 288.5 1.538E-06 317.0 0.2588 343.5 0.6903 371.5 0.9028 389.0 1.0521 288.5 1.538E-06 317.0 0.9446 344.5 0.5971 371.5 0.9402 399.0 1.3199 288.5 1.538E-06 317.0 0.9446 344.5 0.5718 372.0 0.8781 399.5 1.3562 290.0 3.405E-06 317.0 0.9463 345.5 0.6863 372.0 0.8781 399.5 1.3562 290.0 3.405E-06 318.5 0.3488 345.5 0.6863 373.0 0.8046 291.5 1.192E-05 318.5 0.3488 345.5 0.6863 373.0 0.8046 291.5 2.602E-05 319.0 0.3733 346.5 0.6813 374.0 0.7247 292.0 4.777E-05 319.5 0.3889 347.5 0.6665 375.0 0.7266 292.5 6.429E-05 320.0 0.3889 347.5 0.6665 375.0 0.7626 293.5 0.4723 348.5 0.6627 377.0 0.9181 292.0 320.0 0.3889 347.5 0.6665 375.0 0.7626 293.5 0.4023 348.5 0.6627 377.0 0.9181 292.0 0.320.0 0.3889 347.5 0.6665 375.0 0.7626 293.5 2.065E-04 320.5 0.4483 351.5 0.7842 378.0 0.7937 377.0 0.9181 292.0 1.052E-04 320.5 0.4483 351.5 0.7626 379.0 0.6667 377.0 0.9181 292.0 1.052E-04 320.5 0.4823 348.5 0.6627 377.0 0.9181 292.0 0.388E-03 324.0 0.4483 351.5 0.7842 378.0 0.7937 377.0 0.9181 292.5 0.4825 320.0 0.3864 350.5 0.7842 378.0 0.7937 377.0 0.9181 292.0 0.488E-03 323.0 0.3664 350.5 0.7842 378.0 0.7937 377.0 0.9181 292.0 0.4888-03 323.0 0.3664 350.5 0.7842 378.0 0.7937 377.0 0.9181 292.0 0.368E-03 324.0 0.4483 351.5 0.7620 378.5 0.7620 378.0 0.7937 328.5 0.4666 330.0 0.7937 330.0 0.7937 330.0 0.6667 330.0 0.7937 330.0 0.7937 330.0 0.7937 330.0 0.7937 330.0 0.7937 330.0 0.9059 322.5 0.4626 332.0 0.4686 350.0 0.7937 330.0 0.7937 330.0 0.	284.0	3.901E-11	311.5	0.2283	339.0	0.6684	366.5	0.9732	394.0	0.6162
285.5	284.5	8.723E-11	312.0	0.2380	339.5	0.6836	367.0	0.9539	394.5	0.8493
286.0	285.0	1.794E-10	312.5	0.2420	340.0	0.7261	367.5	0.9349	395.0	1.0022
286.5 5.743E-09 314.0 0.2768 341.5 0.6897 389.0 0.9103 386.5 0.8607 287.0 1.354E-08 314.5 0.2842 342.0 0.6998 389.5 0.9767 387.0 0.5268 287.5 3.518E-08 315.0 0.2926 342.5 0.7212 370.0 0.9889 397.5 0.7774 288.0 1.168E-07 315.5 0.2604 343.0 0.7314 370.5 0.8928 389.0 1.0521 288.5 2.398E-07 316.0 0.2589 343.5 0.6903 371.0 0.9057 398.5 1.2416 289.0 5.837E-07 316.5 0.3026 344.0 0.5971 371.5 0.90027 398.5 1.2416 289.0 1.539E-06 317.0 0.3466 344.5 0.5718 372.0 0.8791 399.5 1.3562 290.0 3.403E-06 317.5 0.3693 345.0 0.6476 372.5 0.8865 400.0 1.3701 290.5 1.192E-05 318.0 0.3463 345.5 0.6893 373.0 0.8046 291.0 1.192E-05 318.5 0.3480 346.5 0.6893 373.0 0.8046 291.0 1.192E-05 318.5 0.3899 347.0 0.6704 373.5 0.7244 292.5 4.777E-05 319.0 0.3733 346.5 0.6813 374.0 0.7217 292.0 4.777E-05 319.0 0.3733 346.5 0.6813 374.0 0.7217 292.0 4.777E-05 319.0 0.3783 345.0 0.6916 374.5 0.7155 292.5 6.429E-05 320.0 0.3889 347.0 0.6915 374.5 0.7156 293.0 1.052E-04 320.5 0.4233 348.0 0.6623 375.0 0.7626 293.0 1.052E-04 320.5 0.4233 348.0 0.6663 375.0 0.7626 293.0 1.052E-04 320.5 0.4233 348.0 0.6623 375.5 0.8625 293.5 0.856-04 321.0 0.4233 348.5 0.6724 376.0 0.8716 294.0 3.000E-04 321.5 0.4091 349.0 0.6464 376.5 0.08716 294.0 3.000E-04 322.5 0.3863 350.0 0.7307 377.5 0.9181 295.0 6.00E-03 32.0 0.3869 349.5 0.6627 377.0 0.9181 295.0 6.00E-03 322.5 0.3863 350.0 0.7307 377.5 0.0959 325.0 0.9559 326.0 0.3864 350.5 0.7842 378.0 1.1015 322.5 0.3863 322.5 0.4483 351.5 0.7842 378.0 1.1015 32.75 0.8663 329.7 0.9959 325.5 0.5990 325.0 0.7446 382.0 0.7842 378.0 1.1015 32.7 0.9959 325.5 0.5990 325.0 0.7446 382.0 0.7842 378.0 1.1015 32.7 0.9959 325.5 0.5990 325.0 0.7446 382.0 0.7866 335.0 0.7966 335.0	285.5	5.618E-10	313.0	0.2564	340.5	0.7226	368.0	0.8791	395.5	1.0667
287.0	286.0	1.452E-09	313.5	0.2608	341.0	0.6754	368.5		396.0	0.9371
287.0	286.5							0.9103		
287.5 3.518E-08 315.0 0.2926 342.5 0.7212 370.0 0.9889 397.5 0.7774 288.0 1.168E-07 315.5 0.2604 343.0 0.7314 370.5 0.9828 398.0 1.0521 288.5 2.398E-07 316.0 0.2589 343.5 0.6993 371.0 0.9057 398.5 1.2416 289.0 5.837E-07 316.5 0.3026 344.0 0.5971 371.5 0.9402 399.0 1.3169 289.5 1.539E-06 317.0 0.3446 344.5 0.5718 372.5 0.8365 400.0 1.3169 299.0 3.403E-06 317.5 0.3693 345.5 0.6893 372.0 0.8791 399.0 1.3169 299.0 1.92E-06 318.0 0.3463 345.5 0.6883 373.0 0.8046 2991.0 1.19E-06 318.0 0.3463 345.5 0.6883 373.0 0.8046 2991.0 1.19E-06 318.0 0.3733 346.5 0.6813 374.0 0.7241 299.2 4.777E-05 319.5 0.3693 347.0 0.6915 374.5 0.7125 292.0 4.777E-05 319.5 0.3693 347.0 0.6915 374.5 0.7125 292.5 6.429E-05 320.0 0.3889 347.5 0.6665 375.0 0.7626 293.0 1.05E-04 320.5 0.4423 348.5 0.6623 375.5 0.8425 294.0 3.080E-04 321.5 0.4991 349.0 0.6464 376.5 0.8576 294.0 3.080E-04 321.5 0.4991 349.0 0.6464 376.5 0.8588 294.5 4.169E-04 322.0 0.3969 349.5 0.6627 377.0 0.9181 295.0 6.40E-04 322.5 0.3863 350.0 0.7307 377.5 1.0232 295.5 1.137E-3 323.0 0.3664 350.5 0.7842 378.0 1.105E-294 322.5 0.3663 350.0 