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Graphic technology — Visual opacity of printed white ink

Technologie graphique — Opacité visuelle de l'encre blanche imprimée

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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

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

Methods for measuring the transparency or opacity of printing inks and paints have been described in a number of publications[1]–[4]. Standard methods[1] for paints are based on the reflectance of the colorant when printed over a black background relative to the reflectance of the black background without coloration. The contrast ratio method described in Reference [1] is widely used in the industry for evaluating opacity, but results can vary significantly depending on how it is used especially where white ink printed upon on transparent substrates are measured, or where a standard test substrate is not used.

Methods of measuring opacity and transparency are based on the reflectance of printed and unprinted areas of a substrate. Reflectance is defined as the luminous reflectance factor and expressed as the CIE Y tristimulus value, which is not as perceptually uniform as other derived CIE colour spaces such as 1976 CIELAB. Transparency is related to opacity but is not equal or equivalent to opacity. ISO 2846-1 includes a measure of transparency.

In the transparent imaging model introduced from PDF 1.4, objects can be less than fully opaque, and all of the objects in a stack can potentially contribute to the final appearance of the page. PDF uses the term "solidity" rather than opacity, but these terms are essentially the same. An opacity or "solidity" value of 1,0 describes an ink that completely hides the inks beneath, while a value of 0,0 describes a transparent ink that completely reveals the inks beneath[5], for example a clear varnish. Document creators specify the opacity of one or more inks, and anticipate that this specified opacity is consistent with the visual appearance of both preview and final print. This document is intended to be used to measure the opacity of inks printed using a known configuration of a printing system and so the measured value is not the opacity of the ink per se but of the ink as printed. This aspect is especially important when assessing inks printed using inkjet printers. For the opacity value so measured to be useful, it is important to communicate details of the configuration of the printing system used so that the printing can be repeated.

There is thus a need for a metric for opacity which has better agreement with visual perception. For consistency with the PDF model, it is expected that the metric produces values in the range 0 to 100 for fully transparent and fully opaque prints respectively. These requirements exclude the use of the contrast ratio metric.

The method described in this document was tested using the data reported in Reference [6], and it was shown to correlate well with the visual perception of opacity.

This document is limited to the opacity of "opaque" white inks, as the published work cited in this document was limited to the evaluation of such inks. A method is described in Annex A showing how this document could be extended to test coloured inks. We anticipate that in the future this standard could be extended if there is a need and adequate experimental data. For this reason, the visual opacity metric defined in this document is not the simplest formula that fits the experimental data, but is one that gives good results and can readily be extended to colour inks and substrates if required. The metric is based on functions used in the Spot Colour Tone Value (SCTV) defined in ISO 20564.

Opaque white inks are formulated to be relatively opaque to light in order to hide any underlying matter, in contrast to "transparent" white inks which are formulated to permit transmission of light and are commonly used to extend coloured inks. For the purpose of this document, white ink is an ink formulated with an opaque white colorant that has a neutral colour and a reflectance factor greater than 80 %, and which is intended to have high opacity.

This document is also limited in the range of substrates to which it is intended to apply. Substrates should be either transparent, or have a CIELAB L* lightness of 80 or above and a CIELAB C^*_{ab} chroma of 20 or less.

Various factors can affect the appearance of opacity on a given substrate, including the presence of optical brightening agents in the ink or substrate, and to minimize such effects, it is assumed that the material is viewed and measured under standard conditions, where the viewing condition is defined by ISO 3664[7] P1 or P2 condition and the measurement by ISO 13655 M1 condition.

Graphic technology — Visual opacity of printed white ink

1 Scope

This document specifies a method of measuring the visual opacity of printed specimens of white ink. It is applicable to printing opaque white ink on transparent and white or coloured opaque substrates.

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*

3 Terms and definition

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

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

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

— IEC Electropedia: available at http://www.electropedia.org/

3.1
contrast ratio
ratio of the reflectance of an ink film on a black substrate to that of an identical ink film on a white substrate

3.2
opacity
ability of a film or sheet of material, such as ink, paint or paper, to hide a surface behind and in contact with it

3.3
opaque white
colorant formulated to have a neutral colour and a reflectance factor greater than 80 %, and which is intended to have high *opacity* (3.2)

4 Requirements

4.1 General

Depending on the needs of the final product, white ink may be printed directly on to the substrate, to form a base for other inks to be printed on top, or it may be printed on top of other inks, especially where the substrate is transparent and intended to be viewed from the reverse side. The substrate may be a transparent film or an opaque material such as paper or board.

4.2 Specimen preparation

4.2.1 General

A test chart is prepared which comprises four regions:

— unprinted substrate (S),

— ink on substrate (IS),

— black printed region (B), and

— ink on black printed region (IB).

