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Graphic technology — Multispectral imaging measurement and colorimetric computation for graphic arts and industrial application —

Part 2:
Requirements for decorative surfaces

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 document 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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This document was prepared by Technical Committee ISO/TC 130, *Graphic technology*.

A list of all parts in the ISO 24585 series can be found on the ISO website.

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

In the wood products industry, wood-based panels, for use as furniture or flooring components, are prepared by impregnating a printed base paper with an artificial resin, and then laminating it to a chipboard or fibreboard base by curing the resin using high temperature and pressure. In the decorative printing industry, the base papers are often printed with a simulation like a woodgrain or other natural material.

The assessment of the appearance of such prints during the make-ready and for re-prints have long been done using trial and error. It is common to take a master pattern provided by a customer and to reproduce it. The visual agreement between the master and the reproduction is normally carried out by experienced personnel who visually compare the target and the production, under controlled illumination conditions, using either D65- or D50-like illumination. The necessary changes to improve the visual match were manual recipe updates in the ink kitchen in case of rotogravure printing[1] or manual adjustment of image artwork on calibrated monitors in case of digital printing.

Conventional point measurement devices are occasionally used to objectify the assessment, but their field of view was too large to resolve fine detail and repositioning was also challenging. Such manual and subjective methods gave satisfactory results for the production, but it has the following problems:

— it requires specially trained personnel requiring a long training phase;

— the results of the judgments change over time due to observer fatigue;

— the master aim changes its colours over time for many reasons; and

— the subjective assessment gives rise for debates in cases of dispute.

Multispectral imaging devices were introduced to wood lamination production around the year 2010[2] to improve both process control and quality assurance[3],[4]. First, the spatial resolved inline capturing allowed for a pixel-by-pixel comparison between the master and the pertinent reproduction. Given an appropriate image registration and spectral accuracy multispectral imaging systems allowed for an objective evaluation of the image differences including aspects such as local contrast. Such a comparison typically leads to two different outcomes. On the one hand, a single number index is condensed to uniquely define the visual closeness, which eases communication with customer and the agreement of tolerance schemas. On the other hand, the comparison of tristimulus images leads to a plethora of individual colour difference vectors that can be adapted to the individual press technology to provide guidance for process control and the ink formulation. In both cases, it reduces scads of measurement data (spectra of each pixel in a revolution as measured over a full press run) down to a digestible amount of human and process control information. A single point measurement system is not able to provide this information[5]. This objective assessment can be used for both conventional and digital production of the final panels.

For digital printing presses, which are increasingly used in that industry, the spatial colour difference can be used to alter the image data in the RIP while printing. This improves the visual closeness noticeably and is sometimes called colour looping.

This document defines the requirements for multispectral imaging systems which are needed for the use case of decorative lamination and includes the introduction of an image similarity index, termed SIM_PDE.

Since the sample preparation has an impact on the final product, this document provides guidance with respect to the laboratory preparation of samples, to allow interoperability in the development of process automation in the assessment of the appearance of the print.

Graphic technology — Multispectral imaging measurement and colorimetric computation for graphic arts and industrial application —

Part 2: Requirements for decorative surfaces

1 Scope

This document specifies requirements for multispectral imaging devices to measure and compare the decorative surfaces. Based on spatially resolved spectral measurement of reflecting surfaces, tristimulus images are computed. A metric is provided that reflects the visual closeness between a reference surface and a comparison surface using a single index called SIM_PDE. Recommendations are provided with regard to laboratory sample preparation.

This document is not applicable to functional surfaces.

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 13655, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*

ISO 24585-1, *Graphic technology — Multispectral measurement and colorimetric computation for graphic arts and industrial applications — Part 1 Parameters and measurement methods*

ISO 28178, *Graphic technology — Exchange format for colour and process control data using XML or ASCII text*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 24585-1 and the following 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
decorative surfaces
base papers, printed with a simulation like a woodgrain or other design

Note 1 to entry: Decorative surfaces are usually created in the decorative printing industry. They show either a uniform colour or a texture of some kind. Decorative surfaces are typically not showing a high level of fluorescence.

