BRITISH STANDARD

BS ISO 13656:2000

Graphic technology — Application of reflection densitometry and colorimetry to process control or evaluation of prints and proofs

ICS 17.180.20; 37.100.01

National foreword

This British Standard reproduces verbatim ISO 13656:2000 and implements it as the UK national standard.

The UK participation in its preparation was entrusted to Technical Committee PAI/43, Graphic technology, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

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Summary of pages

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The BSI copyright notice displayed in this document indicates when the document was last issued.

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INTERNATIONAL STANDARD

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Graphic technology — Application of reflection densitometry and colorimetry to process control or evaluation of prints and proofs

Technologie graphique — Application de la densitométrie par réflexion et de la colorimétrie pour la maîtrise ou l'évaluation des procédés des imprimés et épreuves

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 13656 was prepared by Technical Committee ISO/TC 130, *Graphic technology*.

Annexes A to C of this International Standard are for information only.

Introduction

Reflection densitometers and reflection colorimeters (of tristimulus photometric or spectrophotometric type) are both reflectometers measuring the reflectance factor of reflection copy materials. Densitometers conforming to ISO 5-4 and ISO 14981, and colorimeters conforming to ISO 13655 possess a common geometry type, namely either 0°/45° or 45°/0°. It is further specified in ISO 5-4 that densitometric measurements shall be made on a specified black backing; ISO 13655 specifies the same condition for colorimetry in graphic arts. Finally, it is noted that reflectometers of the spectrophotometer type can, in principle, be used as both a densitometer and as a colorimeter.

Notwithstanding the similarities of the instruments, there are fundamental differences between them. The first of these is that the typical densitometer used in graphic arts, as its name implies, displays density values (logarithm of the reciprocal of a weighted average of the spectral reflectance factor) although it may also display other parameters calculated from these values. A colorimeter, on the other hand, normally displays differently weighted averages of the spectral reflectance factor, although frequently it can also display various transformations from these values which may be required for a number of reasons. One such reason is the need to define a more uniform colour space such as CIELAB.

ISO 5-3 requires that for reflection densitometry the incident flux has a spectral power distribution that conforms to CIE illuminant A. In colorimetry, ISO 13655 specifies a spectral power distribution that conforms to CIE illuminant D50 but accepts that such a source is not easily realisable. It requires that D50 be used to calculate the tristimulus values which, together with the weighting functions specified, effectively defines the spectral response whether it be achieved by the use of filters or calculation from spectrophotometric data. In practice most colour measurements in graphic arts today are made with spectrophotometers using a source with a spectral power distribution similar to illuminant A. The measured spectral reflectance data is used to calculate both densitometric and colorimetric data and illuminant D50 is used to calculate the tristimulus values as specified in ISO 13655. The implication of this for colour measurement is that it gives erroneous results when samples fluoresce.

The aim of colorimetry is to provide an instrument response which simulates, as well as possible, that of the standard observer. In graphic arts, colorimetry serves mainly for colour matching and the establishment of colour standards. The availability of inexpensive, hand-held colorimeters, with small sampling apertures, has also permitted the use of colorimetry in process control as a complement to densitometry.

Densitometers are primarily designed for indirect measurement and control of the amount of colorant material of a specified type present in, or on, a substrate. ISO 5-3 defines a number of statuses, each of which is deemed appropriate for a particular application. The primary aim of densitometry for graphic arts is to monitor the amount of colorant per area on a print or proof. For a half-tone print this is a function of the ink film thickness and tone values. However, densitometry is also used for the determination of other process control quantities. A distinctly different task is the evaluation of the density ranges of colour separation input material; this type of densitometry is not covered by this International Standard.

Historically, colour densitometers for reflection type material were first used in preparation for colour separation for determining the density ranges of continuous-tone, coloured original artwork, as measured through the wide-band filters used for colour separation. As the quality of the printed products improved, however, reflection densitometers were also applied to process control in printing. Here, the areas measured consist typically of single-colour patches contained in control strips, printed with the process colours cyan, magenta, yellow and black.

