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Road vehicles — Safety glazing materials — Method for the determination of solar transmittance

Véhicules routiers — Vitrages de sécurité — Méthode de détermination du facteur de transmission du rayonnement solaire

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 35, *Lighting and visibility*.

This second edition cancels and replaces the first edition (ISO 13837:2008), which has been technically revised.

The main changes compared to the previous edition are as follows:

— deletion of definitions of convention “A” and convention “B”;

— deletion of all texts and tables corresponding to air mass 1,0 global;

— revision of 3.1;

— addition of some symbol definitions for variables and parameters;

— addition of calculation methods for luminous transmittance [T_L], solar direct reflectance [R_e], solar direct absorbance [a_e] and colorimetry;

— revision of calculation method for solar UV transmittance $\left[T_{UV(380)}\right]$ to calculate with air mass 1,5 global;

— addition of a new Table 1 for calculation of luminous transmittance [T_L], a new Table 2 for calculation of solar UV transmittance [$T_{UV(380)}$], and a new Table 5 for calculation of colorimetry;

— revision of Table 3 (former Table 1) for calculation of solar UV transmittance [$T_{UV(400)}$], Table 4 (former Table 2) for calculation of solar direct transmittance [T_e], solar direct reflectance [R_e], and Table A.1 for explanation of the derivation process;

— revision of Annex A to list the source of values in the new solar weight tables and give out the derivation process of Table 3 as an example;

— deletion of Figure A.1 and Figure A.2;

— moving of texts of Annex B to 5.3.7 and revision of text structure;

— revision of Bibliography;

— editorial update.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

A review of existing standards and industry specifications and procedures reveals a lack of agreement with respect to the basis for defining and measuring the ultraviolet (UV), visible (VIS), infrared (IR) transmittance and colorimetry (L^*, a^*, b^*) properties of glazing materials. To avoid the continued preparation and promulgation of conflicting standards by individual entities, there is an interest in the automotive and glazing industries to harmonize on a worldwide basis the test procedures and protocols used to assess the solar transmittance properties of glazing materials.

Road vehicles — Safety glazing materials — Method for the determination of solar transmittance

1 Scope

This document specifies test methods to determine the luminous, the direct and total solar transmittance, and the colorimetry of safety glazing materials for road vehicles.

This document applies to monolithic or laminated, clear or tinted samples of safety glazing materials. Essentially flat sections of glazing parts can be used in this test, as well as flat samples of the same materials.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/CIE 11664-4:2019, *Colorimetry — Part 4: CIE 1976 L*a*b* colour space*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1.1
air mass
ratio of the mass of atmosphere in the actual observer-sun path to the mass that would exist if the observer were at sea level, at standard barometric pressure, and the sun were directly overhead

3.2 Symbols

T_L	luminous transmittance for CIE standard illuminant A with 2 degree view through a glazing
T_λ	transmittance through a glazing at wavelength λ within a specified $\Delta\lambda$
W_λ	normalized luminous transmittance weighting coefficient
$T_{UV(380)}$	ultraviolet (UV) direct solar energy transmitted through the glazing at a specified upper limit value (380 nm)
$E'_{\lambda(n)}$	normalized relative spectral distribution of global solar radiation
$T_{UV(400)}$	ultraviolet (UV) direct solar energy transmitted through the glazing at a specified upper limit value (400 nm)

T_e	direct solar energy (e) transmitted through the glazing
R_e	direct solar energy (e) reflected by the glazing
R_λ	external reflectance (R) of a glazing at wavelength λ within a specified $\Delta\lambda$
a_e	direct solar energy (e) absorbed by the glazing
T_{TS}	total solar energy ($T_e + q_i$) transmitted through the glazing
q_i	secondary heat flux through the glazing
h_e	heat flux of the safety glazing material towards the outside
h_i	heat flux of the safety glazing material towards the inside
v	wind velocity
ε_i	corrected emissivity
X_{10}, Y_{10}, Z_{10}	tristimulus values calculated using the CIE 1964 standard colorimetric observer under CIE standard illuminant D65 spectral power distribution
$W_{10,X(\lambda)}$, $W_{10,Y(\lambda)}$, $W_{10,Z(\lambda)}$	pre-calculated weighting functions for tristimulus integration using the CIE 1964 standard colorimetric observer
X_n, Y_n, Z_n	tristimulus values of a specific white colour stimulus calculated using the colour-matching functions of the CIE 1931 standard colorimetric system
L^*, a^*, b^*	coordinates of the CIE 1976 $L^*a^*b^*$ colour space; L^*, CIELAB lightness; a^*, b^*, CIELAB coordinates
λ	wavelength, in nm
S_λ	relative spectral distribution of global solar radiation
$\Delta\lambda$	uniform λ interval
E_λ	solar energy within a $\Delta\lambda$
E'_λ	E_λ in trapezoidal form ($E_1/2$, E_2 ... E_{n-1}, $E_n/2$)