0.7307 377.5 1.0232 295.5 1.137E-3 323.5 0.4483 351.5 0.7326 379.0 0.9559 295.5 1.137E-3 323.5 0.4085 351.0 0.7620 375.5 0.8568 297.5 3.894E-03 324.5 0.4682 352.0 0.7136 379.0 0.9559 295.5 1.137E-3 323.5 0.4085 351.0 0.7620 375.5 0.8563 297.5 3.894E-03 324.5 0.4682 352.0 0.7136 379.0 0.9559 295.5 5.899E-03 326.0 0.4483 351.5 0.7326 379.0 0.9559 295.5 5.899E-03 326.0 0.4483 351.5 0.7326 379.0 0.9559 295.5 5.899E-03 326.0 0.6128 353.5 0.7841 381.0 0.9772 382.5 0.5590 320.0 0.7201 355.5 0.8043 383.0 0.5744 355.0 0.8043 383.0 0.5784 300.0 0.0116 327.5 0.6121 355.0 0.8043 383.5 0.5597 300.0 0.016 327.5 0.6121 355.0 0.8043 383.0 0.5784 300.0 0.016 327.5 0.6121 355.0 0.8043 383.0 0.5784 300.0 0.016 327.5 0.6121 355.0 0.8043 383.0 0.5784 300.0 0.016 327.5 0.6121 355.0 0.8043 383.0 0.5784 300.0 0.016 327.5 0.6121 355.0 0.8043 383.0 0.5784 300.0 0.016 327.5 0.6121 355.0 0.8043 383.0 0.5784 300.0 0.016 320.0 0.0730 330.0 0.0646 330.0 0.6283 385.5 0.5404 38		1.354E-08					369.5			
288.5     2.398E-07     316.5     0.3026     344.0     0.5971     371.5     0.9402     399.0     1.3169       289.5     1.539E-06     317.0     0.3446     344.5     0.5718     372.5     0.8791     399.5     1.3562       290.0     3.403E-06     317.5     0.3643     345.5     0.6867     372.5     0.8865     400.0     1.3701       290.5     6.192E-06     318.0     0.3463     345.5     0.6883     373.0     0.8046     400.0     1.3701       291.5     2.602E-05     319.0     0.3733     346.5     0.6813     374.0     0.7217     292.0     4.777E-05     319.5     0.3899     347.0     0.6915     374.5     0.7155     0.7526     293.0     1.052E-04     320.5     0.4423     348.0     0.6623     375.5     0.7626     293.0     1.052E-04     320.5     0.4423     348.5     0.6724     376.0     0.8716     294.0     3.080E-04     321.5     0.4091     349.0     0.6462     375.5     0.8568     0.8716	287.5	3.518E-08	315.0	0.2926	342.5	0.7212	370.0	0.9889		0.7774
289.0     5.837E-07     316.5     0.3026     344.0     0.5971     371.5     0.9402     399.0     1.3189       289.5     1.539E-06     317.5     0.3693     345.0     0.6476     372.5     0.8365     400.0     1.3701       290.5     6.192E-06     318.0     0.3463     345.5     0.6883     373.0     0.8046     400.0     1.3701       290.5     6.192E-06     318.5     0.3480     346.0     0.6704     379.5     0.7244       291.5     2.602E-05     318.0     0.3733     346.5     0.6813     374.0     0.7217       292.0     4.777E-05     319.5     0.3699     347.0     0.6915     374.5     0.7165       293.0     1.052E-04     320.5     0.4423     348.0     0.6623     375.5     0.8425       293.5     2.055E-04     321.0     0.4323     348.5     0.6724     376.0     0.8716       294.5     4.168E-04     322.0     0.3869     349.5     0.6627     377.0     0.9181	288.0	1.168E-07	315.5	0.2604	343.0	0.7314	370.5	0.8928	398.0	1.0521
289.0     5.837E-07     316.5     0.3026     344.0     0.5971     371.5     0.9402     399.0     1.3189       289.5     1.539E-06     317.5     0.3693     345.0     0.6476     372.5     0.8365     400.0     1.3701       290.5     6.192E-06     318.0     0.3463     345.5     0.6883     373.0     0.8046     400.0     1.3701       290.5     6.192E-06     318.5     0.3480     346.0     0.6704     379.5     0.7244       291.5     2.602E-05     318.0     0.3733     346.5     0.6813     374.0     0.7217       292.0     4.777E-05     319.5     0.3699     347.0     0.6915     374.5     0.7165       293.0     1.052E-04     320.5     0.4423     348.0     0.6623     375.5     0.8425       293.5     2.055E-04     321.0     0.4323     348.5     0.6724     376.0     0.8716       294.5     4.168E-04     322.0     0.3869     349.5     0.6627     377.0     0.9181	288.5	2.398E-07	316.0	0.2589	343.5	0.6903	371.0	0.9057	398.5	1.2416
289.5     1.539E-06     317.5     0.3693     345.0     0.6476     372.5     0.8395     1.3562       290.5     6.192E-06     318.0     0.3463     345.5     0.6883     373.0     0.8046     400.0     1.3701       291.5     6.192E-06     318.0     0.3463     345.5     0.6883     373.0     0.8046     400.0     1.3701       291.5     2.602E-05     319.0     0.3733     346.5     0.6813     374.0     0.7244     7.7244     7.7244     7.7247     7.7244     7.7247     7.7244     7.7247     7.7244     7.7247     7.7244     7.72			1				1			