For the control of the chromatic colours, especially yellow, it was later discovered that measurements made with narrow-band filters, each centred on the main absorption maximum of one of the process ink colorants, provided features which can be advantageous for certain control applications. These are:

— reduction of the influence of slight hue shifts on density,

— bringing the yellow densities and tone values within the range of those of cyan and magenta,

— improvement of inter-instrument agreement,

— extension of the linear relationship between density and ink film thickness to higher densities,

— reduction of the magnitude of density additivity failure.

It was also found that the readings obtained from densitometers with a means for cross-polarisation to minimise the influence of first-surface reflection were less affected by ink dry-back. Polarisation also contributes to the last two features above. The need for the instrument designer to correct for it in computing the spectral response is described in ISO 5-3 and also in annex B of this International Standard. Standardisation of the minimum efficiency of polarisation is covered by ISO 14981.

The wide range of applications for which densitometry is used, mean that both wide and narrow band instruments, as well as the optional use of polarisation, are in common use in graphic arts. Furthermore, colorimetry is becoming increasingly widely used and all of these options present many alternatives for process measurement within the industry. It is for this reason that this International Standard has been produced. Since the industry increasingly needs to communicate process control information between various participants in production it is essential that this be defined unambiguously. By defining terms, specifying preferred test methods and the requirements for control strips, and defining reporting procedures, such ambiguity should be kept to a minimum.

Many of the parameters measured or calculated in graphic arts process control, including some of those defined later in this International Standard, do not require any specific spectral response to be effective. They are comparative measurements and are in many cases calculated directly from the reflectance data from which density and colorimetric parameters are themselves derived. In isolated production environments various parameters, each of which may be derived from any reasonable spectral product, can be equally effective for process control. It is not the intent of this International Standard to preclude their continued use in such a situation. However, in some situations there are advantages in using specific parameters or spectral products and, furthermore, to aid communication in a distributed production environment it is essential that graphic arts metrology is based on agreed procedures. It is in this context that this International Standard specifies colorimetric and densitometric test methods for the most common process control procedures in graphic arts and specifies the reporting procedures to be employed.

Graphic technology — Application of reflection densitometry and colorimetry to process control or evaluation of prints and proofs

1 Scope

This International Standard applies to process control and evaluation of single and multi-colour proofing and printing in the graphic arts using densitometry and colorimetry. This International Standard:

— defines terms;

— specifies minimum requirements for control strips;

— specifies test methods;

— specifies reporting procedures for the results.

2 Normative references

The following normative documents contain 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 editions of the normative documents 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 5-3, *Photography — Density measurements — Part 3: Spectral conditions.*

ISO 5-4, *Photography — Density measurements — Part 4: Geometric conditions for reflection density.*

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

ISO 12647-2, *Graphic technology — Process control for the manufacture of half-tone colour separations, proof and production prints — Part 2: Offset lithographic processes*.

ISO 12647-3, *Graphic technology — Process control for the manufacture of half-tone colour separations, proofs and production prints — Part 3: Coldset offset lithography and letterpress on newsprint*.

ISO 12647-4[1)], *Graphic technology — Process control for the manufacture of half-tone colour separations, proof and production prints — Part 4: Gravure processes*.

ISO 12647-5[1)], *Graphic technology — Process control for the manufacture of half-tone colour separations, proof and production prints — Part 5: Screen printing*.

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

1) To be published.

ISO 14981[1)], *Graphic technology — Process control — Optical, geometrical and metrological requirements for reflection densitometers for graphic arts use*.

ISO 15790[1)], *Graphic technology and photography — Reflection and transmission metrology — Documentation requirements for certified reference materials, procedures for use, and determination of combined standard uncertainty*.

DIN 16536-2:1995, *Colour density measurements on on-press or off-press prints; Part 2: Instrument specifications for reflection densitometers and their calibration*.

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply; they are given in alphabetical order. Where appropriate they have been taken directly from the CIE International Lighting Vocabulary, ISO 5-1 to 5-4, ISO 12637-1 and ISO 12647-1 as indicated at the end of the definition.

3.1
aperture
see sampling aperture

3.2
colorimeter
instrument for measuring colorimetric quantities, such as the tristimulus values of a colour stimulus

[International Lighting Vocabulary 845-05-18]

NOTE A tristimulus colorimeter achieves this by the analogue integration of the spectral product of object reflectance or transmittance factor, illuminant and filters which are defined by the standard observer functions. A spectrophotometric colorimeter achieves this by calculation from the spectral reflectance or transmittance factor data.

