INTERNATIONAL STANDARD

ISO 2470-1

Second edition
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Paper, board and pulps — Measurement of diffuse blue reflectance factor —

Part 1: Indoor daylight conditions (ISO brightness)

Papier, carton et pâtes — Mesurage du facteur de réflectance diffuse dans le bleu —

Partie 1: Conditions d'éclairage intérieur de jour (degré de blancheur ISO)

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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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 World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 2470-1:2009), of which it constitutes a minor revision including the following modifications:

— references in Clause 2 and in the Bibliography have been updated;

— the terminology (Clause 3) has been revised to be consistent with the information provided in ISO/TR 10688 and, wherever possible, with the symbols used in the CIE International Lighting Vocabulary;

— references to "ISO/TC 6 authorized laboratories" have been eliminated;

— the precision statement has been moved to an informative annex (Annex C).

ISO 2470 consists of the following parts, under the general title *Paper, board and pulps — Measurement of diffuse blue reflectance factor*:

— *Part 1: Indoor daylight conditions (ISO brightness)*

— *Part 2: Outdoor daylight conditions (D65 brightness)*

Introduction

The diffuse reflectance factor (radiance factor) depends on the conditions of measurement, particularly the spectral and geometric characteristics of the instrument used. This part of ISO 2470 is therefore intended to be read in conjunction with ISO 2469 which defines the geometric characteristics of the instrument and also defines the photometric calibration procedure to be adopted.

The definition of ISO brightness is historically linked to the Zeiss Elrepho instrument having, as a light source, an incandescent lamp which excites fluorescence to only a limited extent. It is specified here that, in instruments of the abridged spectrophotometer or filter colorimeter type, the UV content of the illumination be adjusted to conform to the CIE illuminant C as defined by a fluorescent reference standard having an assigned value of ISO brightness as described in Annex B. Only if this is done can the property measured on a fluorescent material be called ISO brightness.

Paper, board and pulps — Measurement of diffuse blue reflectance factor —

Part 1: Indoor daylight conditions (ISO brightness)

1 Scope

This part of ISO 2470 specifies a method for measuring the diffuse blue reflectance factor (ISO brightness) of pulps, papers and boards.

This part of ISO 2470 is limited in its scope to white and near-white pulps, papers and boards. The measurement can only be made in an instrument in which the ultraviolet energy level of the illumination has been adjusted to correspond to the CIE illuminant C[6] using a fluorescent reference standard. The CIE illuminant C is taken to be representative of indoor daylight conditions because it contains a suitable proportion of UV radiation.[9]

NOTE The property called D65 brightness is measured with an instrument adjusted to correspond with CIE standard illuminant D65,[4] which has a much higher UV content than that specified in this part of ISO 2470. The measurement of D65 brightness is described in ISO 2470-2.[2]

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 3688, *Pulps — Preparation of laboratory sheets for the measurement of diffuse blue reflectance factor (ISO brightness)*

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

ISO 7213, *Pulps — Sampling for testing*

3 Terms and definitions

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

3.1
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 part of ISO 2470 are CIE illuminant C and the diffuse radiance factor is strictly the total radiance factor, β, which is the sum of 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_R, is simply the diffuse reflectance factor R.

3.2
diffuse reflectance factor
R
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: The diffuse reflectance factor is influenced by the backing if the body is translucent.

Note 3 to entry: This part of ISO 2470 prescribes diffuse illumination and normal detection in an instrument calibrated in accordance with the provisions of this part of ISO 2470.

3.3
intrinsic diffuse reflectance factor
R_∞
diffuse reflectance factor of a layer or pad of 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 [reflectance] factor

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

3.4
ISO brightness
R_{457}
intrinsic diffuse radiance (reflectance) factor measured with a reflectometer having the characteristics described in ISO 2469, equipped with a filter or corresponding function having an effective wavelength of 457 nm and a half bandwidth of 44 nm, and adjusted so that the UV content of the irradiation incident upon the test piece corresponds to that of the CIE illuminant C

Note 1 to entry: The filter function is described more fully by the weighting function factors given in Annex A and Table A.1.

