TECHNICAL
REPORT

ISO/TR 18486

First edition
2016-02-01

Plastics — Parameters comparing the spectral irradiance of a laboratory light source for weathering applications to a reference solar spectral irradiance

Plastiques — Paramètres de comparaison de la distribution spectrale d'une source de lumière de laboratoire pour les applications de vieillissement et d'une distribution spectrale solaire de référence

Reference number
ISO/TR 18486:2016(E)

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Foreword

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The committee responsible for this document is ISO/TC 61, *Plastics*, Subcommittee SC 6, *Ageing, chemical and environmental resistance*.

Introduction

Laboratory radiation sources generate radiation which is intended to simulate a defined „reference sun“ as perfect as possible, where the fitting to the spectral irradiance in the materials sensitive range is most important. So far, the fitting is described verbally only, e.g. standards concerning artificial weathering, and the user has to decide for himself if the spectral irradiance $E(\lambda)$ indicated by the producer of the laboratory radiation source agrees suitable enough with the „reference sun“ for his specific application or, occasionally, the classification describes the fitting to a wanted „reference sun“ only insufficiently (e.g. for standard weathering tests).

This Technical Report deals with a procedure for the determination of objective factors characterizing the grade of fitting in quantity.

One procedure describes the grade of fitting of a laboratory radiation source to the defined reference sun for specific spectral ranges. A second procedure results in characterizing parameters for the respective wavelength ranges, incorporating known action spectra.

Plastics — Parameters comparing the spectral irradiance of a laboratory light source for weathering applications to a reference solar spectral irradiance

1 Scope

This Technical Report specifies a calculation method which allows calculating a parameter which compares the spectral irradiance of a laboratory radiation source for weathering application to a reference solar spectral irradiance.

2 Terms and definitions

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

2.1

spectral irradiance

E_λ

radiant flux per unit area per wavelength interval

Note 1 to entry: It is measured in watts per square metre per nanometre ($\mathrm{W \cdot m^{-2} \cdot nm^{-1}}$).

2.2

action spectrum

description of the spectral efficiency of radiation to produce a particular polymer response (specific property change of a specific polymer) plotted as a function of the wavelength of the radiation

Note 1 to entry: Data of an action spectrum are specific to the polymer but independent from the radiation source, also named spectral sensitivity.

3 Symbols and abbreviated terms

$E(\lambda)_{ref.}$	spectral irradiance of reference sun ($\mathrm{W \cdot m^{-2} \cdot nm^{-1}}$)
$E(\lambda)_{source}$	spectral irradiance of laboratory radiation source ($\mathrm{W \cdot m^{-2} \cdot nm^{-1}}$)
$E(\lambda)_{scaled}$	scaled spectral irradiance of laboratory radiation source ($\mathrm{W \cdot m^{-2} \cdot nm^{-1}}$)
$s(\lambda)$	action spectrum

4 Significance

Not for all applications of simulated solar radiation (laboratory radiation source) the total sun spectrum is needed. For economic reasons, therefore, it is advisable to simulate only that spectral range being of importance for the respective process or in cases of application where the object's heating has to be observed in close limits, e.g. with biological objects. In this case, both VIS and IR radiation have to be eliminated to a great extent (see Table 1).

Table 1 — Compilation of laboratory radiation sources for different spectral ranges and examples for their applications

Solar simulators for	Examples for application
UV (A+B)	photochemistry, photo dermatology
UV-A	photo dermatology, testing of polymeric material
UV + VIS	testing of polymeric materials
UV + VIS + IR	testing of technical materials or components including thermal stress
VIS + IR	thermal stress of the object, in most cases without photochemistry

Due to the many technical types of laboratory radiation sources, no general characteristics for comparing the spectral irradiance to the reference solar radiation can be given. It is only possible to indicate the comparison for a given wavelength range or for a certain application whose action spectrum is known.

5 Requirements

Historically, CIE 85:1989, Table 4[9] has been used as the benchmark reference spectrum distribution for weathering applications. However, CIE 85[9], which was published in 1989, has several disadvantages: global solar spectral energy distribution starts at 305 nm, the increments are rather rough and the calculation code is no longer available. Therefore, reference spectral irradiance should be used which are calculated with the SMARTS2 model[10] (e.g. ISO/TR 17801, ASTM G177).

For the calculations, a spectral resolution of 1 nm is required.

NOTE CIE is currently revising CIE 85[9] to provide a reference spectrum in the necessary 1 nm resolution.

The spectral irradiance of the solar simulator $E(\lambda)_{source}$ or the scaled laboratory radiation source spectrum $E(\lambda)_{scaled}$ is required with a spectral resolution of 1 nm.

