INTERNATIONAL STANDARD

ISO 11476

Third edition
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Paper and board — Determination of CIE whiteness, C/2° (indoor illumination conditions)

Papier et carton — Détermination du degré de blanc CIE C/2° (éclairage intérieur)

Reference number
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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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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 6, *Paper, board and pulps*.

This third edition cancels and replaces the second edition (ISO 11476:2010), which has been technically revised. The major change is to allow for calculations using ASTM E308 for instruments that have bandpass correction and still maintain the non-bandpass-correction procedure.

It is based on the CIE whiteness formula, published in CIE Publication 15:2004, *Colorimetry*.

Paper and board — Determination of CIE whiteness, C/2° (indoor illumination conditions)

1 Scope

This International Standard specifies the procedure to be used for determining the CIE whiteness of papers and boards, in order to obtain values which correspond to the visual appearance of white papers and boards, with or without fluorescent whitening agents, when they are viewed indoors. It is based on radiance factor 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. This International Standard also specifies the procedures for the determination of CIE tint values and the fluorescent component of CIE whiteness.

In addition, it specifies a method for adjustment of the UV-content to correspond to that of CIE illuminant C,[10][12] since the results obtained when fluorescent whitening agents are present are dependent upon the UV-content of the radiation falling upon the sample. The CIE illuminant C is taken to be representative of indoor illumination conditions because it contains a suitable proportion of UV radiation.[7] This method is not applicable to coloured papers containing fluorescent dyes. It is specific to the situation where the fluorescence occurs in the blue region of the visible spectral range.

This International Standard is read in conjunction with ISO 2469.

NOTE 1 It is recognized that the CIE whiteness formula was developed in the context of the CIE standard illuminant D65,[5] but the similarity between the relative spectral power curves for the C and D65 illuminants within the visible region and the closeness of their correlated colour temperatures (6 770 K and 6 500 K respectively) are taken as a justification for the use of the analogous whiteness formula with the CIE illuminant C.

NOTE 2 A related International Standard, ISO 11475, specifies the procedure for obtaining values corresponding to the appearance of papers viewed under the CIE standard illuminant D65.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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, *Paper, board and pulps — Measurement of diffuse radiance factor (diffuse reflectance factor)*

ISO 2470-1, *Paper, board and pulps — Measurement of diffuse blue reflectance factor — Part 1: Indoor daylight conditions (ISO brightness)*

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.

NOTE The symbols used here are selected to maintain consistency, wherever possible, with the CIE International Lighting Vocabulary ILV. While the definitions used here are based upon the CIE ILV, they have been adapted for this International Standard.

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 reflectance factor is usually 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 International Standard are for CIE Illuminant C 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 radiance factor

Note 1 to entry: For fluorescent (luminescent) materials, the intrinsic total radiance factor, β_∞, is the sum of two portions, 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_∞, is simply the *intrinsic reflectance factor,* R_∞ (3.2).

3.5
CIE whiteness
W
measure of CIE whiteness derived from the CIE tristimulus values determined under the conditions specified in this International Standard

Note 1 to entry: The CIE whiteness is expressed in CIE whiteness units.

3.6
green tint
red tint
T_W
measure of the deviation from *CIE whiteness* (3.5) of the test material towards the green or red region under the conditions specified in this International Standard

Note 1 to entry: The deviation is expressed as CIE tint units.

Note 2 to entry: A positive value of T_W indicates a greenish tint and a negative value indicates a reddish tint.

3.7
fluorescence component
F
measure of the extent to which the *CIE whiteness* (3.5) of the material is affected by excitation of the added fluorescent whitening agent (FWA) under the conditions specified in this International Standard

Note 1 to entry: The absence of a suffix in the terms given in 3.5 to 3.7 is used to indicate that the value refers to the CIE 1931 (2°) observer.

4 Principle

The diffuse radiance factor of the material is determined under standardized conditions after adjustment of the instrument so that the relative UV-content of the illumination corresponds to that of the CIE illuminant C, and the CIE whiteness and tint are calculated. The fluorescence component of the CIE whiteness is calculated from the difference between the diffuse radiance factor value and the value obtained when the fluorescence emission from the material is eliminated, for instance, by the introduction into the light beams of a sharp cut-off UV-absorbing filter.