4 Apparatus

This method requires spectral transmittance data to be obtained from samples of glazing materials using a scanning spectrophotometer. This instrument, preferably equipped with an integrating sphere, shall be capable of measuring transmittance over that part of the electromagnetic spectrum in which the solar energy is transmitted to the earth's surface.

5 Procedure

5.1 Sample preparation

Cut out (if necessary) and clean the flattest area of curved test specimens with distilled water and reagent grade ethanol, or use an alternate procedure appropriate to the material, if necessary. Cut and clean flat samples similarly.

5.2 Measurement

Standardize the spectrophotometer in accordance with the manufacturer's instructions. Measure transmittance/reflectance of cleaned sample and record the sample spectral data in accordance with the instrument manufacturer's recommendation. Note its film/coating side and curvature orientation, if applicable.

5.3 Calculation method

5.3.1 Luminous transmittance [T_L]

The luminous transmittance T_L shall be calculated using the weight data of visible radiation of CIE standard illuminant A in Table 1 and Formula (1):

$$T_L = \sum_{380}^{780} T_\lambda \times W_\lambda \quad (1)$$

5.3.2 Solar UV transmittance [$T_{UV(380)}$]

The solar UV transmittance $T_{UV(380)}$ shall be calculated using the solar weight data in Table 2 and Formula (2):

$$T_{UV(380)} = \sum_{300}^{380} T_\lambda \times E'_{\lambda(n)} \quad (2)$$

5.3.3 Solar UV transmittance [$T_{UV(400)}$]

The solar UV transmittance $T_{UV(400)}$ shall be calculated using the solar weight data in Table 3 and Formula (3):

$$T_{UV(400)} = \sum_{300}^{400} T_\lambda \times E'_{\lambda(n)} \quad (3)$$

NOTE Annex A gives out an example of the derivation process for Table 3.

5.3.4 Solar direct transmittance [T_e]

The solar direct transmittance T_e shall be calculated using the solar weight data in Table 4 and Formula (4):

$$T_e = \sum_{300}^{2\,500} T_\lambda \times E'_{\lambda(n)} \quad (4)$$

5.3.5 Solar direct reflectance [R_e]

The solar direct reflectance R_e shall be calculated using the solar weight data in Table 4 and Formula (5):

$$R_e = \sum_{300}^{2\,500} R_\lambda \times E'_{\lambda(n)} \quad (5)$$

5.3.6 Solar direct absorbance [a_e]

The solar direct absorbance a_e shall be calculated using Formula (6):

$$a_e = 100 - T_e - R_e \tag{6}$$

where 100 is expressed in percentage (%).

5.3.7 Total solar transmittance [T_{TS}]

5.3.7.1 The total solar transmittance T_{TS} shall be calculated by Formula (7):

$$T_{TS} = T_e + q_i \tag{7}$$

5.3.7.2 The secondary heat flux through the glazing q_i of a single glazing shall be calculated by Formula (8):

$$q_i = a_e \times \frac{h_i}{h_i + h_e} \tag{8}$$

5.3.7.3 h_e and h_i mainly depend on the position of the safety glazing material, wind velocity, inside and outside temperatures, as well as on the temperature of the two external glazing material surfaces. As the purpose of this document is to provide basic information on the performance of safety glazing materials, conventional conditions have been stated for simplicity, as specified below:

a) The position of the safety glazing material is vertical;

b) Outside surface:

   1) wind velocities:

      — v_1 = approximately 4 m/s for vehicles at rest;

      — v_2 = 14 m/s for vehicles at 50 km/h;

      — v_3 = 28 m/s for vehicles at 100 km/h;

      — v_4 = 42 m/s for vehicles at 150 km/h.

   2) Hemispherical emissivity = 0,837;

   3) Radiative heat flux was not considered.

c) Inside surface:

   1) natural convection;

   2) emissivity is an optional consideration.

