

## Spectral Transmission Test

## RATIONALE

This document is being written to standardize calculations and communications involving spectral transmission data from safety-glazing materials for road vehicles. This revised document now conforms with the computational convention "A" in ISO 13837.

## 1. SCOPE

The scope of this SAE performance standard is to define the test method by which the direct solar and visible transmittance of safety glazing materials for road vehicles shall be measured. Adherence to this performance standard will facilitate writing, use and referencing of reports by government, industry and other organizations.

## 1.1 Purpose

The purpose of this performance standard is to determine the direct solar and visible and color transmittance of safety glazing materials for road vehicles.

## 1.2 Application

The performance standard applies to monolithic or laminated, clear or tinted samples of safety glazing materials. Essentially flat sections of glazing parts may be used in this test as well as flat samples of the same materials.

## 2. REFERENCES

## 2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

## 2.1.1 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, [www.ansi.org](http://www.ansi.org).

ISO 13837:2008	Road vehicles - Safety glazing materials - Method for the determination of solar transmittance
ISO 9845-1:1992(E)	Solar Energy - Reference solar spectral irradiance at the ground at different receiving conditions - Part 1: Direct normal and hemispherical solar irradiance for air mass 1.5 - Table 1 - Spectral solar irradiance (column 5)

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### 2.1.2 CIE Publications

Available from CIE Central Bureau, Kegelgasse 27, A-1030 Vienna, AUSTRIA

CIE Publication No. 85      Technical Report - Solar Spectral Irradiance

CIE Publication 15:2004      Colorimetry, 3rd ed.

### 2.1.3 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, [www.astm.org](http://www.astm.org)

ASTM E308 (96)      Standard Test Method for Computing the Colors of Objects by Using the CIE System

ASTM E380-93      Practice for the use of the International System of Units (SI) (the Modernized Metric System)

## 3. DEFINITIONS

### 3.1 STANDARDIZE

To adjust an instrument output to correspond to a previously established calibration using one or more homogeneous specimens or reference materials.

### 3.2 TRANSMITTANCE

The ratio of transmitted flux to incident flux, under specified geometric and spectral conditions.

### 3.3 AIR MASS

The 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.

### 3.4 SOLAR UV TRANSMITTANCE ( $T_{UV}$ )

The transmittance weighted, interval by interval, derived from modified ISO 9845-1, Table 1, column 5,  $E_{\lambda_i}$ . (with air mass = 1.5 *global*)<sup>1</sup> distribution from 300 through 400 nanometers (nm) at 5 nm intervals (Table 1).

### 3.5 SOLAR DIRECT TRANSMITTANCE ( $T_{DS}$ )

The transmittance weighted, interval by interval, derived from modified ISO 9845-1, Table 1, column 5,  $E_{\lambda_i}$  (with air mass = 1.5 *global*)<sup>2</sup> distribution from 300 through 2500 (nm) at 5, 10, 50 nm intervals (Table 2).

### 3.6 VISIBLE LUMINOUS TRANSMITTANCE ( $LT_A$ )

Illuminant A spectral power distribution (2856 K correlated color temperature) multiplied by the spectral luminous efficiency function for photopic vision ( $V(\lambda)$ ). The transmittance weighted, interval by interval, according to ASTM E308 (90), 7.1.1 and 7.2.1 (Abridged Calculation Procedure) and Table 5.1, column (y). This is nearly equivalent to CIE Publication No. 15:2004, (Table 1.1, A) times (Table 2.1,  $\bar{Y}(\lambda)$ ) distribution from 380 through 780 (nm) at 10 nm intervals.

NOTE:  $V(\lambda) = \bar{Y}(\lambda)$  (See Note 3, page 20 of CIE Publication 15:2004). See Section 4.2.3.4 below.

<sup>1</sup> The  $T_{UV}$  in modified ISO 9845-1 Table 1, column 5 is equivalent to the  $T_{UV}$  in ISO 13837, Table 1,  $E_{\lambda_i}$ .

<sup>2</sup> The  $T_{DS}$  in modified ISO 9845-1 Table 1, column 5 is equivalent to the  $T_{DS}$  in ISO 13837, Table 2,  $E_{\lambda_i}$ .

