Filter Radiometers for Weathering and Photo Stability Tests

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Introduction

polymer

stabilizer
absorber
pigments
coloring materials
converting additives
polymer plasticizer

material degradation
change of material characteristics

radiation (UV, Light, Heat)
O₂
H₂O
industrial gases

oxygen
water
Introduction

weather factors

polymeric material

boundary climate

molecular modification

macroscopic modification
Introduction

natural weathering

artificial weathering (xenon)

solar simulation device
With regard to the appearance of signs of aging, it is generally exposure to radiation which is seen as the primary cause of aging.

In these cases, sunlight must be reproduced as realistically as possible by the equipment.

The spectral distribution as well as the irradiance of sunlight on the earth’s surface are dependent on the location as well as on the time of day and the time of year.

The spectral distribution specified in CIE publication No. 85, Table 4, today serves as the reference spectrum for global radiation throughout the world.
Spectral energy distribution of solar radiation in accordance with CIE, No. 85, Table 4 and filtered Xenon radiation
Selektive Filter Radiometers

- In order to meet the stringent requirements of current test standards (e.g., ISO 4892 or ISO 11341) for weathering tests, high-quality UV radiometers must be employed to measure and regulate the UV irradiance (ISO 9370).
- The most frequently employed, wavelength-sensitive radiometers offer broad band measurement in the 300nm to 400nm wavelength range, and narrow band measurement with maximum sensitivity at 340nm to simulate daylight and daylight behind window glass.
- Radiometers whose narrow band measurements are spectrally most sensitive at midrange wavelengths around 420nm are employed exclusively for the simulation of daylight behind window glass.
Selektive Filter Radiometers

Typical relative spectral sensitivities of selective filter radiometers
Design and Characteristics

Filter radiometer (XenoCal) with its optical components

- Body for electronic and optical components
- Diffusor
- Quartz dome
- Quartz dome
- Diffusor
- Optical filter
Design and Characteristics

Fixture for measuring cosine response

focal distance

approximately parallel light

lamp

ten

sensor

optical fiber
Design and Characteristics

Illustration of the angle-dependent measurement signal of a XenoCal BB 300-400 sensor. A cosine-shaped decline of the measurement signal is considered to be ideal.
Design and Characteristics

Relative error in the cosine correction of the measurement from Figure before in accordance with DIN EN 13032-1
Design and Characteristics

Measurement signals from two temperature-compensated XenoCal sensors in a weathering device.

- **XenoCal NB 340**
- **XenoCal BB 300-400**

**Filter:** Xenochrome300

**Lamp Wattage Constant:** 1660VA

**Temperature Ramp:**
- 40°C
- 45°C
- 50°C
- 55°C
- 60°C

**Standard Deviation:** 0.73% and 0.66%

**Time (Minutes):**

**Normalized Irradiance:**

**Temperature x 100 (°C):**
Calibration of Selective Filter Radiometers

PTB
(Physikalisch Technische Bundesanstalt)

Set of standard lamps
- Mercury high pressure (wavelength)
- Deuterium (spectral sensitivity)
- Halogene (spectral sensitivity)

Standard lamp

Spectroradiometer (calibrated)

Photometer (calibrated)

Very stable Xenon Arc Lamp

Filter radiometer XenoCal

 Calibration hierarchy for XenoCal filter radiometers
Highly stable xenon lamp as an internal plant reference standard

- Xenon lampe as a Reference Standard
- Airconditioned room
- Stabilized power supply ~ 230V ± 0.1%
- Choking coil
- Xenon lamp with filter
- Constant flow rate for cooling

\[ T_{IN} \approx 20^\circ C \]
\[ T_{OUT} \approx 40^\circ C \]
Xenon Lampe as a Reference Standard

Illustration of the xenon reference lamp over 4.5 hours, measured with a XenoCal UV sensor

- Stability ATLAS calibration unit
- Xenon reference lamp

- Standard deviation 0.22%
- Fluctuation peak to peak app. 1.0%
Xenon Lampe as a Reference Standard

Spectral energy distribution from 250nm to 400nm at the ATLAS calibration stand (xenon reference standard)
Xenon Lampe as a Reference Standard

