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Graphic technology — Methods of adjustment of the colour reproduction of a printing system to match a set of characterization data

Technologie graphique — Méthodes d'ajustage de la reproduction de couleurs d'un système d'impression pour correspondre à un ensemble de données de caractérisation

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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.

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The main task of technical committees is to prepare International Standards. 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.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

ISO/TS 10128 was prepared by Technical Committee ISO/TC 130, *Graphic technology*.

Introduction

As the printing and publishing world has embraced the use of digital data and the preparation of printing plates directly from digital data (often referred to as computer to plate or CTP), it has struggled to find ways to take better advantage of the electronic data manipulation opportunities offered. When traditional half-tone film was the medium of exchange of final material and the input to the printing plate and press operation, the primary methodology available to the printer to match industry aims and standards was to force the press, ink and paper to be as close as possible to the references upon which the printing standards were based. Today, with digital data input, it is recognized that modification of that digital data can be used to compensate (adjust) for some of the differences in press, ink and paper between various printing sites and between the actual conditions at a specific site and the reference or standard printing condition.

As part of the introduction of digital technology, the printing industries (and its standards activities) have begun to establish reference characterization data corresponding to various printing specifications and conditions. Characterization data is generally defined as the relationship between the CMYK digital input values (in the data file exchanged) and the measured colorimetric values for the colour printed in response to these values.

Discussions within Technical Committee ISO/TC 130 have identified three general methods by which compensation for differences in printing conditions can be accomplished. Two of these make use of individual one-dimensional transforms (i.e. plate curves) for each printing channel, but differ in the method by which these transforms are determined. These are referred to as matching of tone value curves and use of near-neutral scales. The third method makes use of multi-dimensional transforms such as International Color Consortium (ICC) device-link profiles.

The features and general methodology for use of these adjustment techniques is the subject of this Technical Specification. The goal is to provide a common understanding of these procedures across the industry, to allow consistency between implementations, and to facilitate communication of the adjustments used/desired in particular workflows.

It is important to recognize that these are not competitive solutions, but each have different strengths and weaknesses in individual workflow applications. It is the choice of the individual print facility and/or the involved trade associations to decide how to best apply these capabilities, made possible through the use of digital data.

The basic assumption behind the use of characterization data and these correction techniques is that a printing process can be repeatedly restored to a prior printing condition and that condition can be maintained both within a run and between runs. A variety of process control methods can be used to achieve this repeatability. Solid ink reflectance density and tone value increase based on the specific materials involved, and tied back to the conditions established during characterization are common process control tools that are used in addition to the data adjustment techniques described in this document. These adjustment techniques work together with process control to achieve the printing quality desired.

The International Organization for Standardization (ISO) draws attention to the fact that it is claimed that compliance with this document may involve the use of a patent concerning recalibrating a multi-colour imaging system given in 4.3.

ISO takes no position concerning the evidence, validity and scope of this patent right.

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Graphic technology — Methods of adjustment of the colour reproduction of a printing system to match a set of characterization data

1 Scope

This Technical Specification specifies three methods for the adjustment of the digital content data that is input to a printing system to achieve consistency in the printed results among a number of presses printing to the same general aim conditions. These three methods are generally identified as

a) the matching of tone value curves,

b) the use of near-neutral scales, and

c) the use of CMYK to CMYK multi-dimensional transforms.

The procedures for establishing the aim condition for the necessary transfer curves, the procedures for determining the individual transfer curves, and a comparison of the applicability of these three methods are included.

These adjustment procedures are applicable to printing systems that use CMYK colourants but are not restricted to those that use traditional ink on paper printing but can involve other marking technologies such as those used for proofing and/or digital printing.

2 Normative references

The following referenced documents are indispensable for the application 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 12642-1, *Graphic technology — Input data for characterization of 4-colour process printing — Part 1: Initial data set*

ISO 12642-2, *Graphic technology — Input data for characterization of 4-colour process printing — Part 2: Expanded data set*

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

ISO 15076-1, *Image technology colour management — Architecture, profile format and data structure — Part 1: Based on ICC.1:2004-10*

3 Terms and definitions

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

3.1
adjustment of a printing system with digital data
systematic modification of the content data received, to enable the results printed on a specific device to match the appearance of the same content data as would have been printed on a reference device

3.2
digital printing
printing directly from digital data when there is no intermediate image carrier, or when the image carrier is refreshed for each impression, and thus each impression can be different in content if desired

3.3
grey balance
set of tone values for cyan, magenta and yellow that are expected to appear as an achromatic grey under specified viewing conditions when printed using the specified printing conditions

NOTE 1 Adapted from ISO 12647-1.