4 Principle

A test piece is illuminated diffusely in a standard instrument and the light reflected normal to the surface is either allowed to pass through a defined optical filter and then measured by a photodetector or measured by an array of photosensitive diodes, where each diode responds to a different effective wavelength. The brightness is then determined directly from the output from the photodetector or by calculation from the photosensitive diode outputs using the appropriate weighting function.

5 Apparatus

5.1 Reflectometer

5.1.1 Reflectometer having the geometric, spectral and photometric characteristics described in ISO 2469 and calibrated in accordance with the provisions of ISO 2469, and equipped for the measurement of blue reflectance factor as defined in Annex A.

5.1.2 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 illuminant C.

5.1.3 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 system for adjustment and control, and this filter shall be

adjusted or the system shall be calibrated with the help of the fluorescence reference standard (5.2.3), so that the UV content of the illumination falling upon the sample corresponds to that of the CIE illuminant C.

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

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

NOTE This frequency interval can be fixed according to a defined schedule or control limits (e.g. from drift analysis of the measuring instrument).

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

5.2.3 Fluorescent reference standard for use in adjusting the UV content of the radiation incident upon the sample, having an ISO-brightness value and other related data as specified in Annex B and fulfilling the requirements for international reference standard of level 3 (IR3) as prescribed in ISO 2469.

5.3 Working standards

5.3.1 Two plates of flat opal glass, ceramic or other suitable non-fluorescent 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.

5.3.3 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.

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

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 a lot of pulps is to be evaluated, the sample shall be selected in accordance with ISO 7213. 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, but preconditioning with elevated temperatures should not be applied since it might change the optical properties.

7 Preparation of test pieces

Regarding pulp samples, prepare laboratory sheets in accordance with ISO 3688.

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 diffuse reflectance 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 not, as may be the case for papers manufactured on double wire machines, ensure that the same side of the sheet is uppermost.

8 Procedure

8.1 Calibrate the instrument according to the instrument maker's instructions, using a non-fluorescent international reference standard of level 3 (IR3) (5.2.2) or a working standard (5.3.1) calibrated in relation to an IR3. If the instrument is of the abridged spectrophotometer type, adjust the setting of the UV-adjustment filter or of a system having a corresponding function (see 5.1.3) using the fluorescent (5.2.3) and non-fluorescent (5.2.2) international reference standards of level 3 (IR3s), in accordance with the instrument maker's instructions.

8.2 Remove the protective sheets from the test piece pad. Without touching the test area, use the procedure appropriate to the instrument to measure the ISO brightness of the top side of the test piece pad. Read and record the value to the nearest 0,05 % or better of the diffuse reflectance factor.

8.3 Move the measured test piece to the bottom of the pad and determine the ISO brightness for the next test piece and similarly for the following test pieces until a total of not less than 10 test pieces has been measured.

8.4 If required, turn the pad upside down and repeat the procedure for the other side.

NOTE 1 If, in the case of fluorescent samples, measurements are made with a filter with a cut-off wavelength of 420 nm placed in the light beam, it is possible to determine the ISO brightness of the non-fluorescent substrate and thus to calculate the contribution of the fluorescent whitening agent to the ISO brightness, but this is outside the scope of this part of ISO 2470.

NOTE 2 In the case of the non-fluorescent substrate or of a non-fluorescent material, the D65 brightness and the ISO brightness are identical.

9 Expression of results

Calculate the mean intrinsic diffuse reflectance factor and its standard deviation for each required side, or the mean of the two sides, as the ISO brightness of the paper, board or pulp, in percent, to the nearest 0,5 % radiance factor. If the mean values differ by more than 0,5 % diffuse reflectance factor and if this difference exceeds three times the standard deviation for the repeat measurements on a given side, the two sides shall be identified and the results reported separately. If the difference is equal to or less than 0,5 % diffuse reflectance factor, the overall average shall be reported.

Although the measurements should be made to the nearest 0,05 % or better, diffuse reflectance factor in accordance with the precision of the instrument, the final result should be expressed only to the nearest 0,5 % diffuse reflectance factor as an indication of the lack of resolution in adjusting the UV filter.