3.2
specimen backing
material placed behind and in contact with the specimen during measurement

Note 1 to entry: This can be white, black or the same material as the specimen self.

3.3
SIM_PDE
index of similarity between a reference image and a test image based on the average colour difference between two identically specified sets of patches

3.4
shading correction
method for adjusting intensity levels in a digital or electronic image, caused by non-uniformities in the illuminating or detecting systems

[SOURCE: ISO 10934:2020, 3.2.44]

4 Multispectral measurement requirements

4.1 Instrument standardization and adjustment

The measurement device or system shall be standardized and possibly adjusted in accordance with its manufacturer's instructions.

NOTE 1 ISO 15790[6] defines the use of a certified reference material (CRM) to check calibration of a measurement system. It also provides additional information relating to the use of CRMs, the determination of combined standard uncertainty and data reporting.

NOTE 2 Where multiple instruments are used for measurement, there can be differences in the resulting data due to the individual characteristics of the instruments and variations in measurement conditions.

4.2 Illumination requirements

4.2.1 Wavelength range

The spectral power distribution shall have sufficient energy at all wavelengths in the range from 400 nm to 700 nm inclusive to make measurements with low noise.

4.2.2 Measurement conditions

The measurement area should be visually uniform. Within the reference plane the measurement area shall be assessed at least at 100 equally spaced measurement positions. The illuminance or luminance should be within 5 % of the average value and shall be within 25 % of the average value.

NOTE 1 The uniformity can be assessed by using an imaging luminance measurement device as described in Reference [7].

NOTE 2 A shading correction is always applied to improve uniformity. In order to retain appropriate signal to noise ratio, this compensation is restricted.

The spectral power distribution of the illumination shall be continuous across the visible range and should exclude the radiant power at wavelengths below the visible spectrum. ISO 13655 describes one way to achieve this by filtering the shorter wavelengths from a source that has radiant power at all wavelengths in the range from 420 nm to at least 700 nm and is noted as M2, UV cut.

NOTE 3 Most specimens tested in this document do not show any significant amount of fluorescence, any instrument source with low levels of light of shorter wavelengths will suffice, including incandescent sources and LED sources that utilize only visible range LEDs and phosphors.

Departures from these nominal requirements shall be reported.

The measurement geometry of the imaging system shall be 45°:0° (influx:efflux). The efflux optics shall be oriented along the normal to the surface of the substrate in the reference plane. The tolerances for the efflux optics given in CIE 176[8] should be met at the centre of the field of view. Unidirectional or bi-directional influx geometry may be used, though this is a departure from CIE 176.

While being measured the specimen shall lie on a flat surface in the reference plane, e.g., a roller for an inline measurement system. The instrument reference plane and the specimen surface shall lie in the same plane.

NOTE 4 Imaging systems inherently work with an area illuminated being larger than the measured area, known as overfilling.

4.3 Specimen preparation and backing requirements

The specimen shall be backed by either a black or a white material that conforms to ISO 13655. Where specimens being measured by reflection are not fully opaque, the backing used should be characterized and the method shown in ISO 13655 or Reference [9] may be used to correct such measurements to a white backing reference.

NOTE For guidance concerning which specimen backing material to use, refer to application standards such as ISO 12647-2[10].

The guidance for preparing the specimen for measurement is provided in Annex A.

4.4 Light capturing requirements

4.4.1 Spatial resolution

The spatial resolution should be at least 35 samples per cm and shall be at least 10 samples per cm in horizontal and vertical direction.

NOTE The wood-based panel industry has identified spatial resolution of minimum 90 dpi to be suitable[11].

4.4.2 Wavelength range, wavelength interval and bandwidth

The data should be measured from 380 nm to 780 nm and shall be measured from 400 nm to 700 nm, inclusive. The number of spectral channels shall not be less than seven.

The spectral estimate procedure is very complex and is influenced by many factors thus making the estimate specific to each device[12]. Therefore, the accuracy of multispectral imaging system is defined indirectly by using the distribution of colour distances, that arise when the reference colour spectra of a colour chart are compared with corresponding spectra reconstructed from the measured camera responses of observed colour patches[13].