5.3.7.4 Under above conventional, average conditions, standard values of h_{e1} to h_{e4} are obtained as follows:

— h_{e1} = 21 W/(m^2·K) at v_1;

— h_{e2} = 56 W/(m^2·K) at v_2;

— h_{e3} = 97 W/(m^2·K) at v_3;

— h_{e4} = 133 W/(m²·K) at v_4;

where

for $v < 5$ m/s, $h_e = 5{,}6 + 3{,}9\,v$ (9)

for $v \geq 5$ m/s, $h_e = 7{,}2\,v^{0{,}78}$ (10)

NOTE For Formulae (9) and (10), see Reference [11].

5.3.7.5 For h_i, expressed in W/(m²·K), shall be calculated by Formula (11):

$$h_i = 3{,}6 + \frac{4{,}4\varepsilon_i}{0{,}837} \tag{11}$$

NOTE For ordinary glass, $\varepsilon_i = 0{,}837$ and h_i = 8 W/(m²·K).

5.3.7.6 The corrected emissivity ε_i is defined and measured in accordance with ISO 10292. If other heat flux is used to calculate the secondary heat flux in order to meet special boundary conditions, this shall be reported.

NOTE Values lower than 0,837 for ε_i (due to surface coatings with higher reflection in the far infrared) are only considered if water condensation on the coated surface can be excluded.

5.3.7.7 For multiple safety glazing materials, e.g. double glazing, and for vehicles at rest and in motion, the definitions and formulae used in ISO 9050 can be applied, if necessary, to calculate the total solar transmittance T_{TS}.

5.3.8 Colorimetry

5.3.8.1 Tristimulus value X_{10}, Y_{10}, Z_{10}

Calculate tristimulus value (X_{10}, Y_{10}, Z_{10}) by CIE standard illuminant D65 tristimulus weighting functions ($W_{10,X(\lambda)}$), ($W_{10,Y(\lambda)}$) and ($W_{10,Z(\lambda)}$) in Table 5. Tristimulus value (X_{10}, Y_{10}, Z_{10}) for the visible range is determined by Formulae (12), (13) and (14):

$$X_{10} = \sum_{380}^{780} T_\lambda \times W_{10,X(\lambda)} \tag{12}$$

$$Y_{10} = \sum_{380}^{780} T_\lambda \times W_{10,Y(\lambda)} \tag{13}$$

$$Z_{10} = \sum_{380}^{780} T_\lambda \times W_{10,Z(\lambda)} \tag{14}$$

5.3.8.2 CIE 1976 L^*, a^*, b^* colour space

Calculate L^*, a^*, b^* values in accordance with ISO/CIE 11664-4:2019, 5.1 using (X_{10}, Y_{10}, Z_{10}) calculated above and white point data in Table 5 as (X_n, Y_n, Z_n).

6 Expression of results

The following information shall be recorded:

— description of the test specimen(s) including size, construction, product name, code/identifier, curvature orientation, and etc., if applicable;

— temperature during measuring;

— any other heat flux used, if applicable, when calculating q_i;

— result of calculated properties, which shall be recorded as follows:

  — T_L, $T_{UV(380)}$, $T_{UV(400)}$, T_e, R_e, a_e, T_{TS} rounded to 0,1 %;

  — X_{10}, Y_{10}, Z_{10} of colorimetry rounded to 0,001;

  — L^*, a^*, b^* rounded to 0,01.

Table 1 — Weighting coefficient for calculation of tristimulus value Y of chromatic system (x,y,z) — CIE Standard Illuminant A

λ, nm	W_λ	λ, nm	W_λ	λ, nm	W_λ
380	0,000 02	515	1,951 86	650	0,818 29
385	0,000 03	520	2,385 28	655	0,637 21
390	0,000 07	525	2,785 89	660	0,486 11
395	0,000 13	530	3,161 04	665	0,362 32
400	0,000 27	535	3,498 43	670	0,265 10
405	0,000 48	540	3,799 68	675	0,195 80
410	0,000 99	545	4,061 86	680	0,146 08
415	0,001 95	550	4,283 92	685	0,104 24
420	0,003 89	555	4,469 26	690	0,073 02
425	0,007 71	560	4,610 96	695	0,051 75
430	0,013 26	565	4,697 40	700	0,037 69
435	0,020 79	570	4,728 62	705	0,027 33
440	0,030 59	575	4,700 35	710	0,019 81
445	0,042 60	580	4,613 70	715	0,014 26
450	0,058 26	585	4,466 77	720	0,010 21
455	0,078 76	590	4,270 36	725	0,007 31
460	0,105 14	595	4,037 75	730	0,005 21
465	0,138 01	600	3,773 39	735	0,003 66
470	0,180 74	605	3,485 45	740	0,002 56
475	0,237 51	610	3,178 18	745	0,001 79
480	0,310 79	615	2,862 16	750	0,001 26
485	0,400 45	620	2,535 72	755	0,000 90
490	0,519 72	625	2,190 20	760	0,000 65
495	0,681 33	630	1,852 33	765	0,000 46
500	0,896 01	635	1,552 84	770	0,000 33
505	1,187 83	640	1,281 17	775	0,000 24
510	1,539 92	645	1,034 41	780	0,000 17