10 Test report

The test report shall include the following information:

a) a reference to this part of ISO 2470, i.e. ISO 2470-1;

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 ISO brightness and standard deviation for each required side, or the mean and standard deviation of the two sides, to the nearest 0,5 % diffuse reflectance factor;

f) the type of instrument used;

g) any departure from this part of ISO 2470 or any circumstances or influences that may have affected the results.

Annex A
(normative)

Spectral characteristics of instruments for measuring ISO brightness

A.1 Filter colorimeters

The effective wavelength of the reflectometer, 457,0 nm ± 0,5 nm, and the half-peak bandwidth of 44 nm are arrived at with a combination of lamps, integrating sphere, glass optics, filters and photoelectric detectors, taking into consideration that these parameters are dependent upon

a) the relative spectral distribution of the radiant flux leaving the integrating sphere,

b) the relative spectral transmittance of the glass optics,

c) the relative spectral transmittance of the filters and spectral sensitivity of the detection system, and

d) the relative spectral responsitivity of the photoelectric detectors, each being a function of wavelength.

A.2 Abridged spectrophotometers

The $F(\lambda)$ of the brightness function at 5 nm intervals is indicated in Table A.1. In an abridged spectrophotometer measuring at 10 nm or 20 nm intervals, the appropriate values given in Table A.1 for the different wavelengths should be used in the calculation of ISO brightness without any attempt to recalculate intermediate values.

For the range of white and near-white papers for which this part of ISO 2470 is applicable, no further treatment of these functions is necessary.

Furthermore, in the case of a filter instrument, the area under the curve of $F(\lambda)$ for wavelengths exceeding 700 nm should be small enough for measurement not to be affected by any infrared fluorescent radiation generated in the sample.

Table A.1 — Relative spectral distribution function $F(\lambda)$ of a reflectometer equipped for measuring ISO brightness

Wavelength nm	$F(\lambda)$	**5 nm weights**	$F(\lambda)$	**10 nm weights**	$F(\lambda)$	**20 nm weights**
400	1,0	0,107	1,0	0,213	1,0	0,425
405	2,9	0,309				
410	6,7	0,715	6,7	1,430		
415	12,1	1,291				
420	18,2	1,942	18,2	3,885	18,2	7,728
425	25,8	2,752				
430	34,5	3,680	34,5	7,364		
435	44,9	4,790				
440	57,6	6,145	57,6	12,295	57,6	24,459
445	70,0	7,467				
450	82,5	8,801	82,5	17,609		
455	94,1	10,038				
460	100,0	10,668	100,0	21,345	100,0	42,463
465	99,3	10,593				
470	88,7	9,462	88,7	18,933		
475	72,5	7,734				
480	53,1	5,665	53,1	11,334	53,1	22,548
485	34,0	3,627				
490	20,3	2,166	20,3	4,333		
495	11,1	1,184				
500	5,6	0,597	5,6	1,195	5,6	2,378
505	2,2	0,235				
510	0,3	0,032	0,3	0,064		
Sum	**937,4**	**100,000**	**468,5**	**100,000**	**235,5**	**100,000**

Annex B
(normative)

UV calibration service

B.1 General

In this part of ISO 2470, reference is made to special reference standards which are required to enable the relative UV content in the illumination falling on the test piece to be adjusted to conform to the CIE illuminant C.

To enable this to be done, the following procedure is established.

B.2 Standardizing laboratories

A laboratory (or laboratories) equipped to make primary spectrofluorimetric measurements using the two-monochromator method[8] is appointed as "standardizing laboratory" in accordance with the provisions of ISO 4094. This laboratory issues "international reference standards of level 2" (IR2) to the authorized laboratories. Such reference standards shall be assigned spectral total radiance factor data for the CIE illuminant C. A standardizing laboratory shall meet the general requirements for quality and competence of its IR2 calibration results in accordance with the provisions of ISO 4094.

B.3 Authorized laboratories

B.3.1 Laboratories having the necessary technical competence and maintaining reference instruments having the characteristics specified in ISO 2469 are appointed as "authorized laboratories" in accordance with the provisions of ISO 4094.

NOTE It is anticipated that these authorized laboratories will be the same as those authorized in accordance with the requirements of ISO 2469, but the standardizing laboratories will not necessarily be the same as those appointed according to ISO 2469 since different equipment is required.