290.0   3.403E-06   317.5   0.3693   345.0   0.6476   372.5   0.8365   400.0   1.3701     290.0   1.192E-05   318.5   0.3480   346.0   0.6704   373.5   0.7244     291.5   2.602E-05   319.5   0.3699   347.0   0.6915   374.5   0.7155     292.5   6.429E-05   320.0   0.3889   347.5   0.6665   375.0   0.7626     293.0   1.052E-04   320.5   0.4423   348.5   0.6623   375.5   0.4225     293.5   2.05E-04   321.0   0.4323   348.5   0.6724   376.0   0.8716     294.0   3.080E-04   321.5   0.4091   349.0   0.6464   376.5   0.8568     295.5   1.437E-03   322.0   0.3969   349.5   0.6627   377.0   0.9181     295.0   6.400E-04   322.5   0.3863   350.0   0.7307   377.5   1.0232     295.5   1.137E-03   323.0   0.3664   350.5   0.7842   378.0   1.1015     296.6   1.650E-03 <td></td>										
290.5     6.192E-06     318.0     0.3463     345.5     0.6883     373.0     0.8046       291.0     1.192E-05     318.5     0.3480     346.0     0.6704     373.5     0.7244       291.5     2.602E-05     319.0     0.3733     346.5     0.6813     374.0     0.7217       292.0     4.777E-05     319.5     0.3699     347.0     0.6915     375.5     0.7155       292.5     6.429E-05     320.0     0.3889     347.5     0.6665     375.0     0.7626       293.0     1.052E-04     320.5     0.4423     348.0     0.6623     375.5     0.8425       293.5     2.055E-04     321.0     0.4323     348.5     0.6724     376.0     0.8716       294.0     3.080E-04     322.1     0.4091     349.0     0.6627     377.0     0.9181       295.5     1.137E-03     323.0     0.3664     350.5     0.7842     376.0     1.1015       296.5     2.088E-03     324.0     0.4483     351.5     0.7842										
291.0										
291.5										
282.0   4.777E-05   319.5   0.3699   347.0   0.6815   374.5   0.7155     292.5   6.429E-05   320.0   0.3889   347.5   0.66623   375.5   0.8425     293.5   2.055E-04   321.0   0.4323   348.5   0.6724   376.0   0.8716     294.0   3.080E-04   321.5   0.4091   349.0   0.6464   376.5   0.8568     294.5   4.169E-04   322.0   0.3969   349.5   0.6627   377.0   0.9181     295.0   6.400E-04   322.5   0.3863   350.0   0.7307   377.5   1.0232     295.5   1.137E-03   323.0   0.3664   350.5   0.7842   378.0   1.1015     296.0   1.650E-03   323.5   0.4085   351.0   0.7620   378.5   1.0727     296.5   2.08BE-03   324.0   0.4483   351.5   0.7326   379.0   0.9559     297.0   2.489E-03   324.5   0.4682   352.0   0.7136   379.5   0.8563     299.5   3.984E-03   325.5   0.5390<										
292.5     6.429E-05     320.0     0.3889     347.5     0.6665     375.0     0.7626       293.0     1.052E-04     320.5     0.4423     348.0     0.6623     375.5     0.8425       293.5     2.055E-04     321.0     0.4323     348.5     0.6724     376.0     0.8716       294.0     3.080E-04     321.5     0.4091     349.0     0.6464     376.5     0.8568       294.5     4.169E-04     322.0     0.3863     350.0     0.7307     377.5     1.0232       295.0     6.400E-04     322.5     0.3863     350.0     0.7307     377.5     1.0232       295.5     1.137E-03     323.0     0.3664     350.5     0.7842     378.5     1.10727       296.5     2.08BE-03     324.0     0.4483     351.5     0.7326     379.0     0.9559       297.5     3.984E-03     324.0     0.4483     351.5     0.7313     380.0     0.8990       298.0     5.347E-03     325.5     0.5390     353.0     0.7140			1				1			
293.0										
293.5     2,055E-04     321.0     0.4323     348.5     0.6724     376.0     0.8716       294.0     3,080E-04     321.5     0.4091     349.0     0.66464     376.5     0.8568       294.5     4,169E-04     322.0     0.3969     349.5     0.6627     377.0     0.9181       295.0     6,400E-04     322.5     0.3863     350.0     0.7307     377.5     1,0232       295.5     1,137E-03     323.0     0.3664     350.5     0.7842     378.0     1,1015       296.5     2,08BE-03     324.0     0.4483     351.5     0.7326     379.0     0.9559       297.0     2,489E-03     324.0     0.4483     351.5     0.7326     379.0     0.9559       297.5     3,984E-03     325.0     0.4748     352.5     0.6731     380.0     0.8990       298.0     5,347E-03     325.5     0.5390     353.0     0.7140     380.5     0.9619       299.5     0.0108     327.0     0.6287     354.5     0.8358										
294.0     3.080E-04     321.5     0.4091     349.0     0.6464     376.5     0.8568       294.5     4.169E-04     322.0     0.3969     349.5     0.6627     377.0     0.9181       295.5     6.400E-04     322.5     0.3663     350.0     0.7307     377.5     1.0232       295.5     1.137E-03     323.0     0.3664     350.5     0.7842     378.0     1.1015       296.5     2.088E-03     324.0     0.4483     351.5     0.7326     379.0     0.9559       297.0     2.489E-03     324.5     0.4682     352.0     0.7136     379.5     0.8663       297.5     3.984E-03     325.0     0.4748     352.5     0.6731     380.0     0.8990       298.5     5.899E-03     326.0     0.6128     353.0     0.7140     380.5     0.9619       299.5     7.299E-03     326.5     0.6400     354.0     0.8279     381.5     0.7884       300.0     0.0108     327.0     0.6287     354.5     0.8358										