5 Apparatus and equipment

5.1 Reflectometer or **spectrophotometer**, having the geometric, spectral and photometric characteristics described in ISO 2469, calibrated in accordance with the provisions of ISO 2470-1 and equipped with a radiation source having an adequate UV-content and a means of adjusting the relative UV-content so that the measured ISO brightness value agrees with the ISO brightness value assigned to a fluorescent reference standard (5.2.2) and corresponding to the CIE illuminant C. [8][11][12] If a filter (the UV-adjustment filter) is used to make this adjustment, it shall have a cut-off value of 395 nm so that it absorbs UV radiation, but does not, at the same time, alter the visible spectrum within the sphere.

NOTE In order to achieve concordance between the conditions for measuring both ISO brightness and CIE whiteness (C/2°), an adjustment based on a fluorescent reference standard (5.2.2) having an assigned ISO brightness value is preferred.

For the measurement of reflectance factors with the fluorescence effect eliminated, the instrument shall be equipped with a sharp cut-off, UV-absorbing filter (the UV-cut-off 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 repeatable reflectance factor value is obtained at 420 nm. The reflectance factor 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, Y, Z of the test piece,[9] evaluated for the CIE illuminant C[10] and CIE 1931 (2°).[4]

5.1.2 In the case of an **abridged spectrophotometer**, a means of calculating the weighted means in accordance with the requirements of the CIE illuminant C and CIE 1931 (2°) observer using the weighting functions given in Annex A and Reference [6], where the Tables A.1 and A.2 are used for instruments without bandpass correction and Tables A.3 and A.4 are used for instruments with bandpass correction.

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

5.2.1 Non-fluorescent reference standard for calibration, fulfilling the requirements for international reference standards of level 3, as specified in ISO 2470-1.

5.2.2 Fluorescent reference standard for use in adjusting the UV-content of the radiation incident upon the sample, having an assigned ISO brightness value, as specified in Annex B, and fulfilling the requirements for international reference standards of level 3, as specified in ISO 2470-1.

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

5.3 Working standards.

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

5.3.2 Stable plastic or other tablet, incorporating a fluorescent whitening agent.

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 should 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 (5.2.1), 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 reflectance of the fluorescent reference standard (5.2.2), determine the ISO brightness value as specified in ISO 2470-1 and compare the value obtained with that assigned to the fluorescent reference standard.

A measured ISO brightness value higher than the assigned value indicates that the relative UV-content of the illumination is too high and a lower value indicates that the relative UV-content is too low.

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

6.4 Repeat the calibration as described in 6.1 using the non-fluorescent standard (5.2.1) with the UV-adjustment in the position which gave the correct ISO brightness value for the fluorescent reference standard. Repeat the measurement of the brightness of the fluorescent standard (5.2.2) as described in 6.2. If the ISO brightness value obtained does not agree with the assigned value, adjust the position of the UV-adjustment filter or other adjustment device until the measurement gives the correct ISO brightness value as described in 6.3.

6.5 Repeat the procedure described in 6.4 until the correct value for the ISO brightness of the fluorescent standard (5.2.2) is obtained with the instrument correctly calibrated to the non-fluorescent

standard (5.2.1). The UV-content is now correctly adjusted with respect to brightness to a relative UV-content equivalent to the CIE illuminant C. Record the setting of the UV-adjustment.

NOTE 1 This setting means that the illumination in the instrument corresponds to the CIE illuminant C for ISO brightness measurement and it will give acceptable agreement for CIE whiteness (C/2°). Variations in the green/red tint value might still arise and it cannot be assumed that the tristimulus values and other parameters will also be exactly those applicable to the illuminant C.

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

6.6 Calibrate the fluorescent tablet (5.3.2) as a working standard by measuring it and assigning an ISO brightness value.

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 and sphere conditions. It shall be recalibrated against a fluorescent reference standard of level 3 (5.2.2) if the lamps are changed.