B.3.2 An authorized laboratory shall make necessary adjustments to correct for differences in the basic photometric level between the instrument at the standardizing laboratory and the level specified for the authorized laboratory in ISO 2469, before calculating the ISO-brightness value of the IR2 and using this value to adjust the UV content of the reference instrument. The calculations shall be carried out using 10 nm data and the weighting functions given in Annex A.

B.3.3 An authorized laboratory shall take steps to ensure that directional effects in the IR2, which may affect the measurements at the standardizing laboratory, are recognized and taken into account when determining the value to be used when transferring this calibration to an instrument providing a diffuse illumination.

B.4 IR3 fluorescent reference standard

B.4.1 The fluorescent reference standard shall consist of white paper, uniform in radiance factor and aged for a sufficient time to give the paper an optical stability of 4 months to 6 months without a deterioration in the ISO-brightness value of more than 0,1 %.

B.4.2 The standard shall be prepared in the form of opaque pads and shall have a smooth non-glossy surface. The pad shall be covered with a suitable protective cover.

NOTE Fluorescent tablets and tiles are suitable local working standards but have been shown not to be suitable for use as transfer standards for this procedure which is specific for white papers.

B.4.3 Since the interactive effect of the fluorescence emission into the integrating sphere creates a slight non-linearity in the brightness scale, the IR2 and IR3 standards shall have a minimum ISO-brightness of 95 % and a minimum fluorescence component of the ISO brightness of 10 percentage points.

B.5 Comments

This procedure is specific for white papers that may contain fluorescent whitening agents which emit light in the blue portion of the visible spectrum (400 nm to 500 nm). This procedure does not provide a valid adjustment for fluorescence in other spectral regions.

Annex C
(informative)

Precision

C.1 General

The following data were obtained by the CEPI Comparative Testing Service, February 2007. The participating laboratories made 10 measurements on each of the four samples.

The means and standard deviations were then calculated as shown in Tables C.1 and C.2.

The calculations were made according to ISO/TR 24498.

The repeatability and reproducibility limits reported are estimates of the maximum difference which should be expected in 19 of 20 instances, when comparing two test results for material similar to those described under similar test conditions. These estimates may not be valid for different materials or different test conditions.

NOTE Repeatability and reproducibility limits are calculated by multiplying the repeatability and reproducibility standard deviations by 2,77, where 2,77 = 1,96 $\sqrt{2}$.

C.2 Repeatability

Table C.1 — Repeatability

ISO brightness	Condition	Number of laboratories	Mean brightness %	Repeatability standard deviation s_r	Coefficient of variation CoV, r %	Repeatability limit r
UV adjusted	Non-fluorescent 1	20	80,36	0,26	0,32	0,72
	Non-fluorescent 2	18	90,63	0,06	0,07	0,17
	Fluorescent 1	20	86,24	0,17	0,20	0,47
	Fluorescent 2	19	99,52	0,09	0,09	0,25

C.3 Reproducibility

Table C.2 — Reproducibility

ISO brightness	Condition	Number of laboratories	Mean brightness %	Reproducibility standard deviation S_R	Coefficient of variation CoV, R %	Reproducibility limit R
UV adjusted	Non-fluorescent 1	20	80,36	0,33	0,41	0,91
	Non-fluorescent 2	18	90,63	0,33	0,36	0,91
	Fluorescent 1	20	86,24	0,30	0,35	0,83
	Fluorescent 2	19	99,52	0,43	0,43	1,19

Bibliography

[1] ISO 187, *Paper, board and pulps — Standard atmosphere for conditioning and testing and procedure for monitoring the atmosphere and conditioning of samples*

[2] ISO 2470-2, *Paper, board and pulps — Measurement of diffuse blue reflectance factor — Part 2: Outdoor daylight conditions (D65 brightness)*

[3] ISO/TR 10688, *Paper, board and pulps — Basic terms and equations for optical properties*

[4] ISO 11664-2:2007 (CIE S 014-2/E:2006), *Colorimetry — Part 2: CIE standard illuminants*

[5] ISO/TR 24498, *Paper, board and pulps — Estimation of uncertainty for test methods*

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