NOTE 2 The user can choose between the following two practical definitions and one theoretical definition of grey, depending upon the particular context:

a) practical definitions:

1) a colour having the same CIELAB a^* and b^* values as the print substrate;

2) a colour that has the same CIELAB a^* and b^* values as a half-tone tint of similar L^* value printed with black ink;

b) theoretical definition: the colorimetric definition of grey is when the CIELAB a^* and b^* values both equal 0.

3.4
tone value
A
proportional printing value encoded in a data file and interpreted as defined in the file format specification

NOTE 1 Most files store these data as 8-bit integer values, i.e. 0 to 255. The tone value, A, expressed as a percentage of a pixel, is typically computed from the equation

$$A = 100 \times \left(\frac{V_\mathrm{p} - V_0}{V_{100} - V_0} \right)$$

where

V_p is the integer value of the pixel in the file;

V_0 is the integer value corresponding to a tone value of 0 %;

V_{100} is the integer value corresponding to a tone value of 100 %.

NOTE 2 Adapted from ISO 12647-1.

3.5
tone value increase
ΔA
difference between the tone value in the digital data file and the tone value on the printed sheet

NOTE Adapted from ISO 12647-1.

4 Procedures

4.1 General

4.1.1 Overview

Printing standards, in general, specify the ink and paper to be used and the process control parameters in colorimetric terms. When the inks are well characterized, densitometric aims may also be included for reference. The ISO 2846 series of International Standards provides the mechanism to specify the colour and transparency of the ink. Specification of paper is not well defined and is generally limited to an identification of colour, translucency or grammage, and a reference to industry grades or classifications.

The outer gamut of the printable colour volume is primarily defined by the combination of the colour of the paper, the colour of solids of the primary inks and of the overprinted solids of two primary inks, and the colour of the overprinted solids of three primary inks in combination with the black ink. These are included in the printing conditions defined in the ISO 12647 series of International Standards and are also typically included in other printing specifications along with reference aims for densitometric data and tone value increase. Characterization data associated with such printing standards is usually prepared from print test data or data from earlier tests. In either case, it is typically modified and smoothed so as to match the specified values for the aim parameters and to represent smooth transitions within the colour volume.

In some situations, a printing system can be adjusted to match a reference by adjusting tone value increase to match the reference. The principal assumptions are

a) if the primary and secondary colour solids are correct, the outer printing gamut is correct,

b) if the tone curves for the individual single colour scales match those of the reference printing condition, then the internal overprint data will also match the reference, and

c) within limits, differences in the tone value increase between presses (or between a press and the reference printing condition) can be compensated for by a series of single channel changes in the input tone values.

It is, of course, assumed that the paper and ink comply with the specifications for the printing standard being matched within reasonable tolerances.

The first two methods described in this Technical Specification use such single channel changes and differ only in the procedure used to determine the individual channel corrections.

The third method assumes that there is sufficient interaction between channels that a series of single channel corrections are not sufficient. It makes use of an ICC device-link transform (or other mechanism which maps the device-dependent printing data of one system into the device-dependent printing data of another system) which essentially is a predefined four-dimensional transform. The reason that an ICC device-link is used instead of classic ICC colour management is that the transforms included in a device-link profile can be tuned to preserve the black channel (single colour black stays as a single colour). Classic ICC colour management converts the CMYK data back into profile connection space (PCS) data and then re-computes the individual colour separations to create a new set of CMYK data.

All three methods depend on the use of the specified paper and ink, and on achieving the correct colorimetric values of the process colour solids and two-colour overprint solids.

Although the descriptions that follow refer to the “press to be used for actual printing”, it is recognized that often process control within an organization is sufficiently managed or that presses belonging to a single “family” (e.g. same brand or similar models) are sufficiently similar that the same set of corrections can be applied in a broader sense than simply to a single press. Furthermore, although the term press is used throughout this document to refer to the intended printing device, these procedures may be used with proofing devices or with digital printing devices operated in traditional half-tone, continuous tone, or non-traditional imaging modes.