6.7 Calibrate the opal glass or ceramic plates (5.3.1) as working standards, as specified in ISO 2469.

6.8 After adjustment of the UV-content as described in 6.1 to 6.5, insert the UV-cut-off filter and calibrate the instrument in this position, using the non-fluorescent standard (5.2.1), with the UV-adjustment unchanged.

7 Sampling and conditioning

Sampling is not included in this International Standard. If the mean quality of a lot is to be determined, sampling shall be in accordance with ISO 186. If the tests are made on another type of sample, make sure that the test pieces taken are representative of the sample received.

Conditioning as described in ISO 187 is recommended, but not required, but preconditioning with elevated temperatures should not be applied since it might change the optical properties.

8 Preparation of test pieces

Avoiding watermarks, dirt and obvious defects, cut rectangular test pieces of 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 radiance factor. Protect the pad by placing an additional sheet on both the 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 twin-wire machines or those coated on both sides, ensure that the same side of each test piece is uppermost so that the CIE whiteness can be determined separately for each side of the paper or board.

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

9 Procedure

9.1 Remove the UV-cut-off filter or other means of eliminating the UV-content from the light beam. Operate the reflectometer or spectrophotometer as described in ISO 2469 and ISO 2470-1.

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

9.3 Move the measured test piece to the bottom of the pad. Repeat 9.2 until 10 test pieces have been measured. 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 or use other means of eliminating the UV-content of the illumination. Operating the reflectometer or spectrophotometer as specified in ISO 2469, measure the intrinsic diffuse radiance factors, β_∞, of the top test piece without fluorescence excitation, i.e. the intrinsic reflected radiance factors.

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

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

10 Calculation and expression of results

10.1 Calculate the CIE whiteness, W, and tint, T_w, values for each test piece according to the following formulae:

$$W = Y + 800\left(x_n - x\right) + 1\,700\left(y_n - y\right) \tag{1}$$

$$T_w = 1\,000\left(x_n - x\right) - 650\left(y_n - y\right) \tag{2}$$

where

x_n and y_n are the chromaticity coordinates of the perfect reflecting diffuser for the illuminant and observer specified ($x_n = 0{,}310\,06$, $y_n = 0{,}316\,16$ for C/2°);

x and y are the chromaticity coordinates of the test piece, calculated as

$$x = \frac{X}{X + Y + Z}$$

$$y = \frac{Y}{X + Y + Z}$$

where X, Y and Z are the tristimulus values of the test piece for C/2° conditions.

10.2 The limiting values for a sample to be considered white are given by:

$$40 < W < \left(5Y - 280\right) \tag{3}$$

$$-4 < T_w < 2 \tag{4}$$

NOTE As stated in the scope, it is recognized that the CIE whiteness formula was originally developed for the D65 illuminant, but it is assumed here that the use of the formula and its limits can be justified because of the similarity of the spectral power distributions of the C and D65 illuminants in the visible region.

10.3 Where relevant, calculate the CIE whiteness without fluorescence excitation, W_0, 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, of the CIE whiteness (C/2°) as the difference between the two CIE whiteness values measured with and without fluorescence excitation.

$$F = W - W_0 \tag{5}$$

where

W is the CIE whiteness determined when the illumination has the desired UV-content corresponding to the C illuminant;

W_0 is the CIE whiteness determined when the radiation which excites fluorescence has been eliminated.

NOTE A UV-cut-off filter with the characteristics defined in 5.1, with a 50 % transmittance at 420 nm and not exceeding 5 % at wavelengths below 410 nm, does not eliminate all the fluorescence effect.

10.4 Calculate the mean values and report the mean CIE whiteness (C/2°) separately for both sides to the nearest integer, and the tint value to one decimal. If either W or T_w falls outside the limits given in 10.2, report that the sample is "not white according to CIE". If W_0 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

Preliminary tests have shown a between-laboratory standard deviation of the order of ±1 CIE whiteness unit.

12 Test report

The test report shall include the following information:

a) a reference to this International Standard, i.e. ISO 11476:2016;

b) the date and place of testing;

c) the precise identification of the sample;

d) whether the test pieces were conditioned and, if so, the conditioning atmosphere used;

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

f) the type of apparatus used;

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