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Paper and board — Determination of CIE whiteness, D65/10° (outdoor daylight)

Papier et carton — Détermination du degré de blanc CIE, D65/10° (lumière du jour extérieure)

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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).

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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 6, *Paper, board and pulps*.

This third edition cancels and replaces the second edition (ISO 11475:2004), which has been technically revised. The major change is to allow for calculations to use ASTM E308 for instruments that have bandpass correction and still maintain the non-bandpass-correction procedure. This third edition also includes Precision Data.

Paper and board — Determination of CIE whiteness, D65/10° (outdoor daylight)

1 Scope

This document specifies the procedure to be used for determining the whiteness of papers and boards. The values obtained correspond to the visual appearance of white papers and boards with or without fluorescent whitening agents when they are viewed under the CIE D65 daylight standard illuminant. It is based on reflectance data obtained over the full visible spectral range (VIS) in contrast to the measurement of ISO brightness which is limited to the blue region of VIS.

In addition, it specifies a method for adjustment of the UV content to correspond to the CIE D65 daylight illuminant[10][11], insofar as results obtained when fluorescent whitening agents are present are dependent upon the UV content of the radiation falling upon the sample. It is specific for white fluorescent paper samples where the emission due to the fluorescent whitening agent (FWA) occurs in the blue region of the visible spectrum.

This method is not applicable to coloured papers containing fluorescent dyes.

This document should be read in conjunction with ISO 2469.

NOTE 1 This document is based on the CIE whiteness formula, published in CIE 15.3-2004[9].

NOTE 2 A related International Standard, ISO 11476, specifying the procedure for obtaining values corresponding to the appearance of these products under indoor illumination, has also been published.

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 186, *Paper and board — Sampling to determine average quality*

ISO 2469:2014, *Paper, board and pulps — Measurement of diffuse radiance factor (diffuse reflectance factor)*

ISO 4094, *Paper, board and pulps — International calibration of testing apparatus — Nomination and acceptance of standardizing and authorized laboratories*

3 Terms and definitions

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

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

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

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

NOTE The symbols used here are selected to maintain consistency, wherever possible, with Reference [8].

3.1
reflectance factor
R
ratio of the radiation reflected by a body to that reflected by the perfect reflecting diffuser under the same conditions

Note 1 to entry: The ratio is expressed as a percentage.

3.2
intrinsic reflectance factor
R_∞
reflectance factor (3.1) of a layer or pad of the material thick enough to be opaque, i.e. such that increasing the thickness of the pad by doubling the number of sheets results in no change in the measured reflectance factor

3.3
diffuse radiance factor
β
ratio of the diffusely reflected radiance of a body in a given direction to that of the perfect reflecting diffuser under specified conditions of irradiation

Note 1 to entry: For fluorescent (luminescent) materials, the specified conditions of irradiation in this document are for CIE Standard Illuminant D65 and the diffuse radiance factor is strictly the total radiance factor, β, which contains two components, the reflected radiance factor, β_R, and the luminescent radiance factor, β_L, so that

$$\beta = \beta_R + \beta_L$$

Note 2 to entry: For non-fluorescent materials, the diffuse radiance factor, β, is simply the *reflectance factor*, R (3.1).

3.4
intrinsic diffuse radiance factor
β_∞

diffuse radiance factor (3.3) of a layer or pad of the material thick enough to be opaque, i.e. such that increasing the thickness of the pad by doubling the number of sheets results in no change in the measured diffuse radiance factor

Note 1 to entry: For fluorescent (luminescent) materials, the intrinsic diffuse radiance factor is, strictly speaking, the total intrinsic radiance factor, β_∞, which contains two components: the intrinsic reflected radiance factor, $\beta_{\infty,R}$, and the intrinsic luminescent radiance factor, $\beta_{\infty,L}$, so that

$$\beta_\infty = \beta_{\infty,R} + \beta_{\infty,L}$$

Note 2 to entry: For non-fluorescent materials, the intrinsic diffuse radiance factor, β_R, is simply the intrinsic *reflectance factor*, R_∞ (3.2).