294.5     4.169E-04     322.0     0.3969     349.5     0.6627     377.0     0.9181       295.0     6.400E-04     322.5     0.3863     350.0     0.7307     377.5     1.0232       295.5     1.137E-03     323.0     0.3664     350.5     0.7842     378.0     1.1015       296.0     1.650E-03     323.5     0.4085     351.0     0.7620     378.5     1.0727       296.5     2.088E-03     324.0     0.4483     351.5     0.7326     379.0     0.9559       297.5     2.489E-03     324.5     0.4682     352.0     0.7136     379.5     0.8563       297.5     3.984E-03     325.0     0.4748     352.5     0.6731     380.0     0.8990       298.0     5.347E-03     325.5     0.5390     353.0     0.7140     380.5     0.9619       299.0     7.299E-03     326.5     0.6400     354.0     0.8279     381.5     0.8794       299.5     0.0108     327.0     0.6287     354.5     0.8346										
295.0   6.400E-04   322.5   0.3863   350.0   0.7307   377.5   1.0232     295.5   1.137E-03   323.0   0.3664   350.5   0.7842   378.0   1.1015     296.0   1.650E-03   323.5   0.4085   351.0   0.7620   378.5   1.0727     296.5   2.088E-03   324.0   0.4483   351.5   0.7326   379.0   0.9559     297.0   2.489E-03   324.5   0.4682   352.0   0.7136   379.5   0.8563     297.5   3.984E-03   325.0   0.4748   352.5   0.6731   380.0   0.8990     298.0   5.347E-03   325.5   0.5390   353.0   0.7140   380.5   0.9619     298.5   5.899E-03   326.0   0.6128   353.5   0.7841   381.0   0.9772     299.0   7.299E-03   326.5   0.6400   354.0   0.8279   381.5   0.8794     390.0   0.0116   327.5   0.6121   355.0   0.8346   382.5   0.6466     300.5   0.0130   328.0   0.5744										
295.5     1.137E-03     323.0     0.3664     350.5     0.7842     378.0     1.1015       296.0     1.650E-03     323.5     0.4085     351.0     0.7620     378.5     1.0727       296.5     2.088E-03     324.0     0.4483     351.5     0.7326     379.0     0.9559       297.0     2.489E-03     324.5     0.4682     352.0     0.7136     379.5     0.8563       297.5     3.984E-03     325.0     0.4748     352.5     0.6731     380.0     0.8990       298.5     5.899E-03     326.0     0.6128     353.5     0.7841     381.0     0.9772       299.0     7.299E-03     326.5     0.6400     354.0     0.8279     381.5     0.8794       299.5     0.0108     327.0     0.6287     354.5     0.8358     382.0     0.7485       300.0     0.0116     327.5     0.6121     355.0     0.8346     382.5     0.6466       300.5     0.0130     328.0     0.5744     355.5     0.8043 <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>										
296.0   1.650E-03   323.5   0.4085   351.0   0.7620   378.5   1.0727     296.5   2.088E-03   324.0   0.4483   351.5   0.7326   379.5   0.8563     297.0   2.489E-03   324.5   0.4682   352.0   0.7136   379.5   0.8563     297.5   3.984E-03   325.0   0.4748   352.5   0.6731   380.0   0.8990     298.0   5.347E-03   325.5   0.5390   353.0   0.7140   380.5   0.9619     298.5   5.899E-03   326.0   0.6128   353.5   0.7841   381.0   0.9772     299.0   7.299E-03   326.5   0.6400   354.5   0.8358   382.0   0.7485     300.0   0.0108   327.0   0.6287   354.5   0.8358   382.0   0.7485     300.0   0.0116   327.5   0.6121   355.0   0.8346   382.5   0.6466     300.5   0.0130   328.0   0.5744   355.5   0.8043   383.0   0.5788     301.5   0.0222   329.0   0.6486 <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>										
296.5     2.088E-03     324.0     0.4483     351.5     0.7326     379.0     0.9559       297.0     2.489E-03     324.5     0.4682     352.0     0.7136     379.5     0.8563       297.5     3.984E-03     325.0     0.4748     352.5     0.6731     380.0     0.8990       298.0     5.347E-03     325.5     0.5390     353.0     0.7140     380.5     0.9619       298.5     5.899E-03     326.0     0.6128     353.5     0.7841     381.0     0.9772       299.0     7.299E-03     326.5     0.6400     354.0     0.8279     381.5     0.8794       299.5     0.0108     327.0     0.6287     354.5     0.8358     382.0     0.7485       300.0     0.0116     327.5     0.6121     355.5     0.8043     383.0     0.5788       301.0     0.0177     328.5     0.5860     356.0     0.7535     383.5     0.5597       301.5     0.0222     329.0     0.6486     356.5     0.7058     3										