3.3
control patch
area produced for control or measurement purposes

[ISO 12647-1]

NOTE This definition is independent of whether the control patch is produced on film, a printing forme or a print substrate by conventional or direct methods.

3.4
control strip
one-dimensional array of control patches

[ISO 12647-1]

3.5
core density (on a half-tone film)
transmittance density in the centre of an isolated opaque image element such as a half-tone dot or line. Unit: 1

[ISO 12647-1]

3.6
density
See reflection density

NOTE (Optical) density can be defined for both transmitting and reflecting samples. However, in the context of this document it is usually only appropriate to reflecting samples. The document uses the term density freely; it should be understood to be reflection density unless otherwise specified.

3.7
doubling/slur patch
control patch for the assessment of the true rolling condition

3.8
film (separation)
image carrier which contains black and white information in analogue form

NOTE Although normal use of the word film would also include colour film materials they are not included in this definition which is restricted to monochrome half-tone film separations, of which there is one for each colour ink to be printed.

3.9
film polarity
polarity (of a film)
positive if clear and solid areas on the film correspond to unprinted and solid areas on the print, respectively; negative if clear and solid areas on the film correspond to solid and unprinted areas on the print, respectively

[ISO 12647-1]

3.10
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

[ISO 12647-1]

NOTE Fringe width is expressed in millimetres.

3.11
half-tone
image composed of dots which can vary in screen ruling (number per centimetre), size, shape, or density, thereby producing tonal gradations

[ISO 12637-1]

NOTE Used especially with printing processes like offset lithography where the ink film thickness or the amount of colorant per unit area is constant throughout the image. However, it is sometimes used in gravure printing where the half-tone dot density may also vary.

3.12
image element
See half-tone

3.13
incident flux
flux incident on the sampling aperture defining the specimen area on which the measurement is made

[ISO 5-1]

3.14
ink-trap
I
for an overprint, a relative measure for the average amount of colorant per unit area of the second-down colorant layer that is deposited on to the first-down colorant layer

NOTE 1 Ink-trap is expressed as a percentage.

NOTE 2 Not to be confused with trap employed in colour separation to attenuate mis-register effects.

NOTE 3 Apparent ink-trap is measured optically; gravimetric ink-trap by weight.

3.15
mid-tone balance control patch
a half-tone control patch, containing all three chromatic process inks, used for assessing the balance between the inks; the cyan tone value is normally in the range between 40 and 60 and the magenta and yellow tone values are selected to approximately produce an achromatic colour

3.16
non-periodic half-tone
image in which the elements composing it do not have a regular frequency

3.17
OK print
OK sheet
during production printing the production print singled out as reference for the remaining production run

[ISO 12647-1]

3.18
overprint
condition where two or more layers of colorant, usually ink, are printed on top of another

3.19
print substrate
material bearing the printed image

[ISO 12647-1]

3.20
process colours (for four-colour printing)
yellow, magenta, cyan and black

[ISO 12647-1]

3.21
reflectance factor
R
ratio of the measured reflected flux from the specimen to the measured reflected flux from a perfect-reflecting and perfect-diffusing material located in place of the specimen. Unit: 1

[ISO 5-4]

3.22
reflection density[2)]
reflectance factor (optical) density[3)]
logarithm to base ten of the reciprocal of the reflectance factor. Unit: 1

3.23
reflectometer
photometer for measuring quantities pertaining to reflection

[International Lighting Vocabulary 845-05-26]

2) ISO 5-4.

3) [International Lighting Vocabulary 845-04-67].

3.24
relative density
density from which the density of a reference such as the film base or the unprinted print substrate, has been subtracted. Unit: 1

[ISO 12647-1]

3.25
sampling aperture
area of the sample that contributes to the measurement

NOTE This is not necessarily the same as the illumination aperture which is the area of the sample illuminated by the instrument or the mechanical aperture created by an opaque mask used to position the densitometer on the specimen. ISO 5-4 makes very specific requirements on the relationship between each of these.

