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Paper, board and pulps — Measurement of diffuse radiance factor (diffuse reflectance factor)

Papier, carton et pâtes — Mesurage du facteur de luminance énergétique diffuse (facteur de réflectance diffuse)

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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.

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

For an explanation of 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 www.iso.org/iso/foreword.html.

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

This sixth edition cancels and replaces the fifth edition (ISO 2469:2014), which has been technically revised.

The main changes are as follows:

— introduction of the method for calibrating to the CIE illuminant C and to the standard illuminant D65, in addition to the procedure for calibration of the non-fluorescent part of the spectrum;

— addition of limit values for brightness and whiteness to check the performance of the calibration (as it is reported for non-fluorescence calibration);

— addition of Effective Residual Ink Concentration (ERIC number) to the list of optical properties based on reflectance and radiance measurements in the introduction;

— update of Annex C in order to reflect the revised version of ISO 4094;

— update of bibliography;

— editorial revision.

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 radiance factor depends on the conditions of measurement, particularly the spectral and geometric characteristics of the instrument used. The diffuse radiance factor as defined by this document is determined using instruments having the characteristics given in Annex A and calibrated with standards delivered in the framework of the organisation described in Annex B.

The diffuse radiance factor is the sum of the reflected radiance factor and the luminescent radiance factor, and the luminescent radiance factor of a luminescent (fluorescent) object is dependent on the spectral power distribution of the illumination. If adequately accurate measurements are carried out on fluorescent objects, the UV-content of the instrument illumination is adjusted to produce the same amount of fluorescence for a fluorescent reference standard as the selected CIE illuminant. The preparation of fluorescent reference standards to enable this adjustment to be made is described in Annex C. The use of these fluorescent reference standards is described in detail in the International Standards describing the measurement of the properties of the materials containing fluorescent whitening agents.

The spectral diffuse radiance factor or the weighted diffuse radiance factor applicable to one or several specified wavelength bands is often used to characterize the properties of pulp, paper and board. Examples of diffuse radiance factors associated with specified wavelength bands are the ISO brightness (diffuse blue radiance factor) and the luminance factor.

The diffuse radiance factor or diffuse reflectance factor is also used as the basis for calculating optical properties, such as opacity, colour, whiteness, effective residual ink concentration (ERIC number) and the Kubelka-Munk scattering and absorption coefficients. These various properties are described in detail in specific International Standards.

Paper, board and pulps — Measurement of diffuse radiance factor (diffuse reflectance factor)

1 Scope

This document describes the general procedure for measuring the diffuse radiance factor of all types of pulp, paper and board. More particularly, it specifies in detail the procedures to be used for calibrating the equipment, and in Annex A, the characteristics of the equipment to be used for such measurements.

This document can be used to measure the diffuse radiance factors and related properties of materials containing fluorescent whitening agents, provided that the UV-content of the instrument illumination has been adjusted to give the same level of fluorescence as a fluorescent reference standard for a selected CIE illuminant, according to the International Standard describing the measurement of the property in question.

Annex C describes the preparation of fluorescent reference standards.

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 4094, *Paper, board and pulps — General requirements for the competence of laboratories authorized for the issue of optical reference transfer standards of level 3*

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/

3.1
radiance factor
β
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 luminescent (fluorescent) materials, the total radiance factor, β, is the sum of two portions, the reflected radiance factor, β_S, and the luminescent radiance factor, β_L, so that

$$\beta = \beta_S + \beta_L$$

For non-fluorescent materials, the reflected radiance factor, β_S, is numerically equal to the reflectance factor, R, defined in 3.3.

Note 2 to entry: The radiance is expressed in $W \cdot m^{-2} \cdot sr^{-1}$.

3.2
diffuse radiance factor
ratio of the radiation reflected and emitted from a body to that reflected from the perfect reflecting diffuser under the same conditions of diffuse illumination and normal detection

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

Note 2 to entry: This document prescribes diffuse illumination and normal detection in an instrument constructed and calibrated in accordance with the provisions of this document. The term "diffuse radiance factor" is used here both for bidirectional and sphere geometries.

3.3
reflectance factor
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 reflected by the perfect reflecting diffuser under the same conditions of illumination

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

Note 2 to entry: This term may be used only when it is known that the test material exhibits no luminescence (fluorescence).