NOTE Values are taken from ISO/CIE 11664-1:2019, Table 1, $\bar{y}(\lambda)$ with 2 degree view and ISO/CIE 11664-2:—, Table A.1, $S_A(\lambda)$.

Table 2 — Solar global radiation through air mass 1,5 and partitioned into uniform spectral trapezoidal intervals (300 nm ~ 380 nm)

λ, nm	$E'_{\lambda(n)}$	λ, nm	$E'_{\lambda(n)}$
300	0,000 000	345	0,073 326
305	0,001 859	350	0,079 330
310	0,007 665	355	0,082 894
315	0,017 961	360	0,087 039
320	0,029 732	365	0,097 963
325	0,042 466	370	0,108 987
330	0,062 108	375	0,113 837
335	0,065 462	380	0,058 351
340	0,071 020	-	-

NOTE Normalized relative spectral distribution of the UV part of global solar radiation (direct + diffuse) S_λ for air mass = 1,5 is calculated from the values given in ISO 9845-1:1992, Table 1, column 5, multiplied by the wavelength interval $\Delta\lambda$. The values in this table are calculated according to the trapezoidal rule.

Table 3 — Solar global radiation through air mass 1,5 and partitioned into uniform spectral trapezoidal intervals (300 nm to 400 nm)

λ, nm	$E'_{\lambda(n)}$	λ, nm	$E'_{\lambda(n)}$
300	0,000 000	355	0,054 947
305	0,001 045	360	0,056 946
310	0,004 634	365	0,064 930
315	0,011 800	370	0,072 925
320	0,019 807	375	0,075 901
325	0,027 019	380	0,077 991
330	0,043 271	385	0,075 890
335	0,042 703	390	0,073 777
340	0,047 644	395	0,092 335
345	0,048 041	400	0,055 446
350	0,052 948	-	-

NOTE Normalized relative spectral distribution of the UV part of global solar radiation (direct + diffuse) S_λ for air mass =1,5 is calculated from the values given in ISO 9845-1:1992, Table 1, column 5, multiplied by the wavelength interval $\Delta\lambda$. The values in this table are calculated according to the trapezoidal rule.

Table 4 — Solar global radiation through air mass 1,5 and partitioned into uniform spectral trapezoidal intervals

λ, nm	$E'_{\lambda(n)}$	λ, nm	$E'_{\lambda(n)}$	λ, nm	$E'_{\lambda(n)}$
300	0,000 000	520	0,015 357	1 000	0,036 097
305	0,000 057	530	0,015 867	1 050	0,034 110
310	0,000 236	540	0,015 827	1 100	0,018 861
315	0,000 554	550	0,015 844	1 150	0,013 228
320	0,000 916	560	0,015 590	1 200	0,022 551
325	0,001 309	570	0,015 256	1 250	0,023 376
330	0,001 914	580	0,014 745	1 300	0,017 756

NOTE Normalized relative spectral distribution of global solar radiation (direct + diffuse) S_λ for air mass = 1,5 is calculated from the values given in ISO 9845-1:1992, Table 1, column 5, multiplied by the wavelength interval $\Delta\lambda$. The values in this table are calculated according to the trapezoidal rule.