3.26
screen frequency
screen ruling
number of image elements, such as dots or lines, per unit of length in the direction which produces the highest value. Unit: cm^{-1}

[ISO 12647-1]

3.27
screen width
reciprocal of screen ruling. Unit: cm

[ISO 12647-1]

3.28
solid
image of uniform coloration intensity with no half-tone structure

3.29
spectral product
product of the spectral power of the incident flux and the spectral response of the receiver, wavelength by wavelength

3.30
spectral response (of the receiver)
product of the spectral sensitivity of the photodetector and the transmittance of the optical elements associated with it

3.31
tone value
dot area (on a print)
A
percentage of the surface which appears to be covered by colorant of a single colour (if light scattering in the print substrate and other optical phenomena are ignored) calculated from the formula:

$$A\,(\%) = 100\left[1 - 10^{-(D_t - D_0)}\right] \Big/ \left[1 - 10^{-(D_s - D_0)}\right]$$

where

D_0 is the reflectance factor density of the unprinted substrate;

D_s is the reflectance factor density of the solid;

D_t is the reflectance factor density of the half-tone.

[ISO 12647-1]

or in its equivalent form:

$$A\,(\%) = 100(R_0 - R_t) / (R_0 - R_s)$$

where

R_0 is the reflectance factor of the unprinted substrate;

R_s is the reflectance factor of the solid;

R_t is the reflectance factor of the half-tone.

NOTE 1 Also known as apparent, equivalent or total dot area.

NOTE 2 The synonym dot area may be applied only to half-tones produced by dot patterns.

NOTE 3 This definition may also be used to provide an approximation of the tone value on certain printing formes.

NOTE 4 In general it is assumed that tone values specified in a digital electronic file are reproduced identically on the film produced on an imagesetter.

NOTE 5 The equation is known as the Murray-Davies equation.

3.32
tone value
dot area (on a half-tone film of positive polarity)
A

Percentage calculated from the formula:

$$A\,(\%) = 100\left[1 - 10^{-(D_t - D_0)}\right] \Big/ \left[1 - 10^{-(D_s - D_0)}\right]$$

where

D_0 is the transmission density of the clear film;

D_s is the transmission density of the solid;

D_t is the transmission density of the half-tone.

NOTE Also known as the film printing dot area.

[ISO 12647-1]

3.33
tone value
dot area (on a half-tone film of negative polarity)
A

Percentage calculated from the formula:

$$A\,(\%) = 100 - 100\left(1 - 10^{-(D_t - D_0)}\right) \Big/ \left(1 - 10^{-(D_s - D_0)}\right)$$

where

D_0 is the transmission density of the clear film;

D_s is the transmission density of the solid;

D_t is the transmission density of the half-tone.

NOTE Also known as the film printing dot area.

[ISO 12647-1]

3.34
tone value increase
difference between a tone value on the print and the corresponding tone value on the half-tone film or in a digital electronic file. Unit: percent

NOTE The synonym “dot gain” may be applied only to half-tones produced by dot patterns.

[ISO 12647-1]

4 Requirements

4.1 Introduction

There are a number of variables that must be controlled in order to produce predictable results in colour reproduction. For a given substrate the most important process variables are the colours of solid patches of the individual process inks and their overprints, slur/doubling and tone value. For production situations where the control of the process is not particularly well defined subclause 4.2 defines the control patches required on the print, the minimum number of patches permitted and their tone value tolerances. Where the printer is reasonably confident of the process variation anticipated a sub-set of these elements will normally be selected that is most appropriate for control of this variation.

Subclause 4.2 also defines the requirements of a film control strip, where used, to produce the control patches. The measurement procedure and data reporting specified in 4.3, 4.4 and 4.5 apply to measurements made on control patches irrespective of whether these were generated from film, by direct-to-plate or direct-to-press.

4.2 Control strip

4.2.1 Film quality

The quality parameters of a film control strip - such as core density, fringe width, and base density - shall conform with the pertinent part of ISO 12647.

4.2.2 Minimum set of control patches

The control strip shall contain doubling/slur patches as well as single-colour and overprint patches for the process colour solids, namely K, C, M, Y, (C+M), (C+Y), (M+Y) and (C+M+Y). In addition it shall contain at least 3 well-defined single colour half-tone control patches, labelled with their nominal tone values, for each of the process colours K, C, M and Y. One shall have a tone value between 20 % and 30 %, another shall have a tone value between 40 % and 50 % and the third shall be between 70 % and 80 %. There shall also be a well-defined half-tone control patch for the measurement of mid-tone balance and an area close to, or within, the control strip for measurement of the unprinted substrate. The complete control strip should be repeated as frequently as possible across the whole width of the press sheet.