3.5
CIE whiteness value
W_{10}
measure of whiteness derived from the CIE tristimulus values

Note 1 to entry: CIE whiteness is dimensionless and is expressed as whiteness units.

3.6
green tint value
red tint value
T_{W10}
measure of the deviation from whiteness of the test material towards the green or red region

Note 1 to entry: The tint value is dimensionless and is expressed as tint units.

Note 2 to entry: A positive value of T_{W10} indicates a greenish tint and a negative value indicates a reddish tint.

3.7
fluorescence component
F_{10}
measure of the extent to which the whiteness of the material is affected by excitation of the added fluorescent whitening agent (FWA)

Note 1 to entry: The suffix 10 in the terms given in 3.5 to 3.7 is used to indicate that the value refers to the CIE 1964 (10°) observer.

4 Principle

The diffuse radiance factor of the material is determined under standardized conditions after the instrument has been adjusted so that a reference standard has the same CIE whiteness value as it would have under CIE standard illuminant D65, and the CIE whiteness value and the tint value are calculated. The fluorescence component of the whiteness is calculated from the difference between this whiteness value and the whiteness value obtained when the fluorescence emission from the material is eliminated, for instance, by the introduction of a sharp cut-off UV-absorbing filter into the light beams.

5 Apparatus and equipment

5.1 Reflectometer or spectrophotometer, having the geometric, spectral and photometric characteristics described in ISO 2469:2014, Annex A, calibrated in accordance with the provisions of ISO 2469:2014, Annex B, and equipped with a light source having an adequate UV content and a means of adjusting the relative UV content so that the measured CIE whiteness value agrees with that corresponding to the CIE standard illuminant D65.

For the measurement of reflectance factors with the fluorescence effect eliminated, the instrument shall be equipped with a sharp cut-off, UV-absorbing filter having a transmittance not exceeding 5,0 % at and below a wavelength of 410 nm and not exceeding 50 % at a wavelength of 420 nm. The cut-off filter shall have characteristics such that a reliable reflectance value is obtained at 420 nm. The reflectance value obtained at 420 nm shall then be considered for computational purposes to be the value which applies at all lower wavelengths at which it is not possible to make any measurement.

For the measurement of fluorescent papers, photometric linearity up to a scale reading of at least 200 % is necessary in the wavelength region corresponding to the fluorescent emission.

5.1.1 In the case of a filter reflectometer, pairs of filters giving the photoelectric detectors of the reflectometer responses equivalent to the CIE tristimulus values X_{10}, Y_{10}, Z_{10} of the test piece, evaluated for the CIE standard illuminant D65 and CIE 1964 (10°) observer[4].

5.1.2 In the case of an abridged spectrophotometer, a means of calculating the weighted means according to the requirements of the CIE standard illuminant D65 and CIE 1964 (10°) observer using the weighting functions given in Annex A and Reference [7], where Table A.1 and Table A.2 are used for instruments without bandpass correction and Table A.3 and Table A.4 are used for instruments with bandpass correction.

5.2 Working standards.

5.2.1 Two plates of flat opal glass or ceramic material, cleaned as described in ISO 2469.

5.2.2 A stable plastic or other tablet incorporating a fluorescent whitening agent.

5.3 Reference standards for calibration of the instrument and working standards.

5.3.1 Non-fluorescent reference standard for calibration, fulfilling the requirements for international reference standards of level 3 (IR3) as prescribed in ISO 2469.

5.3.2 Fluorescent reference standard for use in adjusting the UV content of the radiation incident upon the sample, having whiteness values and other relevant data as specified in Annex B and fulfilling the requirements for international reference standards of level 3 (IR3) as prescribed in ISO 2469.

Use new reference standards sufficiently frequently to ensure satisfactory calibration and UV adjustment.

5.4 Black cavity, having a reflectance factor which does not differ from its nominal value by more than 0,2 % at all wavelengths. The black cavity shall be stored upside down in a dust-free environment or with a protective cover.

