
**Graphic technology — Colour and
transparency of printing ink sets for
four-colour printing —**

**Part 1:
Sheet-fed and heat-set web offset
lithographic printing**

*Technologie graphique — Couleur et transparence des gammes
d'encre d'impression en quadrichromie —*

Partie 1: Impression lithographique offset sur feuilles et à bobines



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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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

This third edition cancels and replaces the second edition (ISO 2846-1:2006), which has been technically revised.

The main change compared to the previous edition is as follows:

- [Annex A](#) has been revised in order to replace the reference substrate and references to other ISO standards have been updated.

A list of all parts in the ISO 2846 series can be found on the ISO website.

Introduction

This document defines the colour and transparency of lithographic printing inks. Different sets of inks (both for proof and production printing) conforming to this document will produce a similar colour when printed on the same substrate at the appropriate film thickness. This enables colour separations for offset-lithographic printing to be based on known colour references and simplifies the task of consistently printing the same images in multiple printing sites.

It should be noted that the colorimetric characteristics specified can only be obtained when the inks are printed on the reference substrate. However, the similarity of two inks on a reference substrate generally ensures similarity on another substrate, and it is this similarity that has enabled the development of industry specifications or standards such as ISO 12647-2^[1], which specifies the colour of these inks on other substrates.

The APCO II/II reference substrate, used for many years, is no longer available and has been replaced by a new developed reference substrate, C2846, with properties which are for the purpose of this document similar to the old substrate. Where the new substrate is used for other purposes than specified in this document, new references may have to be determined.

The colour specified in the previous edition of this document was based on extensive measurements of commercial ink sets made in Europe, Japan and the USA. A working group of ISO/TC 130 process control and material experts examined data sets from various countries at the time that edition was prepared and found that a single set of colour coordinates could adequately represent all three proposals within reasonable tolerances. In addition, they found that the transparency of various inks could also be adequately represented by a new method of evaluation. A review undertaken prior to the revision of this edition suggested that there had been little change in the colour and transparency of the inks commercially available and that the characteristics specified in this document could be reconfirmed.

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Graphic technology — Colour and transparency of printing ink sets for four-colour printing —

Part 1: Sheet-fed and heat-set web offset lithographic printing

1 Scope

This document specifies the colour and transparency characteristics that are to be met by each ink in a process colour ink set intended for proof and production printing using offset lithography. The specified printing conditions (which use a laboratory printability tester), the defined substrate and a method for testing to ensure conformance are also defined. Characteristics are specified for inks used for sheet-fed, heat-set web and radiation-curing processes.

This document does not apply to fluorescent inks and it does not specify pigments (or spectral characteristics — except informatively) in order not to preclude developments which may enable different pigment combinations to be used advantageously while still achieving the colorimetric requirements specified in this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 535, *Paper and board — Determination of water absorptiveness — Cobb method*

ISO 536, *Paper and board — Determination of grammage*

ISO 2144, *Paper, board and pulps — Determination of residue (ash) on ignition at 900 °C*

ISO 2834-1, *Graphic technology — Laboratory preparation of test prints — Part 1: Paste inks*

ISO 6588-1, *Paper, board and pulps — Determination of pH of aqueous extracts — Part 1: Cold extraction*

ISO 8254-1, *Paper and board — Measurement of specular gloss — Part 1: 75 degree gloss with a converging beam, TAPPI method*

ISO 8791-4, *Paper and board — Determination of roughness/smoothness (air leak methods) — Part 4: Print-surf method*

ISO 13655:2009, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*

3 Terms and definitions

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

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

0°:45° or 45°:0°

measurement geometry of a spectrophotometer in conformance with ISO 13655 geometry 0°:45° or 45°:0°

3.2

8°:di or di:8°

hemispherical diffuse geometry, specular component included, with either 8° incidence (influx) (8°:di) or 8° exitance (efflux) (di:8°)

Note 1 to entry: The measurement geometry of a spectrophotometer not in conformance with ISO 13655.

3.3

ink

printing ink

composite material containing colorants, functional components, vehicle and additives

Note 1 to entry: In most cases, applied as a fluid to a substrate by a printing process and setting or drying by either physical (evaporation) and/or chemical (polymerizations, e.g. oxidation, radiation induced, or other) processes to form an image for decorative, informative or technical purposes.