The half-tone dot shape of the image elements used for process control shall be circular and the screen ruling should lie within 10 cm^{-1} of the screen frequency of the subject images. All tone values, including those of the mid-tone control element, shall be within 1 % of the nominal value.

NOTE 1 For positive and negative polarity film control strips, it is desirable to add control patches with several tone values below 10 % and above 90 %, respectively.

NOTE 2 While it is recognized that the control element is specified as circular and actual work can be circular, square, elliptical, etc., the use of a specific shape enables process control checks across jobs, presses, and companies.

4.3 Preparations for measurements

Ensure that the measuring head and the sampling aperture of the instrument are clean. If necessary, observe the manufacturer's warm-up time recommendations, then calibrate the instrument to read accurately relative to the perfect reflecting diffuser, according to the manufacturer's instructions. Set the instrument to the desired mode.

Ensure that the sample is flat and not creased and place it on a flat, black surface which is in conformance with that defined in ISO 5-4 and ISO 13655 (namely a spectrally non-selective, diffusely reflecting material with an ISO visual density of approximately 1,5). Centre the sampling aperture, which should be smaller than the illumination aperture (as defined in ISO 5-4), on the middle of the control patch or spot to be measured. Ascertain that the instrument base and the sample lie in the same plane.

When reading a half-tone, the diameter of a circular sampling aperture should be not less than 15 times the screen width; it shall be not less than ten times the screen width. For the measurement of non-periodic screens the aperture shall be not less than 4 mm in diameter and for image elements greater than 30 µm should be even larger. The area of a non-circular sampling aperture shall not be smaller than that of the circular apertures defined above.

NOTE Where an aperture smaller than that recommended is used a number of readings should be averaged.

4.4 Measurement of reflection density and quantities derived therefrom

4.4.1 Instrument specification

The densitometer shall be in accordance with ISO 14981.

4.4.2 Data reporting

Any densitometric data shall be accompanied by a report specifying the exact conditions used. The report shall indicate conformance with this International Standard and shall include the following parameters:

- Densitometer manufacturer and model name
- Colour channel (K, C, M, Y, or wavelength in nm)
- Spectral response — shall be one of ISO Status I, T, E (as defined in ISO 5-3), DIN I, or DIN E (as defined in DIN 16536-2)

- Polarisation (yes/no)
- Sample backing (if not black)
- Sampling aperture in mm
- Density values relative (substrate density set to zero) or absolute - Not required for values which depend on density differences only
- Combined standard uncertainty (ISO 15790)

4.5 Measurement of colorimetric parameters

4.5.1 Instrument specification

The colorimeter, the conditions of measurement and the calculations shall be in accordance with ISO 13655. If a tristimulus colorimeter is used, the measurement conditions (i.e. backing, geometry, etc.) shall be in accordance with ISO 13655.

NOTE Some colorimeters also report density which is calculated from the spectral data. They may be fitted with polarisation filters. These filters are not recommended for use in the colorimetric mode of these instruments.

4.5.2 Data reporting

The reporting of colour co-ordinates shall be as specified in ISO 13655 and shall be accompanied by a report specifying the exact conditions used. The report shall indicate conformance with this International Standard and, in addition, shall include the following parameters:

- Colorimeter manufacturer and model name (specify if tristimulus photometric type)
- Sample backing (if not black)
- Sampling aperture in mm
- Combined standard uncertainty (ISO 15790)

5 Test methods

5.1 Introduction

Each of the parameters determined from reflectometer data, which are deemed most useful for process control, are described in this clause. Where different methods for defining these parameters are specified the preferred methods are given first and their use is strongly encouraged in order to aid communication between users. Commonly available parameters which have not been defined in this document (such as densitometric hue error and greyness, print contrast and 'Yule-Nielsen' dot area) are not recommended as useful for general communication, even if they serve well for specific applications, and are thus not appropriate for this International Standard. Similarly, colorimetric density (usually defined as log (X_o/X); log (Y_o/Y) and log (Z_o/Z) where X_o, Y_o and Z_o normally specify the reflectance factors or tristimulus values of the substrate) is also excluded since the spectral products do not conform to those specified in this International Standard.

