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Graphic technology — Process control — Certified reference material for opaque area calibration of transmission densitometers

Technologie graphique — Maîtrise de procédé — Matériel de référence certifié pour la calibration des densitomètres transmission en pourcentage de superficie opaque

Reference number
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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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Annexes A to E of this International Standard for information only.

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Introduction

In the graphic arts, the modulation of transmittance or reflectance is often achieved by printing half-tones rather than continuous tones, as would be the case in photography.

The process control of the generation and transfer of half-tone patterns is essential to the graphic arts industry. For the process control of transmission type material one monitors the percentage of the total area that is virtually opaque. Measurements are carried out on well-defined half-tone control patches which contain regularly-spaced, circular half-tone dots. The measuring instrument is either a densitometer or a colorimeter of the spectrophotometer or tristimulus type. The opaque area percentage is usually set equal to the ratio of the relative transmittance factors of the half-tone and that of the solid. With densitometers one calculates the transmittance factors from the ISO standard diffuse (opal) densities, the corresponding expression for the ratio has been given by Murray and Davies, see [E.2] and equations (1) and (2) of clause 3.

In principle, the opaque area percentage for positive-polarity films should be identical to the tone value as defined in the graphic arts; for negative-polarity films it should be identical to 100 % minus the tone value. In reality, however, there may be errors which produce small deviations between the two quantities; there is thus a need for an independent check on the determination of the tone value by densitometers and colorimeters.

In the graphic arts process chain, particularly important steps are "image setting", "film duplication" and "platemaking". During these steps, there is no highly diffusive medium present which could be compared to the opal-glass diffuser of densitometers according to ISO 5-2 [E.3]. It would thus appear that the opal-glass instrument is not the best solution for graphic arts applications. However, the opal-glass design permits a relatively simple construction; such instruments are widely used in the graphic arts industry.

When calibrating a densitometer with a stepped density reference material (at least two steps), usually both the zero point and the slope factor are adjusted. The latter is the ratio of the density difference between the steps as read by the densitometer and the density difference as reported by a national standardizing laboratory. If the ratio deviates from 1, the base of the logarithm used for converting transmittance factor into transmittance factor density is not 10 as required by definition. As a consequence, the tone values calculated from the densities may deviate from the opaque area percentages. It is important to note that the (absolute) ISO standard diffuse density calibration of a densitometer may be dependent on the thickness of the sample. The stepped density reference material used for the density calibration should therefore have the same thickness as the samples to be measured, otherwise only relative densities can be measured. For many graphic arts applications, however, absolute density measurements are not the issue but the control of the opaque area percentage of half-tone film. This quantity determines the size of image elements, such as half-tone dots or lines, produced by transfer steps such as film duplication and platemaking. The densitometer is then zeroed on the clear film and the densities of a half-tone and a solid are measured. The Murray-Davies-formula, [E.2] and equations (1) and (2) of clause 3, is used to determine tone values from the density values, see also ISO 12647-1.

It is known that transmission densitometers of the opal type are subject to multiple oblique-angle interreflections between the opal and the surfaces close to it, see ISO 5-2 [E.3]. These include the two surfaces of the sample and those on the side of the instrument opposing the opal. For samples of low density, reflections from all those surfaces may contribute to the efflux measured at the back of the opal. At (absolute) ISO standard diffuse densities near zero, the densities read by an opal instrument are thus slightly lower than those of a diffuse sphere type instrument; 0,03 is a typical difference. This effect has to be taken into account if transmission densities or reflectance factors read by instruments of different design are compared. For samples of higher densities, the reflections from all surfaces but the surface next to the opal are effectively suppressed. During the measurement of a half-tone pattern, the latter influences the interreflection effect in two ways: The image elements may have a reflectance different from the film base, they also tend to attenuate reflections from surfaces further removed from the opal. Therefore, the tone values determined from densities measured with an opal instrument may differ from the actual opaque area percentage of the sample which can be determined by microscopic measurement or by a sphere type instrument (which does not show the interreflection effect).

ISO 12647-1 specifies that transmission densities shall be measured by instruments complying to ISO 5-2, thus there can be no ambiguity when quoting (absolute) ISO standard diffuse densities such as clear film densities.

The interreflection effect can be artificially attenuated if the opal is kept at a distance of, say, 25 mm from the measured object. Another method is to place a neutral filter with a density of at least 0,3 between the opal and the sample. The filter tends to attenuate the light coming back from the opal towards the sample and also the reflections.