4.1.2 Printing specifications

Whenever possible, printing standards should use the printing conditions defined in the applicable part of ISO 12647, or should be based on these conditions.

4.1.3 Ink specifications

The various parts of ISO 12647 specify use of inks based on the appropriate part of ISO 2846. However, even when the printing specifications used are not based on ISO 12647, the ink specified should be based on the appropriate part of ISO 2846 or use similar testing procedures for its definition.

4.1.4 Characterization data

All characterization data should be based on the ink value data sets defined in either ISO 12642-1 or ISO 12642-2. Measurement of printed samples of these ink value data sets shall be accomplished in accordance with ISO 13655. Colour management profiles based on such characterization data shall be created in accordance with ISO 15076-1.

4.1.5 Determination of tone value

Tone value is traditionally calculated from reflectance density data and is an estimate of the percentage of the surface which appears to be covered by a uniform layer of a colorant of a single colour (if light scattering in the substrate and other optical phenomena are ignored). The choice of which reflectance density filter set to use (reflectance density status as defined in ISO 5) is generally not an issue as long as both the reference characterization data and the press evaluation data are based on the same reflectance density status (as defined in ISO 5).

Use of a spectrophotometer, adjusted so that its spectral pass band is centred on the wavelength region where the print exhibits its maximum light absorbance, provides the best estimate of apparent tone value. However, for process control of a running press, status (see ISO 5) reflectance density data is usually more available and, for that reason, the tone value (and thus tone value increase) “aim” (i.e. value to aim for) is usually based on densitometric data. However, when colorimetric data is available, tone value based on colorimetric data may be used for both the characterization data reference and the press evaluation data. Annex A provides additional information about, and computational techniques for, colorimetric tone value.

4.2 Matching of tone value curves

4.2.1 General

The principal assumption used in this method is that, once the correct process colour solids and two-colour solid overprints are achieved, a satisfactory overall result can be reached by simply matching the achieved tone value curve to the specified tone value curve for each printing primary.

NOTE Because single colour tone value curves and single colour tone value increase curves are directly related, either can be used. For many users, tone value increase curves are easier to visualize and thus are more commonly used.

4.2.2 Press evaluation

To match the colour reproduction of a real printing system to the reference printing condition using tone value curves, it is important to measure press performance using the inks and paper type specified for the reference printing condition being matched. Because the ink, paper, and press combination being used may not result in solids that exactly match the CIELAB colour coordinates specified, it is important to determine the local process control aims that provide the closest match to the colorimetric aims of the process colour solids.

This can be achieved by printing an ink film thickness series (often referred to as a reflectance density series) for each ink on the reference paper either by tagging on to the end of a production printing job using the same materials or by carrying out a specific test. The key issue is that it is important to measure and compute both reflectance density and colorimetry over a varying range. The colour difference between the colour achieved and the aim colour (ΔE) can be used to select a new aim colour for process control. These aims represent the best that can be achieved with the ink, paper, and press being used to match the CIELAB colour coordinates of the aim solids. If, during this test, the two colour overprints do not match the CIELAB colour coordinates specified within the tolerances given (the tolerances in the appropriate part of ISO 12647 should be used as a guide), then the inks or process should be investigated and the press evaluation should not be completed until both solids and two colour overprints are achieved within the specified tolerance.

Once the printing conditions are established that provide the best match to the agreed-upon colorimetric aims for the process colour solids, measurement of a printed image of an ISO characterization test chart (ISO 12642-1 or preferably ISO 12642-2) shall be used to provide a set of characterization data. This data defines the press characteristics at the operating condition that represents the best match that can be achieved to the gamut of the reference printing condition.

The difference between the single colour tone value curve achieved on press and that of the reference printing condition is the tone value correction curve that should be applied to all colour-critical content data. This correction should be determined and applied independently for each channel (C, M ,Y and K).

4.2.3 Press calibration

Press colour adjustment using tone value curves is simply the systematic application of the tone value correction curves determined in 4.2.2 to all content data. This is typically accomplished using plate-setter curves but may also be accomplished using any other digital data manipulation step available in the particular workflow being used.

4.3 Use of near-neutral scales

4.3.1 General

While the matching of tone value curves, described in 4.2, is adequate in many situations, it only takes into account one of the many factors that impact the colour of two and three colour over-prints. While the tone value curve clearly is the most significant, the printed colour is also impacted by ink-trapping, ink transparency and ink-water-press interaction, etc. These can all vary between the press, ink and paper used to create reference printing condition characterization data and the press, paper and ink used for the production printing.