Many of the parameters specified in clause 5, particularly those based on densitometry, are useful for process control but tell the user little about the appearance of the print. Many of these are appropriate measures for controlling a production run, others for defining the difference between proofs and prints and yet others for defining variation within a print. In addition clause 5 includes parameters which are used for some specific evaluation of printing performance (such as ghosting). Some of the parameters in clause 5 do have a colorimetric definition specified but densitometry is the predominant tool.

Where colour appearance and matching are paramount requirements, densitometry should not be used unless it is known that the pigments being matched are very similar. Colorimetry is necessary in the general situation. For graphic arts purposes the uniform colour space recommended is CIELAB as specified in ISO 13655. The parameters of most interest are lightness, chroma, hue angle and colour difference.

Lightness, chroma and hue angle are useful concepts in understanding more about the appearance parameters of the sample being measured than can be obtained from the Lightness, a^* and b^* alone. For colour matching purposes it is normal to select the sample with the smallest colour difference from the reference, although sometimes additional constraints may be put on lightness, hue or chroma. For neutral colours, for example, it is often more important that they have a low chroma rather than a specific lightness.

5.2 Deviation between the coloration of the solids on the OK print of the production run and on the proof print

For every process colour, measure the tristimulus values of the solid patches of the control strip in the regions of the print where the subject images contain this colour. Calculate the CIELAB ΔE^*_{ab} colour differences between corresponding spots on the proof and OK prints. Compare the results to the tolerances specified in the appropriate part of ISO 12647. In the absence of a control strip measure in suitable single-colour solid areas of the subject.

5.3 Density or relative density of a process colour solid

Select the colour channel which gives the highest reading for the process colour of interest. Measure the density of the solid and the density of the unprinted substrate. For density report the measurement obtained from the solid directly; for relative density compute:

$$D_r = D_s - D_0$$

where

D_r is the relative density;

D_s is the density of the solid;

D_0 is the density of the unprinted substrate.

5.4 Tone value on a print

Set the instrument to the colour channel which results in the highest readings for the process colour of interest. The same colour channel shall be used for the substrate measurement. Measure the densities of the unprinted substrate, a solid area and a well-defined half-tone area of the process colour which are as close as possible to each other. If the densitometer does not display tone values directly use the expression given in 3.31 to convert the density values.

NOTE 1 The tone value (dot area) depends slightly on the instrument conditions; especially with the yellow process colour differences of up to 2 % may be observed in the mid-tone between wide-band instruments without polarisation and narrow-band instruments with polarisation.

NOTE 2 Tone value increase is calculated by deducting the tone values of the control strip film, or digital file, from the corresponding tone values on the print. The full tone value increase curve may be determined by obtaining the tone values on a printed control strip with at least 3 half-tone control patches, but preferably containing patches from 10 % to 90 %, in 10 % increments, on the film or digital file. Plot the differences against the tone value of the film or digital file and draw a smooth curve through the data points. This is a graphical representation of the tone value increase function, also known as the dot gain function.

5.5 Apparent ink-trap

From a solid overprint and the single-colour prints of the first-down and second-down inks, set the densitometer to the colour channel which gives the highest value for the second-down ink and determine I_p from the Preucil formula:

$$I_p = (D_o - D_1)/D_2$$

where

I_p is the densitometric ink-trap;

D_o is the density of the overprint;

D_1 is the density of the first-down ink printed alone;

D_2 is the density of the second-down ink printed alone.

NOTE 1 The apparent trap percentage obtained using the Preucil formula is not an absolute measure of the amount of the second-down ink applied to the first-down ink. The value obtained is dependent on the colour sequence. Even if the amounts of ink transferred were identical in both cases the apparent trap would differ because of variations in the opacity of the inks but more importantly the choice of colour channel used. It is clear from the procedure above that a different colour channel is used for each sequence which of itself will provide a different result.

NOTE 2 The true (weight %) ink-trap percentage (I_g) can be obtained using the gravimetric method described in annex A. Microscopic examination of the overprint and image analysis techniques can provide additional information on how the inks lay on the substrate and each other, which is not obtained from the apparent trap percentage.

NOTE 3 Apparent trap percentages can be used in process control to monitor changes in trap during a production run.