The interreflection effect may produce a discrepancy of typically 3 % between the tone value of a half-tone as determined with a transmission densitometer of the opal type and the opaque area percentage as determined from independent measurements of the dot pattern. The discrepancy cannot be circumvented by proper zeroing or adjustment of the slope factor of the instrument, it depends on the magnitude of the opaque area percentage. Thus there is a need for an independent check on the tone value determination by a transmission densitometer and, if necessary, the establishment of a table that converts tone values into opaque area percentages. This International Standard specifies requirements for two types of reference materials that provide half-tone control patches with dot patterns of accurately defined dimensions that may serve as "Certified reference materials" (CRM) if the requirements of ISO 15790[1)] are also fulfilled.

Reference materials may be produced from half-tone film material or a thin glass slab with a chromium deposit. The latter's advantages are a very small fringe width, a wavelength-independent attenuation and a good uniformity of opaque area percentage over the control patch. The thickness, the scattering properties and the wavelength dependence of the transmission density differ from those of graphic arts film material. It might thus be suspected that this invalidates the use of such a reference material as a standard. It has been shown, however, that thickness changes of less than 1 mm shift only the zero point of a densitometer, thus the densitometric opaque area percentage calculation is not affected. Other test series showed that interposing films of varying scattering properties between the chromium/glass reference material and the opal did not affect the opaque area percentage determination, within the measurement accuracy. The absence of a wavelength dependence can be regarded as an asset: Since the wavelength dependencies of graphic arts films differ much from each other, there is no established dependence that could be used for such a reference material.

1) See informative annex E.

Graphic technology — Process control — Certified reference material for opaque area calibration of transmission densitometers

1 Scope

This International Standard defines requirements for a half-tone certified reference material which may be used for the opaque area percentage calibration of transmission densitometers or colorimeters for use in the graphic arts. This International Standard is not applicable to the calibration of transmission densitometers in terms of ISO standard diffuse density.

NOTE Test methods for determining the opaque area percentage are given in the informative annex A.

2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 12647-1:1996, *Graphic technology — Process control for the manufacture of half-tone colour separations, proof and production prints — Part 1: Parameters and measurement methods.*

3 Definitions

For the purposes of this International Standard, the definitions given in CIE 17.4 and the following apply. They are given in alphabetical order.

NOTE For quantities, the preferred unit is given together with the definition. By definition, the unit of formerly so-called “dimensionless quantities” is 1.

3.1
control patch
area produced for control and measurement purposes
[ISO 12647-1]

3.2
core density
transmission density in the centre of an isolated opaque image element such as a half-tone dot or line
Unit: 1
[ISO 12647-1]

3.3
fringe width (of an isolated opaque image element)
average distance between the density contour lines corresponding to 10 % and 90 % of the minimum core density specified for the printing process under consideration
Unit: µm
[ISO 12647-1]

3.4
opaque area percentage
P
percentage of total area that is nearly opaque to radiation in the wavelength range of interest

3.5
polarity (of a transmission object)
positive if clear and solid areas on the object correspond to unprinted and solid areas on the print, respectively. Negative if clear and solid areas on the object correspond to solid and unprinted areas on the print, respectively

3.6
screen ruling
screen frequency
f
number of image elements, such as dots or lines, per length in the direction which produces the largest number
Unit: cm^{-1}
[ISO 12647-1]

3.7
screen width
reciprocal of screen frequency
Unit: cm
[ISO 12647-1]

3.8
tone value
dot area (on a transmission object of positive polarity)
A
percentage calculated from the formula:

$$A = 100\,\% - \frac{1 - 10^{-(D_t - D_0)}}{1 - 10^{-(D_s - D_0)}} \cdot 100\,\% \qquad \text{. . . (1)}$$

where

D_0 is the transmission density of the clear substrate;

D_s is the transmission density of the solid;

D_t is the transmission density of the half-tone.

[ISO 12647-1]

NOTE Also known as film printing dot area.

3.9
tone value
dot area (on a half-tone object of negative polarity)
A
percentage calculated from the formula:

$$A = 100\,\% - \frac{1 - 10^{-(D_t - D_0)}}{1 - 10^{-(D_s - D_0)}} \cdot 100\,\% \qquad \text{. . . (2)}$$

where

D_0 is the transmission density of the clear substrate;

D_s is the transmission density of the solid;

D_t is the transmission density of the half-tone.

[ISO 12647-1]

NOTE Also known as film printing dot area.

4 Requirements

4.1 Materials

The substrate shall consist of a clear material with a pattern of opaque half-tone dots on one side. At normal incidence the (absolute) reflectance factor (front and second surface) shall not be higher than 0,05.

4.2 Thickness

The nominal thickness shall be selected from the range 0,1 mm to 0,8 mm. The measured thickness shall not vary by more than 0,01 mm across the certified reference material.

4.3 Half-tone pattern

The certified reference material shall show control patches whose minimum sizes shall be greater than 5 mm in diameter and should not be smaller than 10 mm in diameter. The shape of the half-tone dots shall be nominally circular. The screen ruling shall be selected from the range 50 cm^{-1} to 70 cm^{-1}, it shall be constant over the certified reference material.