297.0     2.489E-03     324.5     0.4682     352.0     0.7136     379.5     0.8563       297.5     3.984E-03     325.0     0.4748     352.5     0.6731     380.0     0.8990       298.0     5.347E-03     325.5     0.5390     353.0     0.7140     380.5     0.9619       298.5     5.899E-03     326.0     0.6128     353.5     0.7841     381.0     0.9772       299.0     7.299E-03     326.5     0.6400     354.0     0.8279     381.5     0.8794       299.5     0.0108     327.0     0.6287     354.5     0.8388     382.0     0.7485       300.0     0.0116     327.5     0.6121     355.0     0.8346     382.5     0.6466       300.5     0.0130     328.0     0.5744     355.5     0.8043     383.0     0.5788       301.0     0.0177     328.5     0.5860     356.0     0.7535     383.5     0.5597       301.5     0.0222     329.0     0.6486     356.5     0.7088     384.										
297.5     3.984E-03     325.0     0.4748     352.5     0.6731     380.0     0.8990       298.0     5.347E-03     325.5     0.5390     353.0     0.7140     380.5     0.9619       298.5     5.899E-03     326.0     0.6128     353.5     0.7841     381.0     0.9772       299.0     7.299E-03     326.5     0.6400     354.0     0.8279     381.5     0.8794       299.5     0.0108     327.0     0.6287     354.5     0.8358     382.0     0.7485       300.0     0.0116     327.5     0.6121     355.0     0.8346     382.5     0.6466       300.5     0.0130     328.0     0.5744     355.5     0.8043     383.0     0.5788       301.0     0.0177     328.5     0.5860     356.5     0.7058     384.0     0.6469       302.0     0.0222     329.0     0.6486     356.5     0.7058     384.0     0.6469       302.5     0.0307     330.0     0.7201     357.5     0.6268     385.0 </td <td></td>										
298.0     5.347E-03     325.5     0.5390     353.0     0.7140     380.5     0.9619       298.5     5.899E-03     326.0     0.6128     353.5     0.7841     381.0     0.9772       299.0     7.299E-03     326.5     0.6400     354.0     0.8279     381.5     0.8794       299.5     0.0108     327.0     0.6287     354.5     0.8358     382.0     0.7485       300.0     0.0116     327.5     0.6121     355.0     0.8346     382.5     0.6466       300.5     0.0130     328.0     0.5744     355.5     0.8043     383.0     0.5788       301.0     0.0177     328.5     0.5860     356.0     0.7535     383.5     0.5597       301.5     0.0222     329.0     0.6486     356.5     0.7058     384.0     0.6469       302.0     0.0229     329.5     0.7136     357.0     0.6201     384.5     0.7779       302.5     0.0307     330.0     0.7201     357.5     0.6268     385.0										
298.5     5.899E-03     326.0     0.6128     353.5     0.7841     381.0     0.9772       299.0     7.299E-03     326.5     0.6400     354.0     0.8279     381.5     0.8794       299.5     0.0108     327.0     0.6287     354.5     0.8358     382.0     0.7485       300.0     0.0116     327.5     0.6121     355.0     0.8346     382.5     0.6466       300.5     0.0130     328.0     0.57444     355.5     0.8043     383.0     0.5788       301.0     0.0177     328.5     0.5860     356.0     0.7535     383.5     0.5597       301.5     0.0222     329.0     0.6486     356.5     0.7068     384.0     0.6469       302.0     0.0229     329.5     0.7136     357.0     0.6201     384.5     0.7779       302.5     0.0307     330.0     0.7201     357.5     0.6268     385.0     0.8530       303.0     0.0459     330.5     0.6647     358.0     0.5826     385.5										
299.0   7.299E-03   326.5   0.6400   354.0   0.8279   381.5   0.8794     299.5   0.0108   327.0   0.6287   354.5   0.8358   382.0   0.7485     300.0   0.0116   327.5   0.6121   355.0   0.8346   382.5   0.6466     300.5   0.0130   328.0   0.5744   355.5   0.8043   383.0   0.5788     301.0   0.0177   328.5   0.5860   356.0   0.7535   383.5   0.5597     301.5   0.0222   329.0   0.6486   356.5   0.7058   384.0   0.6469     302.0   0.0229   329.5   0.7136   357.0   0.6201   384.5   0.7779     302.5   0.0307   330.0   0.7201   357.5   0.6268   385.0   0.8530     303.0   0.0459   330.5   0.6647   358.0   0.5826   385.5   0.8141     303.5   0.0546   331.0   0.6283   358.5   0.5404   386.0   0.7846     304.0   0.0656   331.5   0.6420   359.0										
299.5     0.0108     327.0     0.6287     354.5     0.8358     382.0     0.7485       300.0     0.0116     327.5     0.6121     355.0     0.8346     382.5     0.6466       300.5     0.0130     328.0     0.5744     355.5     0.8043     383.0     0.5788       301.0     0.0177     328.5     0.5860     356.0     0.7535     383.5     0.5597       301.5     0.0222     329.0     0.6486     356.5     0.7058     384.0     0.6469       302.0     0.0229     329.5     0.7136     357.0     0.6201     384.5     0.7779       302.5     0.0307     330.0     0.7201     357.5     0.6268     385.0     0.8530       303.0     0.0459     330.5     0.6647     358.0     0.5826     385.5     0.8141       303.5     0.0546     331.0     0.6283     358.5     0.5404     386.0     0.7846       304.0     0.0556     331.5     0.6420     359.0     0.6349     387.0			1		1		1			