Table 4 *(continued)*

λ, nm	$E'_{\lambda(n)}$	λ, nm	$E'_{\lambda(n)}$	λ, nm	$E'_{\lambda(n)}$
335	0,002 018	590	0,014 330	1 350	0,003 743
340	0,002 189	600	0,014 663	1 400	0,000 741
345	0,002 260	610	0,015 030	1 450	0,003 792
350	0,002 445	620	0,014 859	1 500	0,009 693
355	0,002 555	630	0,014 622	1 550	0,013 693
360	0,002 683	640	0,014 526	1 600	0,012 203
365	0,003 020	650	0,014 445	1 650	0,010 615
370	0,003 359	660	0,014 313	1 700	0,007 256
375	0,003 509	670	0,014 023	1 750	0,007 183
380	0,003 600	680	0,012 838	1 800	0,002 157
385	0,003 529	690	0,011 788	1 850	0,000 398
390	0,003 551	700	0,012 453	1 900	0,000 082
395	0,004 294	710	0,012 798	1 950	0,001 087
400	0,007 812	720	0,010 589	2 000	0,003 024
410	0,011 638	730	0,011 233	2 050	0,003 988
420	0,011 877	740	0,012 175	2 100	0,004 229
430	0,011 347	750	0,012 181	2 150	0,004 142
440	0,013 246	760	0,009 515	2 200	0,003 690
450	0,015 343	770	0,010 479	2 250	0,003 592
460	0,016 166	780	0,011 381	2 300	0,003 436
470	0,016 178	790	0,011 262	2 350	0,003 163
480	0,016 402	800	0,028 718	2 400	0,002 233
490	0,015 794	850	0,048 240	2 450	0,001 202
500	0,015 801	900	0,040 297	2 500	0,000 475
510	0,015 973	950	0,021 384	-	-

NOTE Normalized relative spectral distribution of global solar radiation (direct + diffuse) S_λ for air mass = 1,5 is calculated from the values given in ISO 9845-1:1992, Table 1, column 5, multiplied by the wavelength interval $\Delta\lambda$. The values in this table are calculated according to the trapezoidal rule.

Table 5 — CIE Standard Illuminant D65 tristimulus weighting functions, 1964 observer 5 nm interval

λ, nm	$W_{10,\ X(\lambda)}$	$W_{10,\ Y(\lambda)}$	$W_{10,\ Z(\lambda)}$	λ, nm	$W_{10,\ X(\lambda)}$	$W_{10,\ Y(\lambda)}$	$W_{10,\ Z(\lambda)}$
380	0,000 344	0,000 037	0,001 516	545	2,025 158	4,404 740	0,035 509
385	0,001 491	0,000 161	0,006 590	550	2,371 959	4,439 978	0,017 854
390	0,005 553	0,000 596	0,024 648	555	2,704 361	4,385 911	0,004 789
395	0,021 409	0,002 272	0,095 611	560	3,034 419	4,291 328	0,000 000
400	0,068 045	0,007 137	0,306 264	565	3,353 073	4,149 482	0,000 000
405	0,162 689	0,016 902	0,738 923	570	3,642 062	3,960 803	0,000 000
410	0,333 558	0,034 467	1,532 714	575	3,931 429	3,782 685	0,000 000
415	0,559 500	0,057 510	2,612 786	580	4,179 901	3,581 346	0,000 000
420	0,822 090	0,085 995	3,909 773	585	4,263 618	3,276 683	0,000 000
425	1,025 842	0,114 299	4,969 621	590	4,268 205	2,966 531	0,000 000
430	1,173 672	0,144 252	5,794 081	595	4,360 648	2,769 290	0,000 000
435	1,474 132	0,204 406	7,411 476	600	4,352 946	2,549 598	0,000 000