The certified reference material shall show control patches with at least the following opaque area percentages:

- circular opaque half-tone dots: 20 % or 25 %, 50 %;
- circular clear half-tone dots: 75 % or 80 %.

In addition, control patches showing 0 % and 100 % (solid) shall be provided. Control patches with 2 % and 98 % should be provided as well.

Deviations of 1 % (absolute) shall be permitted for the choice of the nominal opaque area percentage. All control patches should be labelled with the nominal opaque area percentages.

The fringe width of the half-tone dot pattern (see the informative annex D) should not be greater than 2 µm as determined by the apparatus described in ISO 12647-1. The ISO Status A (blue) and the ISO visual standard diffuse transmission density of the solid (opaque) control patch shall exceed 4,00, the core densities of the half-tone dots shall exceed 3,00.

The ISO Status A (blue) transmission density and the ISO visual standard diffuse transmission density of the clear substrate shall not exceed 0,04, the ISO type 1 printing density of the clear substrate shall not exceed 0,06. All clear areas shall have the same density.

NOTE In case of a chromium/glass certified reference material the transmission densities of the solid will exceed 5,00 if care has been taken to avoid pinholes.

4.4 Reporting and accuracy

The measured opaque area percentages of the control patches of the certified reference material shall be reported together with their associated standard uncertainties. If only a single standard uncertainty is reported this shall be the greatest value for any one of the reported control patches. The uncertainties shall not exceed 0,6 %.

The difference between the measured opaque area percentage and that labelled shall not exceed 1 % for values between 5 % and 95 % and 0,6 % elsewhere. The opaque area percentage difference between any two 2 mm diameter areas of a control patch shall not exceed 0,6 %.

NOTE If the requirements of ISO 15790 are fulfilled, the reference material is termed "Certified reference material" (CRM).

4.5 Traceability

The determination of the reported opaque area percentages shall be traceable to a national standardizing laboratory. Test methods for determining the opaque area percentages of control patches of a certified reference material are given in annex A.

Annex A
(informative)

Test methods for opaque area percentage

A.1 Dimension

Measure the average radius of opaque or clear half-tone dots and their screen ruling on a control patch by means of a calibrated microscope. Calculate for opaque dots

$$P_g = \pi \times r^2 \times f^2 \times 100\ \% \qquad \text{. . . (A.1)}$$

for clear dots

$$P_g\ (\%) = (1 - \pi \times r^2 \times f^2) \times 100\ \% \qquad \text{. . . (A.2)}$$

where

P_g is the opaque area percentage determined from the geometry;

r is the average radius of the half-tone dots;

f is the screen ruling.

A.2 Transmittance factor

With the aid of a integrating sphere instrument measure the transmittance factors of the control patches, including the clear substrate (0 %) and the solid (100 %). Calculate the quantity

$$P_t = \frac{T_0 - T_t}{T_0 - T_s} \cdot 100\ \% \qquad \text{. . . (A.3)}$$

where

P_t is the opaque area percentage determined from transmission measurement;

T_0 is the transmittance factor of the clear substrate;

T_s is the transmittance factor of the solid;

T_t is the transmittance factor of the half-tone.

Annex B
(informative)

Calibration of a transmission densitometer in terms of opaque area percentage

B.1 Principle: As explained in the introduction, an opal densitometer zeroed on the clear substrate will not read the correct opaque area percentages in the mid-tone because of the influence of interreflections at low opaque area percentages. For practical purposes, the mid-tone range is most important. It is therefore useful to adjust the zero point such that the instrument gives the correct value on the 50 % patch of the certified reference material, see B.3. In this case, the instrument will not read 0 on the clear substrate, but a negative value that is caused by the extra light that enters the opal due to the interreflection effect.

B.2 Take a densitometer which conforms to ISO 5-2 and measures ISO standard diffuse density. Set it to the density mode. In order to assure sufficient accuracy, the effective measurement aperture of the densitometer should have a diameter of at least 15 times the screen width; it is not advisable to use diameters below 10 times the screen width. Calibrate the instrument according to the manufacturer′s instructions.

B.3 Put a certified reference material which is in conformance with 4.1 to 4.5 in the light path of the densitometer and orient the side bearing the opaque layer towards the diffuser (opal). Adjust the zero point of the densitometer such that when it is placed on the control patch labelled with “50 %” it reads the following relative ISO standard diffuse density

$$-\lg[(100\ \% - P_{50})/100\ \%] \qquad \text{. . . (B.1)}$$

where

P_{50} is the opaque area percentage reported for the “50 %” patch;

lg is the logarithm to base 10.