Test charts shall be prepared on either a test substrate or a production substrate and measured as described in 4.3. A standard test substrate, such as the reference substrate described in ISO 2846–1:2017, Annex A gives more consistent results, for example to allow comparisons to be made between different printing systems, but in some situations (such as printing using inkjet) it may not be feasible to print on a test substrate and in such cases a substrate of the type used in production may be used. The latter method is only recommended when the production substrate has a significantly lower Y value than the substrate of the test chart.

The test chart substrate shall have a CIE tristimulus value Y of 80 ± 2 (i.e. a CIELAB L* of 92 ± 1). The black region shall have a CIE tristimulus value Y of 5 (CIELAB L* of 27,7) or less. A black test substrate can be used for the black regions, in which case it shall have a CIE tristimulus value Y of 5 or less.

NOTE 1 These values have been chosen to correspond to the ISO 6504-3 test chart.

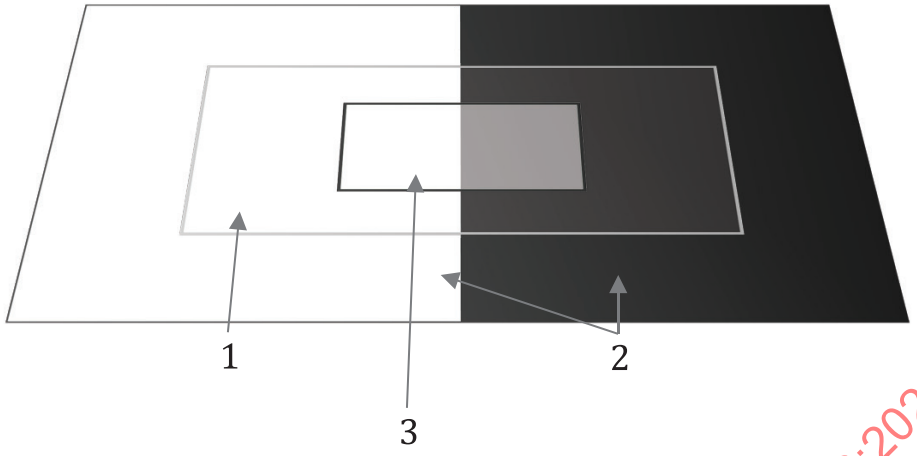
NOTE 2 The requirements for the white test substrate correspond to the test substrate defined in ISO 2846-1

Preparation of samples for different substrates is described in 4.2.2. In all cases the ink density should be the same, or very similar, to that used for production printing.

4.2.2 Printing on transparent substrates

A test form comprising a region of white ink of at least 4 cm × 2 cm shall be printed on the transparent substrate using the printing system configured as intended to be used for production.

This printed test form shall be fixed to a standard opacity test chart so that roughly half of the region of white ink is placed over the black region with the remainder placed over the unprinted test substrate as shown in Figure 1.



Key

1 transparent test substrate

2 pre-printed opacity chart

3 region printed with white ink (minimum size: 4 cm × 2 cm)

Figure 1 — White ink on transparent substrate

The substrate should be fixed to the opacity test chart in the same way as the production prints are fixed to the final product. For example, the printed side of the substrate may be positioned so that the printed side is in contact with the product, the transparent substrate may be fixed with adhesive to the product, heat may be applied to shrink the transparent substrate and so on.

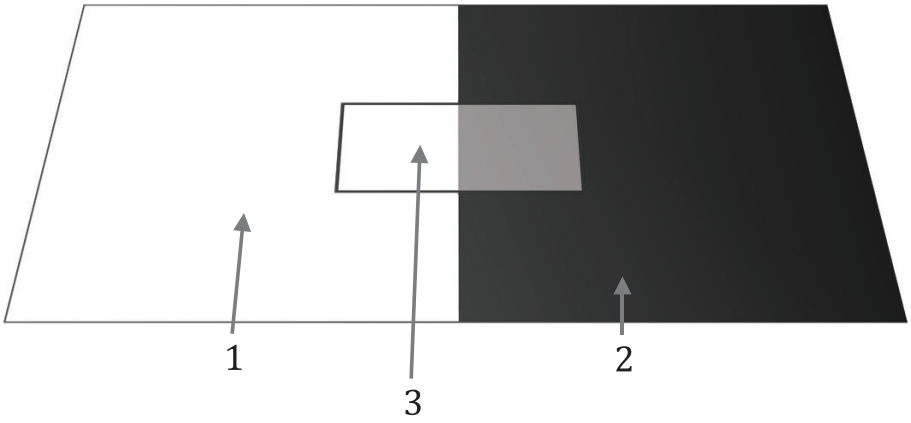
4.2.3 Printing on the test substrate

The ink to be tested shall be printed across a region of the test substrate including a minimum area of 2 cm × 2 cm on both the black region and the substrate.

4.2.4 Printing on production substrate

In many cases, especially when printing using digital printing systems, it is desirable to measure the opacity of an ink as printed by the system on a specific substrate. Examples include printing on melamine or similar plastic substrates.

In this case, a region of the substrate shall be printed with the black process ink. This region should be allowed to dry. When dry, the white ink shall be used to print a region of at least 4 cm × 2 cm half of which should overlap the black region as shown in Figure 2.



