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Committee identification: ISO/TC 6/WG 3

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Paper and board — Determination of colour by diffuse reflectance — Part 2: Outdoor daylight conditions (D65/10°)

Papier et carton — Détermination de la couleur par réflectance diffuse — Partie 2: Conditions de lumière du jour extérieure (D65/10°)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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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 www.iso.org/directives).

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

This fourth edition cancels and replaces the third edition (ISO 5631-2:2015). A minor revision has been carried out to update the Normative and Bibliographic CIE, ISO and joint ISO/CIE references to current versions, of which it constitutes a minor revision. The changes are as follows:

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ISO 5631 consists of the following parts, under the general title *Paper and board - Determination of colour by diffuse reflectance*:

— Part 1: Indoor daylight conditions (C/2°)

— Part 2: Outdoor daylight conditions (D65/10°)

— Part 3: Indoor illumination conditions (D50/2°)

— update of the CIE and joint ISO/CIE Normative and Bibliographic references to current versions.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The colour of an object can be uniquely characterized by means of a triplet of colour coordinates such as the CIE X, Y, Z tristimulus values or the CIELAB 1976 L^*, a^*, b^* coordinates, for a specified CIE illuminant and CIE standard observer.

Apart from the optical properties of the sample, the values of such coordinates depend upon the conditions of measurement, particularly the spectral and geometric characteristics of the instrument used. This ~~part of ISO 5631 document~~ should therefore be read in conjunction with ISO 2469.

This ~~part of ISO 5631 document~~ describes the measurement and description of colour in terms of the CIE standard illuminant D65 and the CIE 1964 (10°) standard observer. The analogous measurement and description of colour in terms of the CIE illuminant C and the CIE 1931 (2°) standard observer are described in ISO 5631-1.

ISO 5631-3 describes the measurement and description of colour in terms of the CIE illuminant D50 and the CIE 1931 (2°) standard observer. This method is especially applicable to comparison of papers in graphic arts situations where the customer wishes to make measurements under these illuminant/observer conditions required by ISO 13655. The choice of illuminant conditions is important when determining the colour coordinates of white papers containing a fluorescent whitening agent. In ISO 5631-1, the UV content of the illumination is lower than those specified in this ~~part of ISO 5631 document~~, approximating UV levels encountered in indoor rather than outdoor viewing conditions.

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Paper and board — Determination of colour by diffuse reflectance — Part 2: Outdoor daylight conditions (D65/10°)

1 Scope

This ~~part of ISO 5631 document~~ specifies a method for measuring the colour of paper and board by the diffuse reflectance method with the elimination of specular gloss.

It can be used to determine the colour of papers or boards that contain fluorescent whitening agents, provided the UV content of the illumination on the test piece has been previously adjusted to give the calibrated colorimetric value corresponding to CIE standard illuminant D65, using a fluorescent reference standard with an assigned CIE whiteness (D65/10°) value provided by an authorized laboratory, as described in ISO 11475.

This ~~part of ISO 5631 document~~ is not applicable to coloured papers or boards that incorporate fluorescent dyes or pigments.

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 11475:2017, *Paper and board* — Determination of CIE whiteness, D65/10° degrees (outdoor daylight)

ASTM E308, *Standard Practice for Computing the Colors of Objects by Using the CIE System*

CIE Publication 015:2018, *Colorimetry*, 4th ed.

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3 Terms and definitions

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

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

— ISO Online browsing platform: available at <https://www.iso.org/obp>

— IEC Electropedia: available at <https://www.electropedia.org/>

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3.1

radiance factor

β

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ratio of the radiance of a surface element of a body in the direction delimited by a given cone, with its apex at the surface element, to that of the perfect reflecting diffuser under the same conditions of illumination

Note 1 to entry: For fluorescent (luminescent) materials, the total radiance factor, β , is the sum of two portions, the reflected radiance factor, β_R , and the luminescent radiance factor, β_L , so that $\beta = \beta_R + \beta_L$.

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For non-fluorescent materials, the reflected radiance factor, β_R , is numerically equal to the reflectance factor, R .

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3.2 intrinsic radiance factor

β_∞
radiance factor (3.1) of a layer or pad of material thick enough to be opaque, such that increasing the thickness of the pad by doubling the number of sheets results in no change in the measured radiance factor

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Note 1 to entry: The intrinsic radiance factor is often expressed as a percentage.