300.0     0.0116     327.5     0.6121     355.0     0.8346     382.5     0.6466       300.5     0.0130     328.0     0.5744     355.5     0.8043     383.0     0.5788       301.0     0.0177     328.5     0.5860     356.0     0.7535     383.5     0.5597       301.5     0.0222     329.0     0.6486     356.5     0.7058     384.0     0.6469       302.0     0.0229     329.5     0.7136     357.0     0.6201     384.5     0.7779       302.5     0.0307     330.0     0.7201     357.5     0.6268     385.0     0.8530       303.0     0.0459     330.5     0.6647     358.0     0.5826     385.5     0.8141       303.5     0.0546     331.0     0.6283     358.5     0.5404     386.0     0.7846       304.0     0.0556     331.5     0.6420     359.0     0.6349     386.5     0.8148       304.5     0.0646     332.0     0.6560     359.5     0.7643     387.0										
300.5     0.0130     328.0     0.5744     355.5     0.8043     383.0     0.5788       301.0     0.0177     328.5     0.5860     356.0     0.7535     383.5     0.5597       301.5     0.0222     329.0     0.6486     356.5     0.7058     384.0     0.6469       302.0     0.0229     329.5     0.7136     357.0     0.6201     384.5     0.7779       302.5     0.0307     330.0     0.7201     357.5     0.6268     385.0     0.8530       303.0     0.0459     330.5     0.6647     358.0     0.5826     385.5     0.8141       303.5     0.0546     331.0     0.6283     358.5     0.5404     386.0     0.7846       304.0     0.0556     331.5     0.6420     359.0     0.6349     386.5     0.8148       304.5     0.0646     332.0     0.6560     359.5     0.7643     387.0     0.8213       305.0     0.0798     332.5     0.6540     360.0     0.8074     387.5										
301.0     0.0177     328.5     0.5860     356.0     0.7535     383.5     0.5597       301.5     0.0222     329.0     0.6486     356.5     0.7058     384.0     0.6469       302.0     0.0229     329.5     0.7136     357.0     0.6201     384.5     0.7779       302.5     0.0307     330.0     0.7201     357.5     0.6268     385.0     0.8530       303.0     0.0459     330.5     0.6647     358.0     0.5826     385.5     0.8141       303.5     0.0546     331.0     0.6283     358.5     0.5404     386.0     0.7846       304.0     0.0556     331.5     0.6420     359.0     0.6349     386.5     0.8148       304.5     0.0646     332.0     0.6560     359.5     0.7643     387.0     0.8213       305.0     0.0798     332.5     0.6540     360.0     0.8074     387.5     0.8086       305.5     0.0848     333.0     0.6413     360.5     0.7621     388.0										
301.5 0.0222 329.0 0.6486 356.5 0.7058 384.0 0.6469   302.0 0.0229 329.5 0.7136 357.0 0.6201 384.5 0.7779   302.5 0.0307 330.0 0.7201 357.5 0.6268 385.0 0.8530   303.0 0.0459 330.5 0.6647 358.0 0.5826 385.5 0.8141   303.5 0.0546 331.0 0.6283 358.5 0.5404 386.0 0.7846   304.0 0.0556 331.5 0.6420 359.0 0.6349 386.5 0.8148   304.5 0.0646 332.0 0.6560 359.5 0.7643 387.0 0.8213   305.0 0.0798 332.5 0.6540 360.0 0.8074 387.5 0.8086   305.5 0.0848 333.0 0.6413 360.5 0.7621 388.0 0.8000   306.0 0.0819 333.5 0.6154 361.0 0.7001 388.5 0.7935   306.5 0.0892 334.0 0.6275 361.5 0.6842 389.0 0.8606										
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302.5     0.0307     330.0     0.7201     357.5     0.6268     385.0     0.8530       303.0     0.0459     330.5     0.6647     358.0     0.5826     385.5     0.8141       303.5     0.0546     331.0     0.6283     358.5     0.5404     386.0     0.7846       304.0     0.0556     331.5     0.6420     359.0     0.6349     386.5     0.8148       304.5     0.0646     332.0     0.6560     359.5     0.7643     387.0     0.8213       305.0     0.0798     332.5     0.6540     360.0     0.8074     387.5     0.8086       305.5     0.0848     333.0     0.6413     360.5     0.7621     388.0     0.8000       306.0     0.0819     333.5     0.6154     361.0     0.7001     388.5     0.7935       306.5     0.0892     334.0     0.6275     361.5     0.6842     389.0     0.8606			1		1		1		1	
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306.5 0.0892 334.0 0.6275 361.5 0.6842 389.0 0.8606			1		1		1		1	
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## 2. Referenced Documents