A comparison of the colorimetric data of the reference characterization data and that of the intended production printing for a reference near-neutral scale allows individual transforms (tone value adjustment curves) to be determined for each ink channel. While similar to the tone value correction curves of the method described in 4.2, they provide the ability to compensate for some of these secondary variations that also impact the three-colour neutral scale.

When the reference characterization data used has been designed to produce good grey balance for a reference near-neutral scale, this approach also allows the printing process to be monitored using grey balance in addition to, or in place of, using tone value curves.

4.3.2 Reference near-neutral scale

The use of near-neutral scales to determine the required tone value adjustment curves can be used with any reference characterization data. As noted above, if the characterization data to be matched has been designed to produce good grey balance for a particular reference near-neutral scale, grey balance patches of that near-neutral scale can be used with process control procedures based on grey balance.

While not required, it is convenient to use a predefined near-neutral set of CMY tone value scales to extract near-neutral data from either reference characterization data or that of the intended production printing. One such scale, used by some industry groups, is shown in Table 1 as an example.

Table 1 — Example near-neutral CMY tone scale

Step	Cyan tone value	Magenta tone value	Yellow tone value
1	0,00	0,00	0,00
2	1,96	1,18	1,18
3	3,92	2,75	2,75
4	5,88	4,31	4,31
5	7,84	5,49	5,49
6	10,20	7,45	7,45
7	14,90	10,98	10,98
8	20,00	14,90	14,90
9	25,10	18,82	18,82
10	30,20	23,14	23,14
11	34,90	27,06	27,06
12	40,00	31,37	31,37
13	45,10	35,69	35,69
14	49,80	40,00	40,00
15	54,90	45,10	45,10
16	60,00	50,20	50,20
17	65,10	55,29	55,29
18	69,80	60,39	60,39
19	74,90	65,88	65,88
20	80,00	71,76	71,76
21	85,10	78,04	78,04
22	89,80	84,31	84,31
23	94,90	92,16	92,16
24	98,04	96,86	96,86
25	100,00	100,00	100,00

NOTE The tone values of this scale are reported to two decimal places because most characterization data is recorded as 8-bit per channel data and these values correspond to the quantization intervals associated with 8-bit data. As the colorimetric data to be associated with this neutral scale is usually computed or interpolated from colour characterization data, this minimizes an additional set of rounding errors.

4.3.3 Press evaluation

As with the method described in 4.2, it is important to first evaluate the press performance using the inks and paper type specified for the reference printing condition being matched. The press evaluation test should be conducted by first matching the aim solid ink colours. Then, an ISO 12642-2 or similar target can be printed to allow characterization data to be measured. This can be used to compute the colorimetric values associated with the near-neutral scale to be used. Alternatively, an image of the near-neutral scale can be included on the test form and the appropriate data measured directly.

Given the reference characterization data and the characterization data for the press being calibrated, a wide variety of colour analysis tools can be used to determine the tone values required on the press being calibrated to match the colorimetric values of the reference near-neutral scale of the aim characterization data.

The differences in the CMY tone values between those specified in the near-neutral scale being used and those required to match the CIELAB colour coordinates of the near-neutral scale computed from the reference characterization data are the required CMY tone value correction curves. A single colour black tone scale is used to determine the K tone value correction curve.

4.3.4 Press calibration

Press colour adjustment using tone value correction curves determined from use of near-neutral scales is identical to colour adjustment using tone curve methods to determine the required correction. It is simply the systematic application of the tone value correction curves determined in 4.3.3 to all content data. This is typically accomplished using plate-setter curves but may also be accomplished using any other digital data manipulation step available in the particular workflow being used.

4.4 Use of CMYK to CMYK multi-dimensional transforms

4.4.1 General

The matching of tone value curves, described in 4.2, or the use of near-neutral scales, described in 4.3, to determine a set of CMYK tone value correction curves is adequate in many situations. However, they both assume that there is not a strong interaction between the individual printing channels and that the inks being used are generally similar in colour and transparency to those used for the reference characterization data being matched. Multi-dimensional colour transforms (such as an ICC device-link colour management profile) are capable of taking into account a full four-dimensional interaction between the printing colours (inks).