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3.3 reflectance factor

R
ratio of the radiation reflected by a surface element of a body in the direction delimited by a given cone, with its apex at the surface element to that of the perfect reflecting diffuser under the same conditions of illumination

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

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Note 2 to entry: The reflectance factor is influenced by the backing if the body is translucent.

3.4 intrinsic reflectance factor

R_∞
reflectance factor (3.3) of a layer or pad of material thick enough to be opaque, such that increasing the thickness of the pad by doubling the number of sheets results in no change in the measured reflectance factor

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Note 1 to entry: The reflectance factor of a non-opaque sheet is dependent on the background and is not a material property.

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3.5 tristimulus values

X_{10}, Y_{10}, Z_{10}
amount of the three reference colour stimuli, in a given chromatic system, required to match the stimulus considered

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Note 1 to entry: In this part of ISO 5631 document, the CIE standard illuminant D65 and the CIE 1964 (10°) standard observer are used to define the trichromatic system.

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Note 2 to entry: The subscript 10 is applied to conform to the CIE convention that tristimulus values have the subscript 10 when the CIE 1964 (10°) standard observer is used.

3.6 CIELAB colour space

three-dimensional, approximately uniform colour space, produced by plotting, in rectangular coordinates L^*, a^*, b^* , quantities defined by the formulae given in Clause 9

Note 1 to entry: The quantity, L^* , is a measure of the lightness of the test piece, where $L^* = 0$ corresponds to black and $L^* = 100$ is defined by the perfect reflecting diffuser. Visually, the quantities a^* and b^* represent respectively the red-green and yellow-blue axes in colour space, such that

- $+a^*$ is a measure of the degree of redness of the test piece,
- $-a^*$ is a measure of the degree of greenness of the test piece,
- $+b^*$ is a measure of the degree of yellowness of the test piece, and
- $-b^*$ is a measure of the degree of blueness of the test piece.

If both a^* and b^* are equal to zero, the test piece is achromatic.

4 Principle

The light reflected from a sample under specified conditions is analysed either by a tristimulus-filter colorimeter or by an abridged spectrophotometer, and the colour coordinates are then calculated for D65/10° conditions.

5 Apparatus

5.1 Reflectometer, having the geometric, spectral, and photometric characteristics described in ISO 2469, and calibrated in accordance with the provisions of ISO 2469.

If materials containing fluorescent whitening agents are to be measured, the reflectometer shall be equipped with a radiation source having an adequate UV-content control, adjusted to a UV condition corresponding to the D65 standard illuminant by the use of a reference standard, as described in ISO 11475.

5.1.2 In the case of a filter reflectometer, a set of filters that, in conjunction with the optical characteristics of the basic instrument, give overall responses equivalent to the CIE tristimulus values X_{10} , Y_{10} , and Z_{10} of the CIE 1964 standard colorimetric system of the test piece evaluated for the CIE standard illuminant D65.

In the case of a filter reflectometer, the radiation falling upon the test piece shall have a UV content corresponding to that of the CIE standard illuminant D65.

5.1.3 In the case of an abridged spectrophotometer, the instrument shall have a function that permits calculation of the CIE tristimulus values X_{10} , Y_{10} , and Z_{10} , of the CIE 1964 standard colorimetric system of the test piece evaluated for the CIE standard illuminant D65, using the weighting functions given in Annex A, 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.

In the case of an abridged spectrophotometer, the instrument shall have an adjustable filter with a cut-off wavelength of 395 nm or some other equivalent system, and this filter shall be adjusted so that the UV content of the illumination falling upon the sample corresponds to that of the CIE standard illuminant D65.

5.2 Reference standards, for calibration of the instrument and the working standards, used frequently enough to ensure satisfactory calibration and UV adjustment.

5.2.1 Non-fluorescent reference standard, for photometric calibration, issued by an authorized laboratory in accordance with the provisions of ISO 2469.

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5.2.2 Fluorescent reference standard, for use in adjusting the UV content of the radiation incident upon the sample, having a CIE whiteness ($D_{65}/10^\circ$) value assigned by an authorized laboratory, as prescribed in ISO 11475:2017, Annex B.

5.3 Working standards, calibrated frequently enough to ensure that satisfactory calibration is maintained.

5.3.1 Two plates of flat opal glass, made of ceramic or other suitable material, cleaned, and calibrated as described in ISO 2469.

NOTE In some instruments, the function of the primary working standard can be taken over by a built-in internal standard.