2.1 ASTM Standards: 4

E 490 Standard Solar Constant and Zero Air Mass Solar Spectral Irradiance Tables

E 772 Terminology Relating to Solar Energy Conversion 2.2 *ASTM Adjunct:* 

ADJG0173CD Simple Model for Atmospheric Transmission of Sunshine<sup>4</sup>

#### 3. Terminology

3.1 *Definitions*—Definitions of terms used in this specification not otherwise described below may be found in Terminology E 772.

<sup>&</sup>lt;sup>4</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume Information, refer to the standard's Document Summary Page on the ASTM website.

- 3.2 Definitions of Terms Specific to This Standard:
- 3.2.1 *air mass zero (AM0)*—describes solar radiation quantities outside the Earth's atmosphere at the mean Earth-Sun distance (1 Astronomical Unit). See ASTM E 490.
- 3.2.2 integrated irradiance  $E_{\lambda 1-\lambda 2}$ —spectral irradiance integrated over a specific wavelength interval from  $\lambda_1$  to  $\lambda_2$ , measured in W·m<sup>-2</sup>; mathematically:

$$E_{\lambda 1 - \lambda 2} = \int_{\lambda 1}^{\lambda 2} E_{\lambda} \, d\lambda \tag{1}$$

- 3.2.3 solar irradiance, hemispherical  $E_H$ —on a given plane, the solar radiant flux received from the within the 2- $\pi$  steradian field of view of a tilted plane from the portion of the sky dome and the foreground included in the plane's field of view, including both diffuse and direct solar radiation.
- 3.2.3.1 *Discussion*—For the special condition of a horizontal plane the hemispherical solar irradiance is properly termed global solar irradiance,  $E_G$ . Incorrectly, global tilted, or total global irradiance is often used to indicate hemispherical irradiance for a tilted plane. In case of a sun-tracking receiver, this hemispherical irradiance is commonly called global normal irradiance. The adjective global should refer only to hemispherical solar radiation on a horizontal, not a tilted, surface.
- 3.2.4 *aerosol optical depth (AOD)*—the wavelength-dependent total extinction (scattering and absorption) by aerosols in the atmosphere. This optical depth (also called "optical thickness") is defined here at 500 nm.