Table 5 *(continued)*

λ, nm	$W_{10,\,X(\lambda)}$	$W_{10,\,Y(\lambda)}$	$W_{10,\,Z(\lambda)}$	λ, nm	$W_{10,\,X(\lambda)}$	$W_{10,\,Y(\lambda)}$	$W_{10,\,Z(\lambda)}$
440	1,731 447	0,280 098	8,876 570	605	4,208 285	2,294 746	0,000 000
445	1,845 969	0,356 586	9,676 960	610	3,972 754	2,035 427	0,000 000
450	1,866 332	0,450 374	10,042 997	615	3,626 466	1,761 602	0,000 000
455	1,732 580	0,536 793	9,602 119	620	3,231 216	1,502 059	0,000 000
460	1,532 277	0,649 874	8,847 600	625	2,777 082	1,249 082	0,000 000
465	1,271 867	0,764 672	7,783 323	630	2,320 340	1,015 959	0,000 000
470	0,966 785	0,915 248	6,511 656	635	1,922 411	0,820 015	0,000 000
475	0,657 120	1,092 014	5,115 001	640	1,554 240	0,647 630	0,000 000
480	0,401 561	1,264 877	3,851 285	645	1,210 606	0,493 876	0,000 000
485	0,198 579	1,439 180	2,756 181	650	0,923 956	0,370 620	0,000 000
490	0,075 716	1,587 784	1,944 174	655	0,704 306	0,279 885	0,000 000
495	0,024 087	1,855 731	1,419 123	660	0,526 581	0,208 057	0,000 000
500	0,017 955	2,168 073	1,028 107	665	0,392 268	0,154 153	0,000 000
505	0,072 152	2,482 442	0,743 990	670	0,287 681	0,112 581	0,000 000
510	0,173 780	2,814 353	0,519 713	675	0,200 108	0,078 073	0,000 000
515	0,326 368	3,135 986	0,376 176	680	0,137 601	0,053 575	0,000 000
520	0,530 916	3,434 668	0,273 729	685	0,091 140	0,035 441	0,000 000
525	0,790 607	3,763 625	0,196 791	690	0,059 823	0,023 246	0,000 000
530	1,095 808	4,055 389	0,141 098	695	0,042 087	0,016 343	0,000 000
535	1,388 112	4,215 310	0,093 924	700	0,029 508	0,011 455	0,000 000
540	1,692 577	4,321 548	0,061 437	705	0,020 741	0,008 053	0,000 000
710	0,014 564	0,005 657	0,000 000	750	0,000 687	0,000 269	0,000 000
715	0,009 198	0,003 575	0,000 000	755	0,000 421	0,000 165	0,000 000
720	0,005 765	0,002 243	0,000 000	760	0,000 252	0,000 099	0,000 000
725	0,004 259	0,001 659	0,000 000	765	0,000 220	0,000 087	0,000 000
730	0,003 142	0,001 225	0,000 000	770	0,000 185	0,000 073	0,000 000
735	0,002 269	0,000 886	0,000 000	775	0,000 130	0,000 051	0,000 000
740	0,001 642	0,000 642	0,000 000	780	0,000 091	0,000 036	0,000 000
745	0,001 063	0,000 416	0,000 000	White point	94,811 787	100,000 000	107,324 109

NOTE Values are equivalent to [ISO/CIE 11664-1:2019, Table 2, $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$] times [ISO/CIE 11664-2:—, Table A.1, $S_{D65}(\lambda)$].

Annex A
(informative)

Derivation of solar weight table

A.1 The solar weight tables in this document were derived as follows:

a) Table 1 was derived from ISO/CIE 11664-1:2019;

b) Tables 2, 3 and 4 were derived from ISO 9845-1:1992 (air mass 1,5 global);

c) Table 5 was derived from ISO/CIE 11664-1:2019 and ISO/CIE 11664-2:—.

A.2 The list below explains each column of the spreadsheet in Table A.1, which shows the derivation of Table 3.

— **Column (1)**: ultraviolet wavelengths, in nanometres, from 300 nm to 400 nm, with wavelength interval $\Delta\lambda = 5\text{nm}$.

— **Column (2)**: ultraviolet energy levels at corresponding wavelengths from ISO 9845-1:1992. E_λ values at missing wavelengths from ISO 9845-1:1992 are calculated using spline interpolation method.

— **Column (3)**: E'_λ values were calculated from column (2), as shown in Formula (A.1):

$$E'_\lambda = 5 \times \{E_{300}/2, E_{305}, E_{310}, \cdots E_{395}, E_{400}/2\}; \qquad \text{(A.1)}$$

— **Column (4)**: column (3) normalized (portion of 300 nm to 400 nm normalization) as shown in Formula (A.2):

$$E'_{\lambda(\text{n})} = E'_\lambda / \sum_{300}^{400} E'_\lambda \qquad \text{(A.2)}$$

Table A.1 — Derivation table of Δλ versus $E'_{\lambda(n)}$ for Table 3

(1)	(2)	(3)	(4)
λ, nm[a]	E_λ [b]	E'_λ [c]	$E'_{\lambda(\text{n})}$ [d]
300	0,0	0,0	0,000 000
305	9,2	46,0	0,001 045
310	40,8	204,0	0,004 634
315	103,9	519,5	0,011 800
320	174,4	872,0	0,019 807
325	237,9	1 189,5	0,027 019
330	381,0	1 905,0	0,043 271
335	376,0	1 880,0	0,042 703

[a] See ISO 9845-1:1992, Table 1, column 5.

[b] Air mass 1,5.

[c] $E'_\lambda = E_\lambda \times 5$, except E'_λ at 300 nm and 400 nm.

[d] $E'_{\lambda(\text{n})} = E'_\lambda / \Sigma E_\lambda$.