The colour patches, which should be in conformance with ISO 12641-2, shall be printed on a panel and measured in accordance with ISO 13655 with instrument source condition M2 (UV excluded). The tristimulus values should be computed for CIE illuminant D50 and the CIE 2° Standard Observer using an area averaging spectrophotometer.

The same patches shall be measured by the multispectral imaging device. After spectral estimation of a spectral curve with at least 16 bands, the tristimulus image should also be computed for CIE illuminant D50 and the 2° Standard Observer. Each colour patch should be represented by the average of a minimum of 100 pixels, e.g. a region of interest of 10 x10 pixels. Each colour patch shall be represented by the average of a minimum of 4 pixels, e.g. a region of interest of 2x2 pixels. The median colour difference between the two sets of tristimulus data shall be less than a ΔE_{00} of 1 and the 95th percentile should be below ΔE_{00} of 1,5 and shall be below ΔE_{00} of 2,5.

4.5 Multispectral image storage

The assessment of the visual closeness or similarity is done by computing and comparing tristimulus images. That is mostly done "on the fly" with no explicit access to multispectral image. The multispectral images are not needed to be saved and stored separately.

In case the multispectral image is subject for further communication, it is recommended to use a file format described in CIE 223[14].

4.6 Tristimulus image computation requirements

Except where the application requires a different illuminant or observer model, tristimulus values shall be computed according to ISO 13655. Where other methods of calculating tristimulus values are used the method shall be clearly documented.

NOTE A common condition for illumination is CIE D65 and for observer is CIE 1964, 10° Standard Observer. One option is to compute colorimetry using a 16-point weight set as given in ASTM E 308[15]. Table 5 in ASTM E 308 include 16-point tables (400 nm to 700 nm) for CIE illuminant D65 and both the 1931 (2°) and the 1964 (10°) standard observer functions. A second option is to use the method defined in CIE 15[16].

4.7 Requirements for comparing multispectral images

The multispectral images to be compared shall be based on the same measurement condition. Multispectral images are captured and converted to colorimetric images as specified in 4.6 and then compared as specified in 4.8.

NOTE Direct comparison of spectral data is not defined in this document.

4.8 Requirements for comparing tristimulus images derived from multispectral images

4.8.1 General

The images shall be registered, resampled if needed and converted to CIELAB as specified in 4.6. In this document, the comparison framework is based on computed CIELAB values. This follows the idea of structure similarity index between a master and a test specimen, see [17]. The master specimen is termed reference and the test specimen is termed comparison. The calculation based on sub-areas or patch-like blocks, gave rise to the term SIM_PDE, reflecting the similarity based on “patched distance evaluation “.

Registration may involve rotation, scaling and translation of the tristimulus test image to better align with the reference image.