### 3.2.4.1 *Discussion*—See **X1.1**.

3.2.5 solar irradiance, spectral  $E_{\lambda}$ —solar irradiance E per unit wavelength interval at a given wavelength  $\lambda$ . (Unit: Watts per square meter per nanometer,  $W \cdot m^{-2} \cdot nm^{-1}$ )

$$E_{\lambda} = \frac{dE}{d\lambda} \tag{2}$$

- 3.2.6 spectral passband—the effective wavelength interval within which spectral irradiance is allowed to pass, as through a filter or monochromator. The convolution integral of the spectral passband (normalized to unity at maximum) and the incident spectral irradiance produces the effective transmitted irradiance.
- 3.2.6.1 *Discussion*—Spectral passband may also be referred to as the spectral bandwidth of a filter or device. Passbands are usually specified as the interval between wavelengths at which one half of the maximum transmission of the filter or device occurs, or as full-width at half-maximum, FWHM.
- 3.2.7 *spectral interval*—the distance in wavelength units between adjacent spectral irradiance data points.
- 3.2.8 *spectral resolution*—the minimum wavelength difference between two wavelengths that can be identified unambiguously.
- 3.2.8.1 *Discussion*—In the context of this standard, the spectral resolution is simply the interval,  $\Delta\lambda$ , between spectral data points, or the *spectral interval*.
- 3.2.9 total precipitable water—the depth of a column of water (with a section of 1 cm<sup>2</sup>) equivalent to the condensed water vapor in a vertical column from the ground to the top of the atmosphere. (Unit: cm or g/cm<sup>2</sup>)

- 3.2.10 *total ozone*—the depth of a column of pure ozone equivalent to the total of the ozone in a vertical column from the ground to the top of the atmosphere. (Unit: atmosphere-cm)
- 3.2.11 *wavenumber*—a unit of frequency,  $\upsilon$ , in units of reciprocal centimeters (symbol cm<sup>-1</sup>) commonly used in place of wavelength,  $\lambda$ . The relationship between wavelength and frequency is defined by  $\lambda \upsilon = c$ , where c is the speed of light in vacuum. To convert wavenumber to nanometers,  $\lambda \cdot \text{nm} = 1 \cdot 10^7 / \upsilon \cdot \text{cm}^{-1}$ .

#### 4. Technical Basis for the Tables

- 4.1 These tables are modeled data generated using an air mass zero (AM0) spectrum based on the extraterrestrial spectrum of of Gueymard (1,2) derived from Kurucz (5), the United States Standard Atmosphere of 1976 (USSA) reference Atmosphere (6), the Shettle and Fenn Rural Aerosol Profile (7), the SMARTS2 V. 2.9.2 radiative transfer code. Further details are provided in X1.3.
- 4.2 The 37° tilted surface was selected as it represents the average latitude of the contiguous forty-eight states of the continental U.S., and outdoor exposure testing often takes place at latitude tilt.
- 4.3 The documented USSA atmospheric profiles utilized in the MODTRAN spectral transmission model (6) have been used to provide atmospheric properties and concentrations of absorbers.
- 4.4 The SMARTS model Version 2.9.2 is available at Internet URL: http://rredc.nrel.gov/solar/models/SMARTS.
- 4.5 To provide spectral data with a uniform spectral step size, the AM0 spectrum used in conjunction with SMARTS2 to generate the terrestrial spectrum is slightly different from the ASTM extraterrestrial spectrum, ASTM E 490. Because ASTM E 490 and SMARTS2 both use the data of Kurucz (5), the SMARTS2 and E 490 spectra are in excellent agreement although they do not have the same spectral resolution.
- 4.6 The current spectra reflect improved knowledge of atmospheric aerosol optical properties, transmission properties, and radiative transfer modeling (8).
- 4.7 The terrestrial solar spectral in the tables have been computed with a spectral bandwidth equivalent to the spectral resolution of the tables, namely 0.5 nm.

## 5. Significance and Use

- 5.1 This standard does not purport to address the mean level of solar ultraviolet spectral irradiance to which materials will be subjected during their useful life. The spectral irradiance distributions have been chosen to represent a reasonable upper limit for natural solar ultraviolet radiation that ought to be considered when evaluating the behavior of materials under various exposure conditions.
- 5.2 Absorptance, reflectance, and transmittance of solar energy are important factors in material degradation studies. These properties are normally functions of wavelength, which require that the spectral distribution of the solar flux be known before the solar-weighted property can be calculated.
- 5.3 The interpretation of the behavior of materials exposed to either natural solar radiation or ultraviolet radiation from artificial light sources requires an understanding of the spectral