NOTE 4 Apart from the well-known Preucil formula, numerous others have been proposed. Most of those are derived from the Preucil formula but contain adjustable parameters. None of them is entirely free from the shortcomings mentioned in note 1.

NOTE 5 For densitometers with polarisation and narrow-band spectral products, I_p is closer to I_g (the true ink-trap percentage by weight) than for those without.

5.6 Doubling and slur

Set the instrument to the colour channel which gives the highest reading for the process colour of interest. Determine the densities of each of the line screen patterns of different orientation within the doubling/slur control patches. The reflection density difference is a relative measure for doubling and/or slur.

5.7 Variation of the coloration on a single print

As well as the need to control the uniformity of inking across the press it is often useful to characterise the variation in inking across or along the printing direction; for example, to quantify the effects of mechanical ghosting in offset and other printing defects. It is normal to make such measurements on solid areas of colour, usually on a single ink, in order to locate the cause of the problem most precisely. In such circumstances densitometry shall be the method to be used because of the higher sensitivity to variation in inking.

However, it is sometimes necessary to determine the variation in colour of solid areas, or an overprint of mixed half-tone values, to define the effect rather than the cause. In this case colorimetry shall be used because it defines the perceived colour differences more accurately.

5.7.1 Densitometry

Set the instrument to the colour channel which gives the highest reading. Measure the densities on the single colour solids. Calculate the quantity:

$$100\left[\left(D_{\max} / D_{\min}\right) - 1\right]$$

where

$D_{\max}$ is the maximum density value obtained on the single colour solids on the print;

$D_{\min}$ is the minimum density value obtained on the single colour solids on the print.

Report the variation in percent.

5.7.2 Colorimetry

Determine the CIELAB colour differences (ΔE_{ab}^{*}) between locations with identical composition (e.g. "K12C60M45Y100", "K 100 %", "balance patch C75M70Y70") across the print. Report the differences stating the composition of the measurement locations.

5.8 Variation of the coloration of the solid over the finished production run

Select a representative sample of at least 15 copies from the production run. For runs over 150,000 copies select additional copies in proportion. Measure the solid patches of the control strip in the regions of the print where the subject images contain this colour. Compare the results to the tolerances specified in the appropriate part of ISO 12647.

5.8.1 Colorimetry (preferred)

Measure the CIELAB values L^*, a^* and b^* for each of the samples from the production run and calculate the ΔL^*, Δa^* and Δb^* differences with respect to the mean value of the production run. Calculate the mean values of ΔL^*, Δa^* and Δb^* and the respective standard deviations. Determine the 95 % confidence limits (i.e. the range in which 95 % of samples are located) by multiplying the standard deviations by 1,96. Finally compute the CIELAB colour difference (ΔE_{ab}^{*}) for each of the mean and confidence range values. The colour differences obtained from the mean values represent the colour deviation of the production centre from the OK print while those obtained from the confidence limits represent the colour variation within the production run.

5.8.2 Densitometry (additional)

Set the instrument to the colour channel which gives the highest reading for the process colour of interest. Determine the differences between corresponding locations of the samples from the production run with respect to the mean value of the production run. Calculate the statistical quantities "mean" and "standard deviation" for each location; then characterise the direction and the extent of the variation of the coloration of the solid for the measured location. Repeat the procedure for the other locations.

Annex A
(informative)

Gravimetric verification of ink-trap

The following is a laboratory procedure for determining the precise weight of ink applied to a previously printed ink film in comparison to that applied to unprinted substrate. It is not to be read as a process control procedure. The sample preparation procedure is in accordance with ISO 5737, *Prints — Preparation of standard prints for optical tests*.

On a printability tester, prepare prints of the first-down ink on the substrate with the desired coloration of the solid as measured by colorimetry or densitometry. Use a printing forme which prints a solid except for a small unprinted patch. Likewise, with a printing forme of the same type, prepare prints of the second-down ink onto the unprinted substrate with the desired coloration of the solid. Determine the thickness of the ink film transferred onto the print gravimetrically from either the mass loss of the printing forme (preferred) or the mass gained by the printed substrate. (Weighing the printing forme is, in general, more accurate than determining the mass gain of the substrate, providing that a suitably accurate analytical balance is used, because of the sensitivity of the mass of the substrate to environmental conditions.) The resultant value is the thickness of the second-down ink printed alone, s_s.