3.4

standard ink

process ink

ink (3.3) intended for four-colour printing which, when printed on the reference substrate and within the applicable range of ink film thicknesses, complies to the colorimetric and transparency specifications of this document

3.5

transparency

ability of an ink (3.3) film to transmit light

Note 1 to entry: It is generally expressed as some measure of the unwanted scattering.

3.6

transparency value

T

reciprocal of the slope of the regression line between ink (3.3) film thickness and colour difference for overprints of chromatic inks over black substrate

4 Test method

4.1 Procedure

Colorimetric conformance shall be verified by printing each ink on the reference substrate, described in Annex A, at a range of ink film thicknesses. The colours of the resultant test prints shall be measured and the colour difference determined between the sample and the pertinent value given in Table 1. If at least one of these samples has a smaller colour difference than that specified in 5.2, the ink conforms colorimetrically to this document.

NOTE It is often more convenient to determine the colorimetric conformance of an ink graphically. This is achieved by calculating the colour difference (ΔE^*_{ab}) from the values in Table 1 for each of the prints made and plotting this against the ink film thickness. The ink conforms if the resultant curve shows a pronounced minimum which is below the ΔE^*_{ab} value specified in Table 1. (See Annex B for further information.)

Transparency value, T , shall be determined by printing each of the chromatic process inks on to a black substrate meeting the requirements of 4.2.2, at a range of ink film thicknesses. The colour difference, ΔE^*_{ab} , is determined for each sample between the overprinted and unprinted black substrate. The gradient of the linear regression of ink film thickness against colour difference shall be determined. An ink conforms to the transparency requirements of this document if the reciprocal of the gradient is negative, or greater than the value specified. (See Annex B for further information.)

The gradient of the regression equation may be determined directly from the data obtained. However, it is recommended that it be obtained from a graphical plot of the values of ΔE^*_{ab} against ink film thickness. Such a plot enables any unexpected characteristics of the data to be easily visualized. (See [Annex B](#) for further information.)

If one or more printed samples of each ink conform to the colorimetric values within the tolerances specified at an ink film within the thickness range specified, and the ink also meets the transparency criteria, that ink can be said to comply to this document.

4.2 Test print preparation

4.2.1 Prints for colorimetric evaluation

For each of the inks to be evaluated, several test prints shall be made, each produced at a different ink film thickness, according to the conditions specified in ISO 2834-1.

They shall be made on the reference substrate specified in [Annex A](#). The range of ink film thicknesses produced shall encompass the range specified for the process for which the ink is intended. (See [5.4](#).)

4.2.2 Prints for transparency evaluation

The test prints for transparency evaluation shall be produced by printing the inks to be tested on a black substrate such that a minimum of four samples is achieved, each with a different ink film thickness. The printing shall be undertaken as described in ISO 2834-1. The range of ink film thicknesses achieved shall not exceed that defined in [5.4](#).

NOTE Test prints with ink film thicknesses below 0,7 μm can cause errors in the transparency evaluation.

The black substrate shall have a lightness, L^* , less than 6 when determined in accordance with ISO 13655:2009, M0, M1 or M2 (with the exception that a white backing shall be used when measuring the print; see [4.3](#)). The black substrate shall have a gloss of (80 ± 5) GU measured according to ISO 8254-1.

Although in principle, it is possible for the user to produce themselves the black substrate by printing, it is difficult to ensure that the lightness is sufficiently low without adversely affecting the gloss and printing properties of the substrate. It is usually preferable to use a black substrate or a substrate pre-printed commercially. However, if it is necessary to print the black, the recommendations given in [Annex B](#) should be followed. Appropriate substrates are the contrast card or the contrast strip¹⁾.

4.2.3 Drying of test prints

Prior to colour measurement, all samples shall be thoroughly dried. Inks formulated for oxidation drying shall be left for at least 24 h, those formulated for radiation curing shall be dried with an appropriate radiation source within the appropriate time and energy and heat-set inks shall be heat dried with appropriate drying equipment.

NOTE Be aware that the appropriate time for radiation curing inks can be down to parts of a second only.

4.3 Colour measurement procedures

Test prints shall be measured in accordance with ISO 13655 using white backing. Measurement condition M1 should be used. M0 or M2 may be used and should not give difference in results.