Key

1 production substrate

2 black region printed with process black ink

3 region printed with white ink (minimum size: 4 cm × 2 cm)

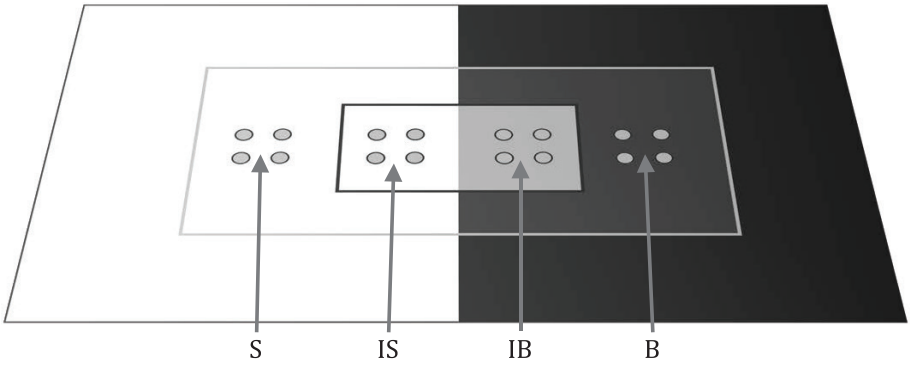
Figure 2 — Printing on production substrate

4.3 Measurements

CIE XYZ measurements of printed and unprinted specimens for the purpose of determining visual opacity shall be made according to ISO 13655, using 45°:0° (or 0°:45°) geometry and, CIE Illuminant D50 for colorimetric computation. The measurement condition should be M1. Where this is not possible, measurement conditions M0 or M2 may be used. In that case, the measurement condition used shall be reported. Where the region being measured (which may be a combination of print and opacity test chart) is not completely opaque, measurements shall be made using white backing.

All measurements for opacity tests shall be made using the same measurement condition. When comparing measurements made using different instruments, the second set of measurements should use the measurement conditions reported by the first one.

CIE XYZ measurements shall be made of the four regions shown in Figure 3. If using a measurement aperture of 4 mm or less, a minimum of four measurements should be made at different points across each region and their mean value recorded. If using a larger aperture of 6 mm, 8 mm or 10 mm, readings at only two different points are required.



Key

S substrate
IS ink on substrate
IB ink on black region
B black region

Figure 3 — Measurement points

4.4 Calculation of opacity

4.4.1 General

Visual opacity shall be calculated by the method in 4.4.2. Figure 4 illustrates the four regions of unprinted substrate (S), ink on substrate (IS), black printed region (B) and ink on black printed region (IB) whose measurements are used in the calculations.

Key

S substrate
IS ink on substrate
IB ink on black region
B black region

Figure 4 — Measurement regions for substrate and ink

Visual opacity is defined from measurements of the white ink printed upon white and black regions, as in 4.4.2.

4.4.2 Visual opacity

Visual opacity shall be expressed as Formula (1):

$$O_V = \frac{V_{IBy} - V_{By}}{V_{ISy} - V_{By}} \tag{1}$$

where

$$V_{IBy} = f\left(\frac{Y_{IB}}{Y_S}\right) \cdot 116 - 16;$$

$$V_{By} = f\left(\frac{Y_B}{Y_S}\right) \cdot 116 - 16; \tag{2}$$

$$V_{ISy} = f\left(\frac{Y_{IS}}{Y_S}\right) \cdot 116 - 16;$$

and where

$$f(u) = (u)^{\frac{1}{3}} \quad \text{if } u > \left(\frac{6}{29}\right)^3$$

$$f(u) = \left(\frac{841}{108}\right) \cdot (u) + \left(\frac{4}{29}\right) \qquad \text{if } u \leq \left(\frac{6}{29}\right)^3 \tag{3}$$

where

u is either (Y_{IB}/Y_S) or (Y_B/Y_S) or (Y_{IS}/Y_S);

Y_{IB}, Y_B, Y_{IS}, Y_S are the CIE Y measurements of the regions *B*, *IB*, *IS* and *S*, respectively.

NOTE Formulae (1) to (3) result in substrate-relative values and are similar to those for the calculation of SCTV in ISO 20654.

4.4.3 Extension of visual opacity calculation for coloured inks and substrates

Although there is currently no empirical data to support the extension of the visual opacity metric to inks or substrates with a colour other than white, such a metric is envisaged and is described in Annex A.

5 Reporting

The following shall be reported:

a) visual opacity according to this document, i.e. ISO 23498:2020;

b) information regarding the inks and printing systems used;

c) the printing system used and the printing conditions;

d) a description of the substrate used, i.e. whether a test substrate or production substrate, and if the latter the characteristics of the substrate including:

   1) CIE XYZ measurements made according to ISO 13655;

   2) the type of material (e.g. paperboard, plastic, etc.);