Note 3 to entry: In this document, it has been considered advisable to introduce the term radiance factor rather than reflectance factor into the title, because the increasing use of fluorescent whitening agents in papermaking means that the measurement is seldom limited to reflectance. From a single measurement the instrument cannot distinguish between the two factors.

3.4
diffuse reflectance factor
R
ratio of the reflection from a body to that from the perfect reflecting diffuser under the same conditions of diffuse illumination and normal detection

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

Note 2 to entry: This document specifies diffuse illumination and normal detection in an instrument constructed and calibrated in accordance with the provisions of this document.

3.5
international reference standard level 1
IR1
primary optical reference standard, the perfect reflecting diffuser, the ideal diffuser exhibiting isotropic diffuse reflection with a reflectance equal to 1, used for calibration of optical transfer standards

Note 1 to entry: Reflectance is defined as the ratio of the reflected to the incident radiation.

[SOURCE: ISO 4094:2017, 3.4]

3.6
international reference standard level 2
IR2
secondary optical reference transfer standard for the certification of level 3 *(IR3)* (3.7) standards or for the calibration of instruments, consisting of a material certified against an *international reference standard of level 1* (3.5) by a standardizing laboratory, as specified in the relevant International Standard

Note 1 to entry: This document refers to two types of IR2: a non-fluorescent IR2, whose spectral reflectance factors have been determined by a standardizing Laboratory in relation to the IR1; and a fluorescent IR2, whose total spectral radiance factors corresponding to a specified CIE illuminant have been determined by a standardizing laboratory. A non-fluorescent IR2 is used to calibrate the photometric scale of an authorized laboratory's reference instrument, and a fluorescent IR2 standard is used to adjust the UV level of an authorized laboratory's reference instrument.

[SOURCE: ISO 4094:2017, 3.5]

3.7
international reference standard level 3
IR3
tertiary optical reference transfer standard consisting of a material certified against an *international reference standard of level 2* (3.6) by an authorized laboratory, as specified in the relevant International Standard, and used by a testing laboratory for the calibration of instruments

Note 1 to entry: This document refers to two types of IR3: a non-fluorescent IR3, whose spectral reflectance factors have been determined by an authorized laboratory in relation to the non-fluorescent IR2; and a fluorescent IR3, whose calibration values have been determined by an authorized laboratory in relation to the fluorescent IR2. A non-fluorescent IR3 is used to calibrate the photometric scale of a testing laboratory's instrument. A testing laboratory uses a fluorescent IR3 to adjust the UV level of the testing laboratory's instrument.

[SOURCE: ISO 4094:2017, 3.6]

3.8
working standard
physical standard whose radiance (reflectance) factors have been determined by calibration with a suitable international reference standard (IR3) for subsequent use on a single instrument that conforms to specific requirements

Note 1 to entry: The specific requirements are given in this document.

3.9
primary working standard
working standard that is used routinely to validate and check a given measuring instrument for its intended use

Note 1 to entry: The assigned radiance (reflectance) factors of the primary working standard may not be transferred to a different instrument, even of the same type (see 3.8). However, it is possible to use a primary working standard for validation purposes only on instruments of the same type.

3.10

control plate
secondary working standard
working standard that is used on an infrequent basis to monitor and validate the performance of a given primary working standard

Note 1 to entry: When one or more control plates give anomalous results on a given instrument, it can be necessary to re-calibrate the primary working standard used with that instrument with an appropriate international reference standard (IR3).

4 Principle

A test piece is irradiated diffusely in a standard instrument and the light reflected (and emitted as a result of fluorescence) in a direction normal to the surface is passed to a detection system. This detection system may consist either of a defined optical filter and photodetector or of an array of photodetectors where each detector responds to a specific effective wavelength. The desired radiance factors are determined directly from the output from the photodetector in the former case or by calculation from the detector array outputs using appropriate weighting functions in the latter case.

5 Apparatus

5.1 Reflectometer

Reflectometer having the geometric, spectral and photometric characteristics in accordance with Annex A.

5.2 Reference standards

For photometric calibration of the instrument and its working standards, use a non-fluorescent reference standard issued by an authorized laboratory (AL), as defined in Annex C, and fulfilling the requirements for an IR3, in accordance with Annex B.

Use reference standards sufficiently frequently to ensure satisfactory calibration.