### 3.7 COLOR TRANSMITTANCE (X, Y, Z)

Illuminant  $D_{65}$  spectral power distribution (6500 K correlated color temperature) multiplied by the CIE 1964 supplementary standard colorimetric observer (see ASTM E308 (96)). The transmittance is weighted, interval by interval, according to ASTM E308 (96), Table 5.19. This is equivalent to CIE Publication No. 15:2004 (Table 1.1,  $D_{65}$ ) times (Table 2.2,  $\bar{x}_{10}(\lambda)$ ,  $\bar{y}_{10}(\lambda)$ ,  $\bar{z}_{10}(\lambda)$ ) distribution from 380 through 780 (nm) at 10 nm intervals. See Section 4.2.3.5 below.

## 4. TEST METHOD

### 4.1 Apparatus - Measuring Instrument

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, must be capable of measuring transmittance over that part of the electromagnetic spectrum in which the sun's energy is transmitted to the earth's surface. Required wavelength range: 300 - 2300 nm. Preferred wavelength range: 300 - 2500 nm.

### 4.2 Procedure

#### 4.2.1 Sample Preparation

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

#### 4.2.2 Measurement

Standardize the spectrophotometer according to the manufacturer's instructions. Place a clean sample normal to the measuring beam in the transmittance sample position. Note its film side and curvature orientation if applicable. Record the sample spectral data according to the instrument manufacturer's recommendation.

#### 4.2.3 Calculation

Compute direct solar transmittance by integration using the solar weight data in Tables 1 and 2.

4.2.3.1 Transmittance (T) for the solar range ( $\lambda_1$  to  $\lambda_n$ ) is determined by Equation 1 and Equation 2.

$$\%T_{UV}(400) = \sum_{300}^{400} \%T_{\lambda} \times E'_{\lambda}(n) \quad (\text{see Table 1 for } E'_{\lambda}(n)) \quad (\text{Eq. 1})$$

$$\%T_{DS}(1.5) = \sum_{300}^{2500} \%T_{\lambda} \times E'_{\lambda}(n) \quad (\text{see Table 2 for } E'_{\lambda}(n)) \quad (\text{Eq. 2})$$

where:

$E'_{\lambda}(n)$  is the normalized trapezoidal solar energy in wavelength interval ( $\Delta\lambda_n$ ).

$\%T_{UV}(400)$  is the ultraviolet transmittance to 400nm

$\%T_{DS}(1.5)$  is the visible and near-infrared transmittance for air mass 1.5

4.2.3.2 Measure transmittance at intervals of 5 nm from 300 to 400 nm, 10 nm from 400 to 800 nm, and 50 nm from 800 to 2500 nm. Transmittance must be measured to at least 2300 nm. If it is not possible to measure transmittance to 2500 nm, the last value must be multiplied by the remaining ( $E'_{\lambda} \times \Delta\lambda$ ) weight values.

4.2.3.3 This standard defines the determination of the direct solar transmittance of safety glazing materials.

4.2.3.4 Luminous transmittance ( $LT_A$ ) for the visible range (380 to 780 nm) is determined by the following function:

$$\%LT_A = \sum_{380}^{780} \%T_\lambda \times V(\lambda) \times E_\lambda(A) \times \Delta\lambda \quad (\text{Eq. 3})$$

NOTE: This is equivalent to summing the product of the "Y" column of Table 5.1 in ASTM E308 (96) by  $\%T_\lambda$  of the specimen.

4.2.3.5 Color transmittance for the visible range is determined by the following functions:

$$\%T_x = \sum_{380}^{780} \%T_\lambda \times X_{10}(\lambda) \times E_\lambda(D_{65}) \times \Delta\lambda$$

$$\%T_y = \sum_{380}^{780} \%T_\lambda \times Y_{10}(\lambda) \times E_\lambda(D_{65}) \times \Delta\lambda \quad (\text{Eqs. 4})$$

$$\%T_z = \sum_{380}^{780} \%T_\lambda \times Z_{10}(\lambda) \times E_\lambda(D_{65}) \times \Delta\lambda$$

NOTE: These equations are equivalent to summing the products of the "X," "Y," and "Z" columns of Table 5.19 in ASTM E308 (96) by  $\%T_\lambda$  of the specimen. See 3.7.