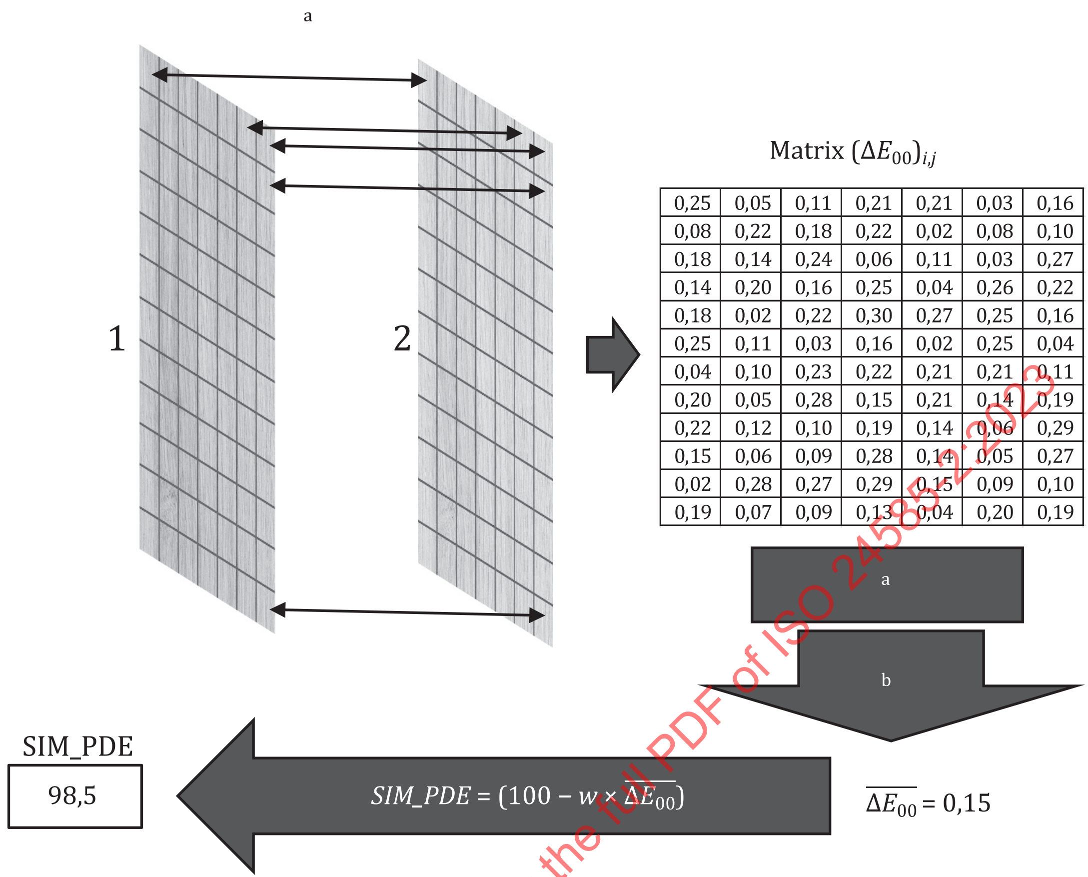
NOTE See References [18] and [19] for further details on how images can be registered to each other.

For the comparison a rectangular region of interest (ROI) is selected from the image of the reference material to represent the first section of data. From the corresponding region of the image of the comparison material, the image section matching the ROI is then registered. The image of the comparison material shall contain at least the image of the ROI in its entirety.

4.8.2 Comparison method

The following method shall be used for comparison between reference and comparison specimen.

The two registered regions are divided into small rectangular areas. The CIELAB values of corresponding areas are calculated and compared using $\Delta E00$ distances. That process is shown in Figure 1 with some example values.



0,25	0,05	0,11	0,21	0,21	0,03	0,16
0,08	0,22	0,18	0,22	0,02	0,08	0,10
0,18	0,14	0,24	0,06	0,11	0,03	0,27
0,14	0,20	0,16	0,25	0,04	0,26	0,22
0,18	0,02	0,22	0,30	0,27	0,25	0,16
0,25	0,11	0,03	0,16	0,02	0,25	0,04
0,04	0,10	0,23	0,22	0,21	0,21	0,11
0,20	0,05	0,28	0,15	0,21	0,14	0,19
0,22	0,12	0,10	0,19	0,14	0,06	0,29
0,15	0,06	0,09	0,28	0,14	0,05	0,27
0,02	0,28	0,27	0,29	0,15	0,09	0,10
0,19	0,07	0,09	0,13	0,04	0,20	0,19

Key

1 reference
2 comparison
a outlier removal
b mean
[a] Block comparison.

Figure 1 — Flowchart computing the similarity index based on the reference and the comparison specimen and exemplary values

Each area, i.e. block, is composed of a size of 3,84 mm × 3,84 mm. For a given image resolution of 125 µm per pixel (approx. 200 dpi) that results in 32×32 pixels, where areas at the image border should be filled with the outer colour values. That results in n areas where n = i*j, with i being the number of areas along the vertical and j the number of areas along the vertical axis. For each area the average CIELAB values is calculated and the ΔE_{00} distances are computed between the corresponding areas. The resulting difference map termed ΔE with *i* lines and *j* rows. In order to avoid negative SIM_{PDE} values a clipping as defined in Formula (2) shall be performed. That processing step shall be followed by an outlier removal step. Here, all blocks with a ΔE_{00} above the 95 % quantile shall be omitted resulting in a number of block values *m*, with $m < n$.

