Optical Calibration Laboratory
Illuminant and observer conditions

Brief guideline

Background
Well defined settings of the UV content of the illumination used in colorimetric instruments are needed whenever the samples to be measured are or may be suspected to be fluorescent. Colorimetric measurements are based on a simple model of the human colour perception. The CIE model most often used takes two parameters for the viewing conditions: the illuminant and the size (expressed in degrees) of the viewed object. The latter is distinguished as different standard observers. Only a limited set of illuminants and only two standard observers are included in the CIE system.

Conditions used in the pulp and paper industry
Illuminants used in the paper industry are

- CIE illuminant C
- CIE standard illuminant D65
- CIE standard illuminant D50

If a colorimetric value is reported as having been calculated according to a certain illuminant, this does not automatically mean that the spectrum of the actual light source used in the measurement resembles the spectrum of the illuminant. In many cases, the spectrum of the light source used is unimportant (see section /glyph817 on fluorescent samples).

The two standard observers defined by CIE are

- CIE 1931 standard observer – the 2° observer
- CIE 1964 standard observer – the 10° observer

Each of the observers is defined by three colour matching functions used in the calculation of the CIE tristimulus values \(X,Y,Z\) and \(X_{10},Y_{10},Z_{10}\) respectively.

The pulp and paper industry uses the following combinations of illuminant and observer function

- \(C/2°\)
- \(D65/10°\)
- \(D50/2°\)

Relevant ISO standards
ISO 5631-1:2009 Paper and board – Determination of colour by diffuse reflectance – Part 1: Indoor daylight conditions (C/2 degrees)
ISO 5631-2:2008 Paper and board – Determination of colour by diffuse reflectance – Part 2: Outdoor daylight conditions (D65/10 degrees)
ISO 11475:2004 Paper and board – Determination of CIE whiteness, D65/10 degrees (outdoor daylight)
ISO 11476:2000 Paper and board – Determination of CIE-whiteness, C/2 degree (indoor illumination conditions)

**Brightness calculations**

The diffuse blue reflectance factor (ISO brightness) is calculated from radiance factor data according to a special set of weighting factors, Table 1. These weighting factors define a function with an effective wavelength of 457 nm and a width at half height of 44 nm, and the calculated brightness is usually designated $R_{457}$

$$R_{457} = \frac{\hat{a} R(l_i) \times F(l_i)}{\hat{a} F(l_i)}$$

(1)

**Table 1 – Weighting factors for the calculation of ISO brightness.**

<table>
<thead>
<tr>
<th>Wavelength $l_i$ nm</th>
<th>$F(l_i)$ for $Dl = 10$ nm, arbitrary units</th>
<th>$F(l_i)$ for $Dl = 20$ nm, arbitrary units</th>
</tr>
</thead>
<tbody>
<tr>
<td>380</td>
<td>0,0</td>
<td>0,0</td>
</tr>
<tr>
<td>390</td>
<td>0,0</td>
<td>0,0</td>
</tr>
<tr>
<td>400</td>
<td>1,0</td>
<td>1,0</td>
</tr>
<tr>
<td>410</td>
<td>6,7</td>
<td>6,7</td>
</tr>
<tr>
<td>420</td>
<td>18,2</td>
<td>18,2</td>
</tr>
<tr>
<td>430</td>
<td>34,5</td>
<td>34,5</td>
</tr>
<tr>
<td>440</td>
<td>57,6</td>
<td>57,6</td>
</tr>
<tr>
<td>450</td>
<td>82,5</td>
<td>82,5</td>
</tr>
<tr>
<td>460</td>
<td>100,0</td>
<td>100,0</td>
</tr>
<tr>
<td>470</td>
<td>88,7</td>
<td>88,7</td>
</tr>
<tr>
<td>480</td>
<td>53,1</td>
<td>53,1</td>
</tr>
<tr>
<td>490</td>
<td>20,3</td>
<td>20,3</td>
</tr>
<tr>
<td>500</td>
<td>5,6</td>
<td>5,6</td>
</tr>
<tr>
<td>510</td>
<td>0,3</td>
<td>0,3</td>
</tr>
<tr>
<td>520</td>
<td>0,0</td>
<td>0,0</td>
</tr>
</tbody>
</table>