Conforming to ISO 13655:2009, M1 means that samples shall be measured spectrally, with a $0^\circ:45^\circ$ or $45^\circ:0^\circ$ geometry instrument, and for calculation of CIELAB colour values, the CIE 1931 (2°) standard

1) Comparison test strips CT2846 with contrast band from IGT Testing Systems (www.igt.nl), NL-1316 BX Almere, The Netherlands. These products are examples of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of these products.

colorimetric observer data are used together with CIE standard illuminant D50 including calibrated UV level; see Reference [3]. Where spectral data are obtained at wavelength intervals greater than 5 nm, the weighting functions for the standard colorimetric observer specified in ISO 13655 shall be used.

For calculating the colour difference from the reference values, the CIE 1976 colour difference, ΔE^*_{ab} , shall be used.

NOTE For the comparison of measurements, it is useful to record the following details:

- the ink designation and batch number;
- the ink layer thicknesses;
- the substrate used;
- the printability tester used and the settings used on the tester (speed, force, printing form);
- environmental conditions (lab temperature and relative humidity);
- spectrophotometer used;
- any deviations from this document.

5 Requirements for colour, transparency and ink film thickness range

5.1 General

For an ink to conform to this document, it shall meet the specifications for colour defined in 5.2, and the specification for transparency defined in 5.3, at an ink film thickness within the range specified in 5.4.

5.2 Colorimetric values

When printed in accordance with Clause 4, an ink shall produce a colour that falls within the defined colour difference tolerances, ΔE^*_{ab} , from the L^* , a^* , b^* values specified in Table 1.

Table 1 — Colorimetric values for M1, 0°:45° geometry, illuminant D50, 2° observer

Ink	CIELAB values ^a			ΔE^*_{ab}	Tolerances ^a			
	L^*	a^*	b^*		ΔE_{00}^b	Δa^*	Δb^*	L^*
Yellow	91,0	-5,1	95,0	4,0	2,8	—	—	—
Magenta	50,0	76,0	-3,0	4,0	2,8	—	—	—
Cyan	57,0	-39,2	-46,0	4,0	2,8	—	—	—
Black	18,0	0,8	0,0	—	—	±1,5	±3,0	18,0 ^c
^a Parameters L^* , a^* , b^* , ΔE^*_{ab} , Δa^* and Δb^* are defined in ISO 13655:2009, M1.								
^b ΔE_{00} values are presented for information only.								
^c For black, there is no symmetrical tolerance for L^* but an upper limit.								

NOTE 1 Typical spectral data for inks conforming to this document are provided in Annex C. Reference spectral data for 8°:di or di:8° geometry are also included in Annex C.

NOTE 2 Reference data for tristimulus values calculated from the CIE 1931 (2°) standard colorimetric observer, together with CIE illuminant D65, are included in Annex D for both 8°:di or di:8° and 0°:45°. Tristimulus data for 8°:di or di:8° geometry and illuminant D50 are also included in Annex D.

5.3 Transparency characteristics

When printed in accordance with Clause 4, an ink shall produce a transparency value, T , greater than that specified in Table 2.

Table 2 — Transparency requirements

Ink	Transparency, <i>T</i>
Yellow	>0,08
Magenta	>0,12
Cyan	>0,20

For highly transparent inks (usually cyan), the slope of the regression line may be zero or negative. In such a situation, the transparency value is considered to be approaching infinity and therefore meets the specification. A constant, but large colour difference is an indication of opacity, even though the *T* value is within specification.

NOTE For information concerning transparency evaluation using instruments with different geometry, see [B.3.2](#).

5.4 Ink film thickness

The range of ink film thicknesses within which a standard ink shall conform is provided in [Table 3](#) for the different ink drying processes specified in this document.

Table 3 — Range of ink film thicknesses in micrometres

Drying mechanism	Ink			
	Cyan	Magenta	Yellow	Black
Drying by oxidation/setting	0,7 to 1,1	0,7 to 1,1	0,7 to 1,1	0,7 to 1,3
Radiation curing	0,7 to 1,3	0,7 to 1,3	0,7 to 1,3	0,9 to 1,3
Heat-set web	0,7 to 1,3	0,7 to 1,3	0,7 to 1,3	0,9 to 1,3

Annex A (normative)

Reference substrate

For the purposes of this document, a lightfast gloss-coated wood-free paper free of optical brightener shall be used as the printing substrate, the characteristics of which shall be as follows:

Colorimetric values

Specification: CIELAB values

$$L^* = 97,5 \pm 1,0$$

$$a^* = -0,15 \pm 1,0$$

$$b^* = 4,0 \pm 1,0$$

Method: ISO 13655:2009, M1, white backing (see [4.3](#))