Calculated values from Equations 4, abbreviated to X, Y, Z are inserted into the following CIELAB ( $L^*$ ,  $a^*$ ,  $b^*$ ) equations:

$$\begin{aligned} L^* &= 116 \times \left( \frac{Y}{Y_n} \right)^{\frac{1}{3}} - 16 \\ a^* &= 500 \times \left[ \left( \frac{X}{X_n} \right)^{\frac{1}{3}} - \left( \frac{Y}{Y_n} \right)^{\frac{1}{3}} \right] \\ b^* &= 200 \times \left[ \left( \frac{Y}{Y_n} \right)^{\frac{1}{3}} - \left( \frac{Z}{Z_n} \right)^{\frac{1}{3}} \right] \end{aligned} \quad (\text{Eqs. 5})$$

where:

$$X_n = 94.811$$

$$Y_n = 100.000$$

$$Z_n = 107.304 \quad (X_n, Y_n, \text{ and } Z_n \text{ are taken from Table 5.19 of ASTM E308 (96)).$$

4.2.4 Expression of Results

Record thickness, type, construction, and curvature orientation, if applicable, of the specimen, the instrument used, and the specimen's direct solar and visible transmittance rounded to 0.1%. Report color transmittance rounded to 0.1%  $L^*$  and 0.01  $a^*$  and  $b^*$  in accordance with ASTM E380 (93) rounding convention.

TABLE 1 - SOLAR UV TRANSMITTANCE

$\lambda$ (nm)	$E'_\lambda(\eta)$
300	0.000000
305	0.001045
310	0.004634
315	0.011800
320	0.019807
325	0.027019
330	0.043271
335	0.042703
340	0.047644
345	0.048041
350	0.052948
355	0.054947
360	0.056946
365	0.064930
370	0.072925
375	0.075901
380	0.077991
385	0.075890
390	0.073777
395	0.092335
400	0.055446

$$\%T_{UV}(400) = \sum_{300}^{400} \%T_\lambda \times E'_\lambda(\eta)$$

Normalized relative spectral distribution of air mass 1.5 global solar radiation,  $E'_\lambda(\eta)$ , multiplied by the trapezoidal wavelength interval,  $\Delta\lambda$ . (Modified wavelength intervals in ISO 9845-1:1992(E), Table 1, column 5 and equivalent to ISO 13837, Table 1.)

TABLE 2 - SOLAR DIRECT TRANSMITTANCE

$\lambda$ (nm)	$E'\lambda(n)$	$\lambda$ (nm)	$E'\lambda(n)$	$\lambda$ (nm)	$E'\lambda(n)$
300	0.000000	410	0.011712	850	0.049016
305	0.000048	420	0.011973	900	0.039872
310	0.000214	430	0.010839	950	0.016652
315	0.000545	440	0.013166	1000	0.037501
320	0.000915	450	0.015431	1050	0.034127
325	0.001248	460	0.016175	1100	0.020859
330	0.001999	470	0.015988	1150	0.012512
335	0.001973	480	0.016466	1200	0.021415
340	0.002201	490	0.015565	1250	0.023934
345	0.002219	500	0.015661	1300	0.018651
350	0.002446	510	0.016043	1350	0.001642
355	0.002538	520	0.015016	1400	0.000136
360	0.002630	530	0.015900	1450	0.003746
365	0.002999	540	0.015681	1500	0.009548
370	0.003369	550	0.015790	1550	0.013934
375	0.003506	560	0.015539	1600	0.012093
380	0.003603	570	0.015184	1650	0.011636
385	0.003506	580	0.014646	1700	0.010440
390	0.003408	590	0.014112	1750	0.008111
395	0.004265	600	0.014568	1800	0.001553
400	0.007684	610	0.015020	1850	0.000231
		620	0.014760	1900	0.000000
		630	0.014502	1950	0.000682
		640	0.014525	2000	0.001878
		650	0.014547	2050	0.004040
		660	0.014333	2100	0.004507
		670	0.014079	2150	0.004134
		680	0.012749	2200	0.003604
		690	0.011426	2250	0.003583
		700	0.012375	2300	0.003468
		710	0.013315	2350	0.003242
		720	0.010313	2400	0.002251
		730	0.011094	2450	0.001070
		740	0.012248	2500	0.000433
		750	0.012119		
		760	0.009197		
		770	0.010675		
		780	0.011438		
		790	0.011201		
		800	0.032812		

$$\%T_{DS}(1.5) = \sum_{300}^{2500} \%T_{\lambda} \times E'_{\lambda}(n)$$

Normalized relative spectral distribution of air mass 1.5 global solar radiation,  $E'_{\lambda}(n)$ , multiplied by the trapezoidal wavelength interval,  $\Delta\lambda$ . (Modified wavelength intervals in ISO 9845-1:1992(E), Table 1, column 5 and equivalent to ISO 13837, Table 2.)