**Brightness standards**


**UV conditions**

Modern spectrophotometers usually use one or more xenon flash lamps as light source. Two UV-absorption filters with cut-off wavelengths of 395 nm and 420 nm adjust the UV-content of the lamp. If either of the filters is inserted in the light beam before the light enters the integrating sphere we have the UV-excluded conditions.
• UVex(395)
• UVex(420)

In most instruments, the 395 nm filter can be partly inserted into the beam making it possible to adjust the UV content of the source. This filter is sometimes called the UV trim filter or the UV adjustment filter. Different positions of the UV trim filter gives the following UV conditions:

• UV(full) The filter is not in the beam. The UV content is the maximum UV content of the instrument and is not defined since it changes with the ageing of the lamp and the sphere.
• UV(D65) The UV content corresponds to the UV content of illuminant D65. Note however that the light source in the instrument is not spectrally identical to illuminant D65.
• UV(C) The UV content corresponds to the UV content of illuminant C. Note however that the light source in the instrument is not spectrally identical to illuminant C.

If both filters are used at the same time, the UV condition is strictly to be the product of the two, e.g. UV(C) × UVex(420), but this is usually considered to be UVex(420).

In the Konica Minolta CM-3630 instrument, the UV conditions are obtained by a combination of separate measurements at the UV(full), UVex(395) and UVex(420) conditions.

Non-fluorescent samples
In the measurement of non-fluorescent samples, the UV condition is not important except that UVex(420) is not acceptable. If the sample is sensitive to UV radiation, UVex(395) may be recommended. The following ISO standards for whiteness and brightness apply.

• ISO brightness (ISO 2470-1:2009) and D65 brightness (ISO 2470-2:2008). These normally give the same results when the sample is non-fluorescent.

Samples containing optical brighteners
When measurements are made on samples containing optical brightening agents (OBA) the UV condition must match the measured quantities according to the following table.

<table>
<thead>
<tr>
<th>Weighting function</th>
<th>UV(C)</th>
<th>UV(D65)</th>
<th>UVex(420)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D65/10°</td>
<td>Outdoor whiteness, $W_{D65/10}$, ISO 11475</td>
<td>Whiteness without fluorescence, $W_{D65/10, 0}$</td>
<td></td>
</tr>
<tr>
<td>C/2°</td>
<td>Indoor whiteness, $W_{C/2}$, ISO 11476</td>
<td>Whiteness without fluorescence, $W_{C/2, 0}$</td>
<td></td>
</tr>
</tbody>
</table>
### Weighting function

<table>
<thead>
<tr>
<th></th>
<th>UV(C)</th>
<th>UV(D65)</th>
<th>UVex(420)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F(l)</td>
<td>ISO brightness, $R_{457}$</td>
<td>D65 brightness, $R_{457,D65}$</td>
<td>Brightness without fluorescence, $R_{457,0}$</td>
</tr>
<tr>
<td></td>
<td>ISO 2470-1</td>
<td>ISO 2470-2</td>
<td></td>
</tr>
</tbody>
</table>

The fluorescent components of the quantities $W_{D65/10}$, $W_{C/2}$, $R_{457}$ and $R_{457,D65}$ are calculated as

\[
\begin{align*}
W_{D65/10,F} &= W_{D65/10} - W_{D65/10,0} \\
W_{C/2,F} &= W_{C/2} - W_{C/2,0} \\
R_{457,F} &= R_{457} - R_{457,0} \\
R_{457,D65,F} &= R_{457,D65} - R_{457,0}
\end{align*}
\]  

Note that there is no whiteness defined for D50/2°.

For more information, contact optics@innventia.com or www.innventia.com/optics