NOTE If fluorescent materials are measured, a fluorescent reference standard issued by an authorized laboratory is needed to enable the UV-content of the instrument illumination to be adjusted to produce the same amount of fluorescence as the selected CIE illuminant. This UV adjustment procedure is described in detail in Annex C. The use of these fluorescent reference standards is described in the International Standards for the determination of specific optical properties.

5.3 Working standards

For measurements on non-fluorescent materials, two working standards of opal glass, ceramic or other suitable material with flat surfaces.

NOTE In some instruments, the function of the primary working standard (see 6.4) can be fulfilled by a built-in internal standard.

For measurements on white fluorescent materials, stable fluorescent working standards of plastic or other material incorporating a fluorescent whitening agent are required. These working standards are described in the relevant International Standards.

5.4 Black cavity

For calibration or validation of the low end of the photometric scale. This black cavity shall have a radiance factor which does not differ from its nominal value by more than 0,2 percentage points at all wavelengths. The black cavity shall be stored upside-down in a dust-free environment or with a protective cover. During calibration, the instrument shall be adjusted to the nominal value of the black cavity.

It is not yet possible to institute a system of reference standards to enable testing laboratories to check the reflectance factor of the black cavity. At the time of delivery, the level should be guaranteed by the instrument maker. Questions concerning the use and condition of the black cavity should be resolved by contacting the instrument maker.

6 Calibration of the instrument and its working standards

6.1 General

Handle each IR3 carefully and protect the test area from contamination. Store it in darkness when not in use. It is recommended to store IR3s in temperature conditions not exceeding 24 °C, and preferably below 10 °C for long term storage in airtight packages.

Before use, condition the unopened packages in the laboratory atmosphere to reach temperature equilibrium. Then, unpack and condition the IR3s in the laboratory atmosphere.

6.2 Photometric calibration of the instrument and UV setting

6.2.1 Step 1

Using the procedure appropriate to the instrument, calibrate the photometric scale of the instrument with a non-fluorescent IR3. Using the values assigned to the non-fluorescent reference standard (5.2), 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.

6.2.2 Step 2

When the measurements are made on fluorescent materials, carry out also a UV-calibration with a fluorescent IR3. Using the appropriate measurement procedure, measure the diffuse radiance factors of the fluorescent IR3, calculate the brightness/whiteness value and compare the value obtained with that assigned to the fluorescent reference standard.

NOTE Brightness measurement is used to perform UV C setting and whiteness measurement for UV D65 setting.

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

6.2.3 Step 3

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

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

6.2.4 Step 4

Repeat the calibration as described in 6.2.1 using the non-fluorescent IR3 with the UV-adjustment filter in the position which gave the correct brightness/ whiteness value. Repeat the measurement of the brightness/whiteness of the fluorescent IR3 as described in 6.2.2. If the brightness whiteness value obtained does not agree with the assigned value, adjust the position of the UV-adjustment filter until measurement gives the correct brightness/whiteness value as described in 6.2.3.

6.2.5 Step 5

Repeat 6.2.4 until the correct value for the brightness/whiteness of the fluorescent reference standard is obtained with the instrument correctly calibrated to the non-fluorescent IR3. The deviation between the measured and the assigned brightness of the non-fluorescent IR3 used for the primary calibration shall not exceed 0,05. The deviation between the measured and the assigned ISO brightness of the fluorescent IR3 used for the primary calibration shall not exceed 0,3. The deviation between the measured and the assigned CIE whiteness of the fluorescent IR3 used for the primary calibration shall not exceed 0,5. The relative UV-content is now correctly adjusted with respect to brightness so that the setting gives the ISO brightness value equivalent to the CIE illuminant C and CIE 1931 (2°) observer, and 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 settings of the UV-adjustments.

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 most instruments available on the market at the time of publication, the procedure indicated in 6.2.2 to 6.2.5 is performed automatically.

All calibrations are thus related to the IR1 through a calibration chain comprising an IR2 and an IR3 to which absolute values have been assigned respectively by a standardizing laboratory and by an authorized laboratory using an instrument conforming to this document.

6.3 Value assignment to the working standards for their intended use

Clean the working standards (see 6.4) and measure their radiance factors using an instrument previously calibrated with a set of IR3s and read off and record the values to the nearest 0,01 percentage point. This value assignment of the working standard is instrument-specific, for given conditions of