NOTE While ICC-type colour management and ICC device-link profiles are used here as the example and reference, it is recognized that there are other methodologies that are capable of achieving similar results.

It is important to understand that the method defined here is not classic colour management. The classic colour management approach (using ICC as the example) would use profiles associated with the reference characterization data to convert the CMYK printing data back to a colorimetric encoding in profile connection space (PCS). Then, using profiles derived from the characterization data of the production printing, convert from PCS back to a set of CMYK data that will produce the same colour appearance on the press in use.

However, for colours inside the printing gamut, the same colour can be produced with various combinations of CMYK tone values. Because the relationship of the amount of black used in producing any colour and the use of black-only (e.g., for text, dropped shadows, etc.) is important in many printing applications, classic colour management cannot be used.

A modified set of transforms, called device-link profiles in ICC colour management, can be designed to transform directly from one set of CMYK data to another set of CMYK data. When constructing such transforms, software algorithms can be used to preserve the relationship between the black tone values and those of the other process colours and to maintain other aspects of the original colour values important to their printability.

4.4.2 Press evaluation

The starting point used to create a device-link profile is the characterization data for the reference printing condition to be matched and the characterization data for the intended press to be used for printing. This is similar to the starting point for 4.3.

4.4.3 Press calibration

Press colour adjustment using device-link profiles is simply the systematic application of the transforms of the device-link profile to all content data either by the raster image processor (RIP) driving the plate setter or in any other data manipulation step in the workflow capable of accomplishing the required multi-dimensional transforms.

5 Applicability of each method

There are no explicit requirements that dictate which method of press colour adjustment is preferred. However, in general, the use of device-links as the adjustment method find wider applicability in those printing and proofing technologies that use colourants that differ from the traditional inks specified in ISO 2846 (all parts) (e.g. digital printing). It is also expected that the colour characterization of printing done with extreme non-periodic screens will differ sufficiently from traditional characterization data that the use of device-links as the adjustment method will be required.

The matching of tone value curves or the use of near-neutral scales, rather than the use of device-link transforms, will find greatest applicability in those printing processes where the printing colourants and processes are similar to the processes and colourants used to create the reference printing condition. The choice between the matching of tone value curves and the use of near-neutral scales will largely depend on the choice of the process control procedures to be used in the control of the subsequent printing operation.

There may be some situations when the most effective method of adjustment will be a combination of the application of tone value correction curves (using either method to determine the desired correction) followed by the application of multi-dimensional transforms (e.g. ICC device-link profiles).

Annex A
(normative)

Tone value

A.1 General

Tone value, better know to some as apparent dot area, is a tool invented by the graphic arts community to monitor the relative changes in tone reproduction of an image as it moves through the various stages of film reproduction (positive and negative), to a printing plate, and eventually to the printed image. It was initially tied to half-tone images that used centre-weighted dot patterns. It is an estimate of the fractional area coverage that has the same light absorption as the sample being measured. For reference, absorption is equal to 1 minus the reflectance. In computing the apparent fractional area coverage, the sample is assumed to be composed either of areas that have the absorption of the substrate (clear film or bare paper) or of uniform areas of a fixed absorption level equivalent to the maximum exposed reflectance density of the film or the solid area of the ink. This is an important assumption because half-tone images on either film or paper are not uniform and, in addition, images on paper include an effect called optical gain. Optical gain is associated with the scattering of light within the paper substrate and results in more absorption of light than is accounted for by the actual area covered by ink.

Integrated reflectance measurements combine optical gain, non-uniformities in the “solid” areas, and variations in absorption at the edges of dots, etc. In addition, this is further complicated by the fact that the absorption (reflectance) of paper, film, ink, etc. varies as a function of the wavelength of the light being measured.

Traditionally, status reflectance density (see ISO 5) was the common tool available to measure both film and paper and it is often used to provide the estimates of tone value. From an ideal point of view, measurements made over a very narrow wavelength band at the point of maximum absorption of the ink or marking (light absorption) media used are probably the most accurate measure to use to estimate tone value. When available, colorimetric data can also be used to estimate tone value. Any measure that is directly related to the absorption of light by the marking media being used is a valid candidate. In general, the closer the spectral band pass of the measurement system matches the wavelengths of maximum absorption of the marking medium, the more consistent the estimate of tone value will be.