Water absorptiveness

Specification: (25 ± 5) g/m² after 60 s

Method: ISO 535

Gloss

Specification: (80 ± 4) GU

Method: ISO 8254-1

Mass per area

Specification: (170 ± 10) g/m²

Method: ISO 536

Ash content

Specification: 20 % to 30 %

Method: ISO 2144

pH

Specification: 8 to 10

Method: ISO 6588-1

Roughness

Specification: 0,5 µm to 0,7 µm at a pressure of 1 N/mm²

Method: ISO 8791-4

NOTE This material is the gloss-coated wood-free paper C2846 from IGT Testing Systems.²⁾

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2) This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

Annex B (informative)

Extended explanation of the test procedures, including examples

B.1 Colorimetric verification

To evaluate whether an ink meets the specifications of this document, it is necessary to print a number of samples, each of known ink film thickness, which adequately represent the range of ink film thicknesses specified for that ink in [5.4](#). These samples shall be prepared on a printability tester according to the method described in ISO 2834-1. A small quantity of ink is run up on the inking system, the printing form is weighed prior to printing and then the test sample is printed on the reference substrate. The form is then re-weighed and the difference noted. If the mass density of the ink is known (this may be determined by weighing a known volume of ink) and the printed area is measured, it is possible to calculate the ink film thickness applied to the substrate from the difference in mass before and after printing. The ink film thickness, s , can be calculated using the following formula:

$$s = \frac{\Delta m}{\rho \times A}$$

where

s is the ink film thickness;

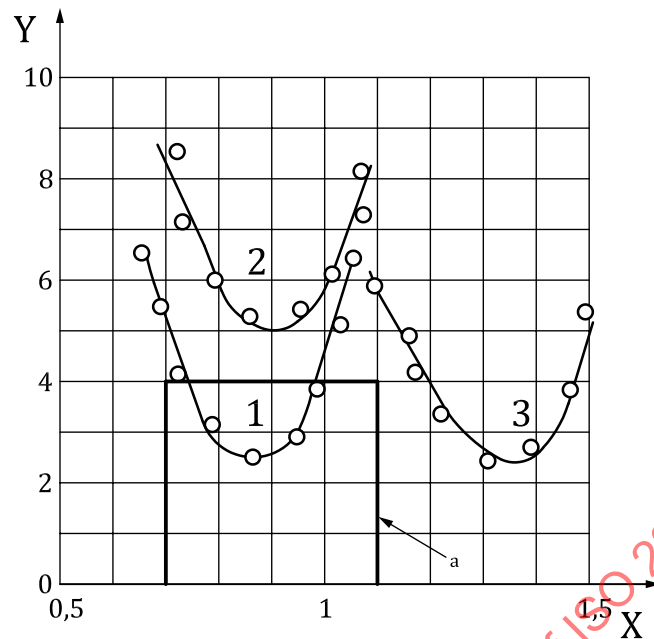
Δm is the difference in mass of the form before and after printing;

ρ is the mass density of the ink;

A is the printed area.

A number of samples are obtained covering the range of ink film thicknesses specified in this document and preferably beyond, for higher precision.

When dry, several printed samples, distributed throughout the range of ink film thicknesses, are selected and their colour measured. This is undertaken with the sample lying on a white backing ([4.3](#)) and measured using preferably measuring mode M1 and with 2° observer and illuminant D50. The CIELAB colour difference between each sample and the colour specified in [Table 1](#) of this document are then calculated and plotted as a function of the ink film thickness as shown in [Figure B.1](#). The ink meets the specifications of this document if, at some ink film thickness in the specified range, it falls below the colour difference specified in [Table 1](#) of this document. [Figure B.1](#) shows the tolerance range for an oxidative setting ink. Curve 1 in that figure shows an ink which conforms to this document. Curves 2 and 3 are examples of inks which deviate from this document. Curve 2 belongs to an ink of the wrong colour, most probably of incorrect hue, whereas curve 3 shows an ink of the correct colour but at the wrong concentration of colorant.

**Key**

X s, ink film thickness in micrometres

Y ΔE^*_{ab} , colour difference

1 ink drying by oxidation/setting which conforms to this document

2 ink drying by oxidation/setting which does not conform to this document due to a deviation in colour

3 ink drying by oxidation/setting which does not conform to this document; it is correct in colour but not in concentration

a Tolerance range.