The weighting parameter *w* was chosen by linear scaling with a value of *w*=10, so that a SIM_PDE = 90 is obtained as shown in Formula (1):

$$\overline{\Delta E_{00}} = 1, w = 10, with\ SIM_{PDE} = 100 - w \cdot \overline{\Delta E_{00}} = 100 - 10 \cdot 1 = 90 \tag{1}$$

To avoid negative numbers a clipping step is required, which defines the ΔE_{00} block values as follows. For each block difference, i.e. block value shown as Formula (2):

$$(\Delta E_{00})_{i,j} = \begin{cases} (\Delta E_{00})_{i,j}, & (\Delta E_{00})_{i,j} \leq \dfrac{100}{w} \\ \dfrac{100}{w}, & (\Delta E_{00})_{i,j} > \dfrac{100}{w} \end{cases} \tag{2}$$

With *w*=10 this results in Formula (3):

$$(\Delta E_{00})_{i,j} = \begin{cases} (\Delta E_{00})_{i,j}, & (\Delta E_{00})_{i,j} \leq 10 \\ 10, & (\Delta E_{00})_{i,j} > 10 \end{cases} \tag{3}$$

These distances are averaged for all m blocks using Formula (4):

$$\overline{\Delta E_{00}} = \frac{1}{m} \cdot \sum_{i,j} \begin{cases} (\Delta E_{00})_{i,j}, & (\Delta E_{00})_{i,j} \leq 95\,\%\ quantile\ of\ Matrix\ (\Delta E_{00})_{i,j} \\ 0, & (\Delta E_{00})_{i,j} > 95\,\%\ quantile\ of\ Matrix\ (\Delta E_{00})_{i,j} \end{cases} \tag{4}$$

and the final similarity value is calculated using Formula (5):

$$SIM_{PDE} = 100 - w \cdot \overline{\Delta E_{00}} \tag{5}$$

The SIM_PDE value is calculated analogously to the colour-rendering index and it is dimensionless. For reporting, it shall be rounded to one decimal place.

NOTE In practical situations, the values are understood and communicated as percentage values, e.g. a SIM_PDE=94 is written as SIM_PDE = 94 %. Whilst that is mathematically not correct, it is considered to be practically useful.

5 Data reporting requirements

When data generated in accordance with this document are reported, they shall be accompanied by the following information preferably collected in a one-page protocol:

a) a statement of the used measurements and computations, default: M2 source, 45°:0° geometry, wb, illuminant/observer D50/2°. In case the default settings are used no explicit reporting is required;

b) date and time of last calibration of the multispectral imaging device;

c) date and time when making the reference and comparison image;

d) the measured similarity index (SIM_PDE) and the weighting parameter (w, default w=10) and if present the required SIM_PDE;

e) any departure from the recommended requirements stipulated in this document if present;

f) conformance level as defined in Clause 6.

Optionally the reporting should include:

— a description of the panels being measured;

— a warning light (traffic light system) with indivisibly agreed upon tolerances;

— additional warnings for selected image areas or colour difference channels;

— a description of the instrumentation used, including, but not limited to, the brand, model number and sampling aperture information;

— the wavelength interval used for calculation.

When colour charts such as control patches are measured, the data is to be reported in electronic form and shall be in accordance with ISO 28178.