Print the second-down ink on to the prints of the first-down ink with a printing forme of the same type. Control the correct coloration of the solid by colorimetry or densitometry on the unprinted patch of the first forme. Determine the thickness of the second ink film transferred; this is the thickness of the second-down ink on the overprint, s_o.

Calculate the ink-trap from the formula:

$$I_\mathrm{g}(\%) = 100\,(s_\mathrm{o} / s_\mathrm{s})$$

where

I_g is the gravimetric (true) ink-trap;

s_o is the thickness of the second-down ink on the overprint;

s_s is the thickness of the second-down ink printed alone.

Report the gravimetric ink-trap stating the colour sequence used.

NOTE Gravimetric ink-trap is often close to 100 % and sometimes even higher, if the first-down ink is more ink-receptive than the unprinted substrate.

Annex B
(informative)

Polarisation in densitometry

Light that is reflected from a surface usually consists of two components; first-surface (or specular) reflection and backscattering from below the surface. Whereas the first component is associated with the property "gloss" of the sample print, only the second component depends on the colour. When, in process control, the primary aim of densitometry is to provide a measure of the amount of colorant per area, some densitometer designers have sought to eliminate the first component from the measurement.

With high-gloss samples, the standard 0°/45° or 45°/0° densitometer geometry almost suppresses the influence of specular reflection. With less glossy surfaces, however, these geometries allow appreciable amounts of the specular component light to reach the detector. Some manufacturers provide densitometers where polarisation devices suppress the light originating from first-surface reflection. These instruments rely on the fact that specular reflection leaves the state of polarisation essentially unchanged whereas it is nearly destroyed by backscattering from below the surface. With polarisation filters in the illuminating and the sensing channels, respectively, at appropriately chosen angles, it is possible to suppress first-surface reflection by a factor of 50.

While it is obvious that the use of polarisation weakens the correspondence between the visual impression and the density value, the following facts are beneficial to process control purposes:

— The approximate linear relationship between density and amount of colorant per area is extended to higher densities.

— The additivity error of the densities is reduced.

— The time dependence of reflection density due to ink drying or setting is reduced.

It is important that the spectral and other optical properties of the polarising filters are taken into account during the design of the instrument. A densitometer that conforms to specifications given in ISO 5-3 and ISO 5-4 without polarisation may fail to do so after the addition of polarisation filters. Likewise, an instrument with polarisation that was designed to conform to specifications given in ISO 5-3 and ISO 5-4 may not conform after the filters have been removed.

The calibration of densitometers with polarisation requires high gloss optical quality test objects which, incidentally, can also be used for densitometers without polarisation, see ISO 14981.

Annex C
(informative)

Tone value on a printing forme

Under certain conditions it may be possible to determine tone values on the printing forme using a densitometer. These may serve as some measure of the printing area percentage in the absence of more accurate methods. The following conditions should be met:

— the printing and the non-printing parts of the surface show a density difference of at least 0,7;

— there are no density variations in both the printing and non-printing parts of the surface;

— the densitometer is a precision instrument which reports either to three decimal places or gives the tone values directly;

— the effective measurement aperture of the densitometer should have a diameter not less than 15 times the screen width.

Test method: Take a reflection densitometer and measure on the same printing forme the densities of non-printing area, a solid control patch and a half-tone control patch. If the (developed) printing forme is light sensitive, measure immediately after development, before extensive exposure to daylight. If the density difference between the printing and the non-printing areas is lower than 0,7, the contrast may be enhanced by inking the printing forme in a reproducible manner. Use the filter setting of the densitometer that results in the highest density for the solid area control patch. (In the case of readings being obtained with a spectrophotometer the tone value may be computed by selecting a narrow spectral band within the absorption band of the coating and defining this as the colour channel. Alternatively, if it is desired to obtain readings with a minimum of effort, all 'colour channels' provided with the instrument may be tested and that used which provides the highest density.) If the densitometer reading depends on direction, average over at least 10 measurements, where half of the measurements are made with the densitometer parallel to the around-the-cylinder direction of the printing forme and half with the densitometer perpendicular to that direction.

Calculate the tone value of the half-tone control patch on the printing forme from the expression defined in 3.31.

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