6 Calculation methods

6.1 Characterizing parameter for a wavelength range

6.1.1 Choice of the wavelength range

A wavelength range of $\lambda_1 \leq \lambda \leq \lambda_2$ for the characterizing fitting should be selected. The wavelength range should be larger than 10 nm.

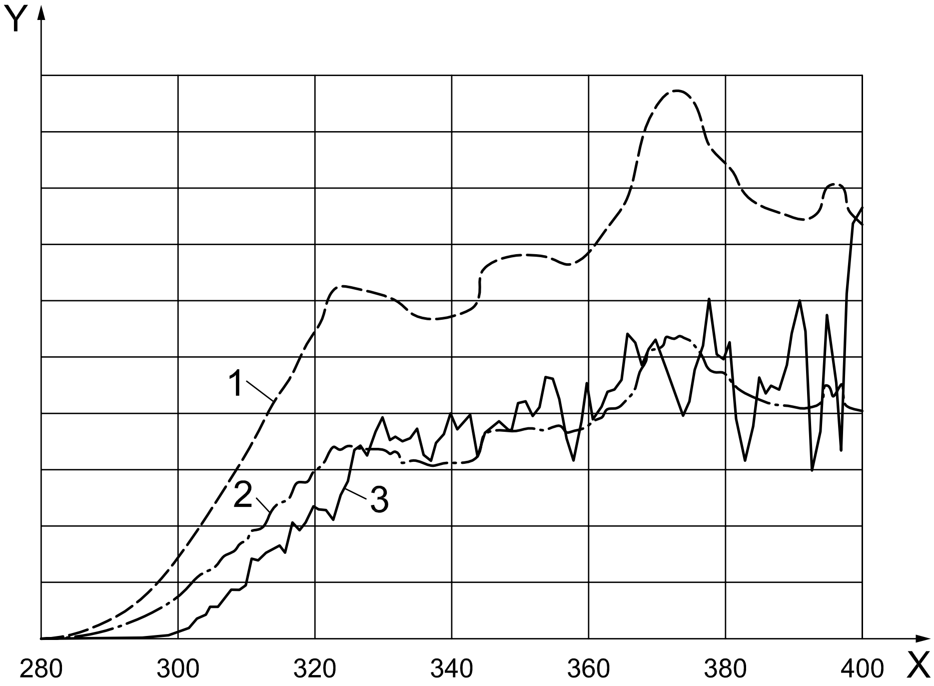
NOTE Table 1 shows examples of relevant wavelength ranges.

6.1.2 Scaling condition

The spectral irradiance of the laboratory radiation source $E(\lambda)_{source}$ is scaled according to the reference sun distribution $E(\lambda)_{ref.}$, in the chosen wavelength range (for example, see Figure 1).

Swap equation terms.

$$\int_{\lambda_1}^{\lambda_2} E\left(\lambda\right)_{ref.} d\lambda = \int_{\lambda_1}^{\lambda_2} E\left(\lambda\right)_{scaled} d\lambda \tag{1}$$



Key

1 reference sun $E(\lambda)_{ref.}$

2 laboratory radiation source $E(\lambda)_{source}$

3 scaled laboratory radiation source $E(\lambda)_{scaled}$ according to 6.1.2

X wavelength in nm

Y spectral irradiance (au)

Figure 1 — Example for scaling according to 6.1.2

6.1.3 Characterizing parameter $f_{\lambda 1-\lambda 2}$ for a wavelength range

The characterizing parameter $f_{\lambda 1-\lambda 2}$ for the wavelength range $\lambda_1 \le \lambda \le \lambda_2$ is calculated by Formula (2):

$$f_{\lambda_1-\lambda_2} = \frac{\int_{\lambda_1}^{\lambda_2} \left| E\left(\lambda\right)_{scaled} - E\left(\lambda\right)_{ref.} \right| \cdot d\lambda}{\int_{\lambda_1}^{\lambda_2} E\left(\lambda\right)_{ref.} \, d\lambda} \times 100 \qquad (2)$$

NOTE For an ideal fitting of $E(\lambda)$ to a reference sun, the parameter f reads $f = 0$. The higher the number, the worse is the fitting.

6.2 Characterizing parameter for a known action spectrum

6.2.1 Choice of the wavelength range with action spectrum

A wavelength range of $\lambda_1 \le \lambda \le \lambda_2$ for the characterizing fitting should be selected.

For the selected wavelength range, the action spectrum should be known in the spectral resolution of 1 nm.