EXAMPLE 1 Similarity Index according to ISO 24585-2; SIM_PDE = 90,1 %

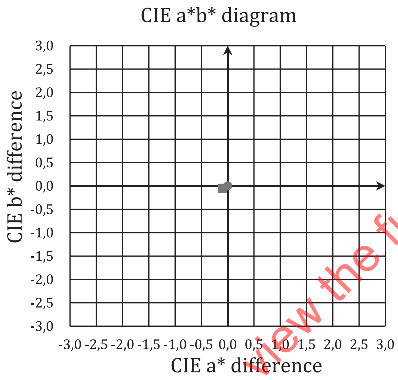
EXAMPLE 2 Similarity Index according to ISO 24585-2; SIM_PDE = 85,1 %, M2, D65/10°, bb

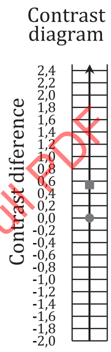
An exemplary protocol is shown in Figure 2.

Customer XYZ

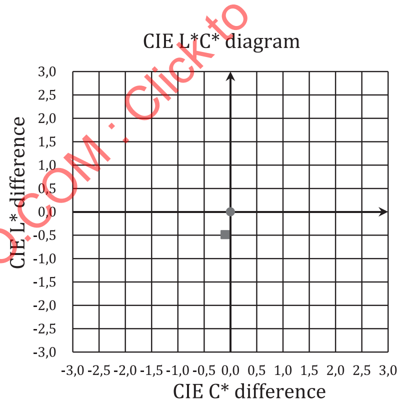
Customer	
Order number	
Customer ID	

Customer order	
Decor ID	
Decor name	





Device	ACMS
Serial Number	ASZ120300125-007
Conformance	Default Setup ISO 24585-2
Filter	No
Geometry	45°/0°
Illumination	D50
Observer	2°
Scan Area	115 × 300mm
Wavelength Interval	380nm-780nm (81 bands)
Master scanned	2022-09-28T13:43+01:00
Sample scanned	2022-09-28T13:45+01:00
Last Calibration	2022-08-27T12:34+01:00



Probe	Symbol	Similarity Index [%]		Clearance
MASTER	●	Target	Actual	
SAMPLE	■	92,00	95,34	✓

Figure 2 — Exemplary protocol that shows a data reporting of a given specimen

6 Conformance

A multispectral imaging system may claim conformance "Default Setup ISO 24585-2:2023" to this document when all default normative parameters of Clause 4 are met. This can be seen in Clause 5 a) and b). In other cases, such as systems using the allowed departures, the conformance statement shall be "Alternative setup according to ISO 24585-2:2023".

Annex A
(informative)

Checklist for specimen preparation

A.1 Overview

In the decorative printing industry, the base papers are often printed with a simulation like a woodgrain or other natural material. The subsequent impregnation with resin in the manufacture of the final product changes the appearance of the paper. It is necessary to carry out a similar impregnation in the laboratory to obtain specimens for appearance assessment. This is done during the make-ready of the print job to ensure that the printed paper will produce the desired appearance when impregnated on the industrial scale. This laboratory-scale impregnation is carried out on a sample of the printed paper, which is then laminated onto a backing board using a pressure plate.

The following information is given to allow interoperability in the development of process automation in the assessment of the appearance of a print during the make-ready to obtain an independent, objective evaluation to get to an OK for a print that matches the proof. This is particularly relevant when repeat orders of a pattern shall be printed months or years after the original run.

A.2 Materials and equipment

The following materials and equipment are necessary to prepare decorative laminates.

A.2.1 Backing board. Backing material cut to the size agreed upon, with agreed thickness and white surface barrier layer. Chipboard is typically used.

A.2.2 Resin. Melamine-formaldehyde resin for furniture or flooring application.

A.2.3 Water, deionized.

A.2.4 Hardener. Amine salts or salts of inorganic acids to be used to initiate crosslinking of the resin.

A.2.5 Form release agent. Mixture of modified surfactants with ester ethylene oxides to avoid adhesion of the resin composition on the pressure plate.

A.2.6 Wetting agent. Mixture of modified surfactants with esterified ethyloxide condensate to ease wetting/penetration of the print.

A.2.7 Cutting device, to cut prints to the desired size.

A.2.8 Pressure plate, typically made from metal with an appropriate size and a defined surface structure.

A.2.9 Lamination press, with a sample chamber of appropriate size, with adjustable temperature and pressure.