NOTE Many densitometers do not provide an independent adjustment of the zero point. Rather, the instrument is set to zero by pressing a button while measuring the desired reference. In this case, the setting of the zero point described in B.3 can be accomplished by zeroing the instrument on a suitable sample selected by trial and error. Useful samples are clear films and those with half-tone patches in the range opaque area percentages from 0,5 % to 7 %.

B.4 Read the control patch labelled with the highest opaque area percentage P_1 and set the slope of the instrument such that it reads the following relative ISO standard diffuse density

$$-\lg[(100\ \% - P_1)/100\ \%] \qquad \text{. . . (B.2)}$$

where

P_1 is the opaque area percentage reported for the measured patch;

lg is the logarithm to base 10.

Repeat the procedures of B.3 and B.4 to insure that the values obtained are within the tolerance.

B.5 Read the relative ISO standard diffuse density of the solid control patch. If the density exceeds 4,00 or if the densitometer shows the maximum reading as specified by the manufacturer, continue with B.6. If the density does not exceed 4,00, the solid area is damaged or the densitometer is not in order.

B.6 Set the densitometer to the tone value mode. Measure the control patches with opaque area percentages above 50 %. If the difference between the measured tone values and the reported opaque area percentages exceed 1 %, the densitometer needs to be calibrated in terms of opaque area percentage. See B.8.

B.7 For the control patches with an opaque area percentage of 50 % and below, place a thin neutral density filter film with a ISO standard diffuse density of approximately 0,3 between the certified reference material and the diffuser (opal) of the densitometer such that the emulsion side of the neutral density filter is in contact with the side of the reference material that bears the opaque layer. Set the instrument to the “density” mode. Adjust the zero point setting such that the density calculated in B.3 is indicated for the 50 % control patch. Set the instrument to the “tone value” mode and measure the patches at and below 50 %. If the difference between the measured and the reported opaque area percentages exceeds 1 %, the densitometer needs to be calibrated in terms of opaque area percentage. See B.8.

B.8 Measure the control patches of the certified reference material with the instrument set to the “tone value mode”. Record the measured values in a table together with the opaque area percentages reported on the certificate. Use this calibration table or a graph prepared from it to convert measured values into opaque area percentages.

NOTE It is evident that colorimeters can be also calibrated in terms of opaque area percentage using an analogous procedure.

Annex C
(informative)

Opaque area percentage determination for a half-tone film

C.1 Take a transmission densitometer conforming to ISO 5-2 (geometry 0°/d or d/0°, “opal”), and calibrate it in terms of opaque area percentage as described in annex B. Orient the colour separation film with the emulsion side towards the diffuser (opal) of the densitometer. Put a thin neutral density filter film with a ISO standard diffuse density of approximately 0,3 between the diffuser and the half-tone film. The emulsion of the filter film should face the emulsion side of the colour separation film.

C.2 Leave the neutral density filter in place. Set the density to zero on the clear film (film base plus fog). Set the densitometer to the “tone value” mode. If this is not possible, continue with C.3. Read the value of the control patch in question and convert it into opaque area percentage with the conversion table generated by the method described in annex B. When reporting results, describe the measurement conditions using the style specified in ISO 5-2.

C.3 Leave the neutral density filter in place. Determine the ISO standard diffuse densities of the clear film (base plus fog), of the half-tone and of the solid. Calculate the tone value from the equation given in 3.8 and convert it into opaque area percentage with the conversion table generated by the method described in annex B. When reporting results, describe the measurement conditions using the style specified in ISO 5-2.

Annex D
(informative)

Determination of quality parameters of half-tone dots on a colour separation film[2)]

D.1 A simple qualitative method is to place a control strip film with a microline target, film emulsion orientation up, on a light table and to cover it with the film to be evaluated, film emulsion orientation down. With a hand-held microscope of between 60 and 100 fold magnification, observe the isolated opaque half-tone dots which are found in those parts of the half-tone film, of positive or negative polarity, that appear lighter. If the microlines are distinctly visible below the half-tone dots then the core density is too low. The fringe width can be estimated by comparing it to the width of the microlines which is stated on the microline target. The colour separation film should be illuminated from below by light of oblique angles of incidence, a condition known as dark field illumination. With some experience, the compliance of half-tone dots to a specified maximum fringe width can be predicted with near certainty.

D.2 A quantitative method may be obtained using a scanning microdensitometer. This is an instrument in which, for instance, the illumination stage of a transmission microscope is equipped such that an aperture, with an adjustable diameter of 3 µm or less, is formed in the centre of the object plane. The film is moveable, in a controlled way, in both x and y directions of the object plane. As the film is moved, the light intensity transmitted by the film is measured with a photodetector which has been calibrated in terms of transmission density. The data may be presented graphically either as a density profile across a half-tone dot, see figure D.1, or by drawing contour lines that connect points of equal density, see figure D.2.

2) Taken from ISO 12647-1.