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

5.4 Black cavity, having a reflectance factor that 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.

NOTE 1 The condition of the black cavity can be checked by reference to the instrument maker.

NOTE 2 The nominal value is given by the manufacturer.

6 Sampling and conditioning

If the tests are being made to evaluate a lot of paper or board, the sample shall be selected 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 according to ISO 187 is recommended but not required, though preconditioning with elevated temperatures should not be applied since it might change the optical properties.

7 Preparation of test pieces

Avoiding watermarks, dirt, and obvious defects, cut rectangular test pieces approximately 75 mm × 150 mm. Assemble at least 10 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 of paper or board 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, or to distinguish between the two sides.

If the top side can be distinguished from the wire side, it shall be uppermost; if not, as can be the case for papers manufactured on twin-wire machines, ensure that the same side of the sheet is uppermost.

8 Procedure

8.1 Ensure that calibration has been performed as described in ISO 11475 according to the instrument maker's instructions.

8.2 Remove the protective sheets from the top and the bottom of the test piece pad. Without touching the test area, use the procedure appropriate to the instrument to obtain the three CIE tristimulus values of the first test piece (or CIELAB values if the instrument is designed to report directly in this colour space). Read and record the tristimulus values to the nearest 0,01 unit.

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8.3 Move the uppermost test piece to the bottom of the pad and determine the values for subsequent test pieces until at least 10 test pieces have been evaluated. If required, repeat the procedure for the other side of the test pieces.

9 Calculation

9.1 CIE tristimulus values

If the instrument has a bandpass of 5 nm or narrower, calculate the CIE tristimulus values in accordance with CIE Publication 015:2018, 4th ed. In all other cases, calculate the tristimulus values using the appropriate weighting functions given in ASTM E308. If the instrument does not provide the CIE tristimulus values directly, obtain them by calculation using the tables provided in Annex A.

9.2 CIELAB coordinates

Calculate the CIELAB coordinates from the tristimulus values X_{10} , Y_{10} , Z_{10} by means of the following formulae:

$$L^* = 116(Y_{10}/Y_{10,e})^{1/3} - 16 \quad (1)$$

$$a^* = 500 \left[(X_{10}/X_{10,e})^{1/3} - (Y_{10}/Y_{10,e})^{1/3} \right] \quad (2)$$

$$b^* = 200 \left[(Y_{10}/Y_{10,e})^{1/3} - (Z_{10}/Z_{10,e})^{1/3} \right] \quad (3)$$

where $X_{10,e}$, $Y_{10,e}$, and $Z_{10,e}$ are the tristimulus values of the perfect reflecting diffuser under D65/10° conditions. These are given as the "white point" values in Annex A.

Alternative formulae shall, however, be used if any of the ratios $X_{10}/X_{10,e}$, $Y_{10}/Y_{10,e}$, and $Z_{10}/Z_{10,e} \leq (24/116)^3$ are satisfied as follows:

- If $(X_{10}/X_{10,e}) \leq (24/116)^3$, replace the term $(X_{10}/X_{10,e})^{1/3}$ in Formula (2) by the expression $(841/108) (X_{10}/X_{10,e}) + 16/116$.
- If $(Y_{10}/Y_{10,e}) \leq (24/116)^3$, replace the term $(Y_{10}/Y_{10,e})^{1/3}$ in Formulae (1), (2), and (3) by the expression $(841/108) (Y_{10}/Y_{10,e}) + 16/116$.
- If $(Z_{10}/Z_{10,e}) \leq (24/116)^3$, replace the term $(Z_{10}/Z_{10,e})^{1/3}$ in Formula (3) by the expression $(841/108) (Z_{10}/Z_{10,e}) + 16/116$.

NOTE 1 The term $(24/116)^3$ is approximately equal to 0,008 856.

NOTE 2 The term $(841/108)$ is approximately equal to 7,787.

NOTE 3 Formula (1) transforms to $L^* = 903,3(Y_{10}/Y_{10,e})$ when $(Y_{10}/Y_{10,e}) \leq (24/116)^3$.

9.3 Dispersion of the results

Since the three-dimensional statistical calculations are extremely complicated, the following simple procedure for assessing the dispersion is recommended.

Calculate the mean values $\langle L^* \rangle$, $\langle a^* \rangle$, and $\langle b^* \rangle$ of the L^* , a^* , and b^* values.

Calculate, for each test piece, the deviation ΔE_{ab}^* from the mean according to Formula (4):

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