Long-term stability of the xenon reference standard over a 300-hour period at various wavelength ranges, standardized to the irradiance at 0 hours
Xenon Lampe as a Reference Standard

Standard deviations from the mean for the spectra from the period from October, to May

<table>
<thead>
<tr>
<th>Wavelength range</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>nm</td>
<td>(%)</td>
</tr>
<tr>
<td>300 - 400</td>
<td>0.71</td>
</tr>
<tr>
<td>340</td>
<td>1.12</td>
</tr>
<tr>
<td>420</td>
<td>1.34</td>
</tr>
<tr>
<td>300 - 800</td>
<td>0.32</td>
</tr>
</tbody>
</table>
Spectral energy distributions of filtered xenon radiation and window-glass filtration in comparison with the calibration source (Xenon reference standard). All spectra standardized to 50W/m². Standardized spectral sensitivity of a XenoCal BB 300-400 filter radiometer.
Spectral Correction Factor

\[ a = \frac{\int_{\lambda_0}^{\lambda_1} s_{Sensor}(\lambda) \cdot E_{e\lambda,cq} \cdot d\lambda}{\int_{\lambda_0}^{\lambda_1} E_{e\lambda,cq}(\lambda) \cdot d\lambda} \cdot\frac{\int_{\lambda_0}^{\lambda_1} E_{e\lambda,mq}(\lambda) \cdot d\lambda}{\int_{\lambda_0}^{\lambda_1} s_{Sensor}(\lambda) E_{e\lambda,mq}(\lambda) \cdot d\lambda} \]

- \( a \) - spectral correction factor (spectral mismatch)
- \( s_{Sensor}(\lambda) \) - spectral sensitivity of the sensor
- \( E_{e\lambda,cq}(\lambda) \) - spectral irradiance of the calibration source
- \( E_{e\lambda,mq}(\lambda) \) - spectral irradiance of the measurement source
Sources of Errors in UV Radiation Measurements

Measurement uncertainties in radiometry

<table>
<thead>
<tr>
<th>No.</th>
<th>Measurement uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Standard lamp</td>
</tr>
<tr>
<td>2.</td>
<td>Spectroradiometer</td>
</tr>
<tr>
<td>3.</td>
<td>Xenon reference standard</td>
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## Sources of Errors in UV Radiation Measurements

### Measurement uncertainties in radiometry

<table>
<thead>
<tr>
<th>No.</th>
<th>Measurement uncertainty</th>
<th>Type of error</th>
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<tbody>
<tr>
<td>1.</td>
<td>Standard lamp</td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Ambient conditions</td>
<td>Coincidental</td>
</tr>
<tr>
<td>1.2</td>
<td>Lamp current stability</td>
<td>Coincidental</td>
</tr>
<tr>
<td>1.3</td>
<td>Lamp current strength</td>
<td>Systemic/coincidental</td>
</tr>
<tr>
<td>1.4</td>
<td>Distance between the lamp and the spectral radiometer’s input optics</td>
<td>Coincidental</td>
</tr>
<tr>
<td>2.</td>
<td>Spectroradiometer</td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Ambient conditions</td>
<td>Coincidental</td>
</tr>
<tr>
<td>2.2</td>
<td>Input optics (cosine error)</td>
<td>Systemic</td>
</tr>
<tr>
<td>2.3</td>
<td>Stray and false radiation</td>
<td>Systemic</td>
</tr>
<tr>
<td>2.4</td>
<td>Measurement electronics</td>
<td>Systemic / coincidental</td>
</tr>
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Sources of Errors in UV Radiation Measurements

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<tr>
<td>3.1</td>
<td>Ambient conditions</td>
<td>Coincidental</td>
</tr>
<tr>
<td>3.2</td>
<td>Voltage fluctuations (lamp wattage)</td>
<td>Coincidental</td>
</tr>
<tr>
<td>3.3</td>
<td>Distance between the lamp and the UV radiometer’s input</td>
<td>Coincidental</td>
</tr>
<tr>
<td></td>
<td>optics</td>
<td></td>
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</table>
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Thank you !!