A.2 Computation of tone value

Because reflectance density is defined as the negative log (base 10) of the reciprocal of reflectance, the equations for computing tone value from reflectance density appear to be different from those that compute directly from reflectance data. However, they are not.

The apparent tone value, A_{ATV}, expressed as a percentage, is calculated with respect to absorption and reflectance, as shown in Equation (A.1).

$$A_{\mathrm{ATV}} = 100 \times \frac{\left(\alpha_{\mathrm{t}} - \alpha_{\mathrm{pap}}\right)}{\left(\alpha_{\mathrm{s}} - \alpha_{\mathrm{pap}}\right)} = 100 \times \frac{\left(R_{\mathrm{pap}} - R_{\mathrm{t}}\right)}{\left(R_{\mathrm{pap}} - R_{\mathrm{s}}\right)} \tag{A.1}$$

where

α_{pap} is the absorption of the paper;

α_{s} is the absorption of the area of solid ink or marking media coverage;

α_t is the absorption of the half-tone tint area;

R_{pap} is the reflectance of the paper;

R_s is the reflectance of the area of solid ink or marking media coverage;

R_t is the reflectance of the half-tone tint area.

In each case, the absorption or reflectance is spectrally weighted by the appropriate densitometric, narrow band, or colorimetric function.

When reflectance density is substituted for reflectance in Equation (A.1), and appropriately rearranged, the relationship is as shown in Equation (A.2)

$$A_{ATV} = 100 \times \left[\frac{1-10^{-\left(D_t - D_{pap}\right)}}{1-10^{-\left(D_s - D_{pap}\right)}} \right] \quad \text{(A.2)}$$

where

D_{pap} is the reflectance density of the paper;

D_s is the reflectance density of the area of solid ink or marking media coverage;

D_t is the reflectance density of the half-tone tint area.

Table A.1 shows the parameters typically used for printing inks for the three methods of computing tone value discussed.

Table A.1 — Parameters used for tone value computation

Colour	Reflectance density [a]	Colorimetry	Narrow band
Cyan	Red	X	640 nm
Magenta	Green	Y	530 nm
Yellow	Blue	Z	420 nm
Black	Visual	Y	460 nm

[a] Typically Status T density (defined in ISO 5-3) is used in some parts of the world and Status E (defined in ISO 5-3) with or without polarization in others.

A.3 Matching between methods

One very critical issue is that both the reference characterization data being matched and the measurements of the printing sample need to be based on the same measurement parameter (reflectance density, colorimetry, or narrow band). When this is not practical, it becomes important to provide correlation between the various measures of tone value. For purposes of traceability, or when data is compared between sites, communication of the chosen measuring method and the correlation methodology used is important.

A common situation encountered is having reference characterization available as colorimetric data and printing process control based on densitometric data. For black ink, the apparent tone values are usually within a few tenths of a tone value unit of each other regardless of the parameter used (e.g. ± 0,2 or ± 0,3 in tone value). For magenta and yellow the tolerance is typically up to ± 1 tone value unit between any two of the methods described.

For cyan, the difference is larger, particularly between the values based on colorimetric data and either narrow band or densitometric data. One simple correction, that reduces this uncertainty to approximately the same magnitude as is found with the other two chromatic ink colours, is to use $X - (0,55 \times Z)$ in place of the X value alone in the computation of cyan tone value.

NOTE In observing the spectral shape of the X tristimulus function, it can be seen that in the region above 575 nm the absorption of the cyan ink determines the response. However, below 575 nm, the response is primarily due to the paper. This simple correction is based on the assumption that when measuring a cyan ink, the Z tristimulus response is a relative measure of the unwanted spectral response of the X tristimulus function to the paper instead of the cyan ink. The value 0,55 is based on the average value for a sampling of printing inks.

More accurate predictions of densitometric tone value from colorimetric date are possible, for all four ink colours and the various density options, but these typically require correlation of densitometric and colorimetric data measured from the specific ink and paper being used.

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[4] ISO 5-4, *Photography and graphic technology — Density measurements — Part 4: Geometric conditions for reflection density*

[5] ISO 2846 (all parts), *Graphic technology — Colour and transparency of printing ink sets for four-colour printing*

[6] ISO 12647 (all parts), *Graphic technology — Process control for the production of half-tone colour separations, proof and production prints*

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

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

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