The condition of the black cavity should be checked by reference to the instrument maker.

6 Calibration

6.1 Using the values assigned to the non-fluorescent reference standard (5.3.1), calibrate the instrument with the UV cut-off filters removed from the radiation beams. The setting of the UV adjustment filter is not important at this stage.

6.2 Using the appropriate measurement procedure, measure the diffuse radiance factors of the fluorescent reference standard (5.3.2), calculate the whiteness value (see 10.1) and compare the value obtained with that assigned to the fluorescent reference standard.

A measured whiteness value higher than the assigned value indicates that the relative UV content is too high and vice versa.

6.3 Using the UV adjustment filter or other adjustment device, adjust the UV content of the illumination until measurement gives the correct whiteness value.

NOTE If the UV content is too low, it may be necessary to replace the UV adjustment filter with a filter which raises rather than lowers the relative UV content.

6.4 Repeat the calibration as described in 6.1 using the non-fluorescent reference standard (5.3.1) with the UV adjustment filter in the position which gave the correct whiteness value. Repeat the measurement of the whiteness of the fluorescent reference standard (5.3.2) as described in 6.2. If the whiteness value obtained does not agree with the assigned value, adjust the position of the UV adjustment filter until measurement gives the correct whiteness value as described in 6.3.

6.5 Repeat 6.4 until the correct value for the whiteness of the fluorescent reference standard is obtained with the instrument correctly calibrated to the non-fluorescent reference standard. The relative UV content is now correctly adjusted with respect to whiteness so that the setting gives the CIE whiteness value equivalent to the CIE standard illuminant D65 and CIE 1964 (10°) observer. Record the setting of the UV adjustment.

NOTE 1 Variations in the green/red tint value can still arise and it cannot be assumed that the tristimulus values and other parameters will also be exactly applicable to the D65 illuminant.

NOTE 2 In some instruments, the procedure indicated in 6.2 to 6.5 is performed automatically.

6.6 Calibrate the fluorescent working standard (5.2.2) as the working standard.

This working standard shall only be used in the specific instrument in which it is calibrated and shall only be used to monitor changes in the lamps. It shall be recalibrated against a fluorescent reference standard of level 3 (5.3.2) if the lamps are changed.

6.7 Calibrate the opal glass or ceramic plates (5.2.1) as working standards as described in ISO 2469.

6.8 After adjustment of the UV content as in 6.1 to 6.5, insert the UV cut-off filter and calibrate the instrument in this position with the UV adjustment unchanged.

7 Sampling

Sampling is not included in this document. If the mean quality of a lot is to be determined, sampling shall be according to ISO 186. Otherwise, the method of sampling should be reported and care should be taken to ensure that the test pieces are representative of the sample available.

8 Preparation of test pieces

Avoiding watermarks, dirt and obvious defects, cut rectangular test pieces approximately 75 mm × 150 mm. Assemble at least 10 of the test pieces in a pad with their top sides uppermost; the number should be such that doubling the number of test pieces does not alter the reflectance factor. Protect the pad by placing an additional sheet on both top and bottom of the pad. Avoid contamination and unnecessary exposure to light or heat.

Mark the top test piece in one corner to identify the sample and its top side.

If the top side can be distinguished from the wire side, it shall be uppermost. If the distinction is not possible, as may be the case for papers manufactured on double-wire machines or those coated on both sides, ensure that the same side of the test piece is uppermost so that the CIE whiteness can be determined separately for each side of the paper or board.

Pulp sheets prepared in accordance with ISO 3688 may be measured in the same way, but whiteness is not normally considered to be a pulp property.

9 Procedure

9.1 Remove the UV cut-off filter from the light beam. Operate the reflectometer or spectrophotometer as described in ISO 2469.

9.2 Remove the protecting sheets from the pad of test pieces and measure the intrinsic diffuse radiance factors of the top test piece.

9.3 Move the measured test piece to the bottom of the pad. Repeat 9.2 until at least 10 measurements have been made. Repeat on the reverse side of the paper or board.

9.4 If an assessment of the fluorescence component is required, place the UV cut-off filter in the light beam. Operate the reflectometer or spectrophotometer as described in ISO 2469, and measure the intrinsic diffuse radiance factor of the top test piece without UV excitation, i.e. the intrinsic reflected radiance factor only.

9.5 Move the measured test piece to the bottom of the pad. Repeat 9.4 until at least 10 measurements have been made. Repeat on the reverse side of the paper or board.

NOTE Normally, the CIE whiteness and tint values will be automatically calculated (see 10.1) for each test piece at the time of measurement. In some instruments, it will be more convenient to measure the whiteness with and without fluorescence excitation on each test piece before proceeding to the next of the 10 pieces.

10 Calculation and expression of results

10.1 Calculate the whiteness, W_{10}, and tint, T_{W10}, values for each test piece, for the two sides separately, according to Formula (1) and Formula (2)[9]:

$$W_{10} = Y_{10} + 800\left(x_{n,10} - x_{10}\right) + 1\,700\left(y_{n,10} - y_{10}\right) \tag{1}$$

$$T_{W,10} = 900\left(x_{n,10} - x_{10}\right) - 650\left(y_{n,10} - y_{10}\right) \tag{2}$$

where

x_{10} and y_{10} are the chromaticity coordinates of the test piece, calculated as:

$$x_{10} = \frac{X_{10}}{X_{10} + Y_{10} + Z_{10}}$$

$$y_{10} = \frac{Y_{10}}{X_{10} + Y_{10} + Z_{10}}$$

X_{10}, Y_{10} and Z_{10} are the tristimulus values of the test piece for D65/10° conditions;

$x_{n.10}$ and $y_{n.10}$ are the chromaticity coordinates of the perfect reflecting diffuser for the illumination and observer specified ($x_{n.10}$ = 0,313 81 and $y_{n.10}$ = 0,330 98 for D65/10°).

10.2 For a sample to be considered white, the following limiting values for both whiteness and tint [Formula (3) and Formula (4)] shall be met[9]:

$$40 < W_{10} < \left(5Y_{10} - 280\right) \tag{3}$$

$$-4 < T_{w,10} < 2 \tag{4}$$

10.3 Where relevant, calculate the CIE whiteness without fluorescence excitation, $W_{0,10}$, i.e. with the UV cut-off filter in the light beam or other means used to eliminate the UV content of the illumination (5.1). Calculate the fluorescence component, F_{10}, of the CIE whiteness D65/10° as the difference between the two CIE whiteness values measured with and without fluorescence excitation, as given in Formula (5):

$$F_{10} = W_{10} - W_{0,10} \tag{5}$$

where

W_{10} is the CIE whiteness determined when the illumination has the desired UV content corresponding to the D65/10° illuminant;

$W_{0,10}$ is the CIE whiteness determined when the radiation which excites fluorescence has been eliminated.

NOTE A cut-off filter which eliminates only the UV component below 400 nm does not eliminate all the fluorescence effect.

10.4 Calculate the mean values and report the mean CIE whiteness (D65/10°) separately for both sides to the nearest integer, and the tint value to one decimal. If either W_{10} or T_{W10} falls outside the limits given in 10.2, report that the sample is "not white according to CIE". If $W_{0,10}$ falls outside the limits given in 10.2, it is not necessary to report this fact. Report the fluorescence component as the CIE whiteness difference to the nearest integer.

11 Precision

Round robin testing of paper samples of different whiteness values have shown a between-laboratory standard deviation of the order of ±1,1 to 1,4 CIE whiteness unit. See Annex C for further details.

12 Test report

The test report shall include the following information:

a) the date and place of testing;

b) the precise identification of the sample;

c) a reference to this document, i.e. ISO 11475;

d) the CIE whiteness value, the tint value and, if required, the fluorescence component of the whiteness for the two sides separately;

e) the type of apparatus used;

f) the type of instrument source used;

g) any departure from this document or any other circumstances that may have affected the results.