Figure B.1 — Example evaluation of oxidative setting printing ink (colour difference plotted as a function of ink film thickness)

B.2 Determination of transparency

Using the same procedure as above, a series of prints shall be made covering the range of ink film thicknesses specified in 5.4. However, for this test, the black substrate may be any gloss-coated paper of reasonable opacity, which has been pre-printed with an area of black ink that has an L^* value not greater than 6 and a gloss of (80 ± 5) GU measured according to ISO 8254-1. Such material may be purchased from IGT Testing Systems or produced by the user by printing the substrate with two or more coatings of black ink, allowing sufficient time between printings for the ink to dry (4.2.3).

For the determination of transparency, each strip of black substrate should be coded and the colour of the black repeatedly measured and averaged on each strip, prior to overprinting with the test inks over the range of ink film thicknesses specified.

After the samples, which have been printed with the test inks, are dry, the colour of each sample should be measured as described in B.1, in the same position on the sample as was measured for the black. (See the cautionary discussion concerning production and measurement of the samples in B.3.)

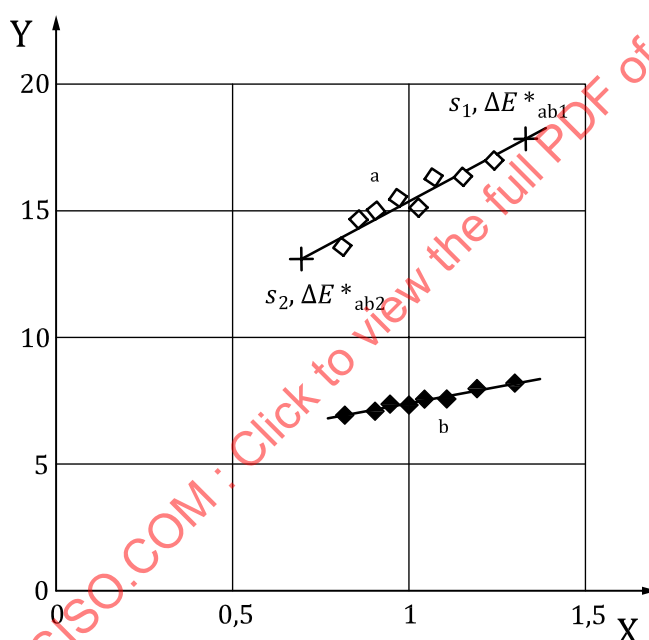
The colour difference between the two measurements is then calculated for each sample and plotted as a function of ink film thickness. The “best fit” straight line through these points is then drawn as shown in Figure B.2 and the slope of the line is calculated. (Alternatively, the gradient of the linear regression equation may be calculated directly from the data.) The reciprocal of this value is then computed and

this is the value T of the transparency measurement. Using the graphical method, this value may be calculated directly as follows (refer to [Figure B.2](#)):

$$T = \frac{s_1 - s_2}{\Delta E_{ab1}^* - \Delta E_{ab2}^*}$$

where

- T is the value of the transparency;
- s_1 is the ink film for the point on the graph at the higher level of film thickness;
- s_2 is the ink film for the point on the graph at the lower level of film thickness;
- ΔE_{ab1}^* is the colour difference for the point on the graph at the higher level;
- ΔE_{ab2}^* is the colour difference for the point on the graph at the lower level.



Key

- X ink film thickness in micrometres
- Y ΔE_{ab}^* , colour difference
- a Transparency value, $T = 0,13$.
- b Transparency value, $T = 0,50$.

Figure B.2 — Assessment of transparency according to this document

Provided the value derived from this calculation is greater than that specified in [5.3](#), the transparency of the ink is in conformance with this document. For perfectly transparent inks (or those close to it), the gradient of the linear regression equation, and therefore its reciprocal, could be negative. This special case would also conform to this document.

B.3 Issues to be noted when preparing and measuring samples for transparency assessment

B.3.1 Selection and printing of the black ink

If transparency is calculated from measurements using samples on which a black ink has to be printed on the substrate by the user, care needs to be taken in the selection of the black ink to be used. A black shall be selected that exhibits little or no bronzing and which exhibits a similar level of gloss to the same sample when overprinted by the test ink. Any pre-printed material cited in 4.2.2 can give rise to anomalous results if the gloss change is significant. Any measure of transparency based on optical measurements could be affected by such surface phenomena and care needs to be taken to select materials which minimize them. If this is not done, erroneous results may well be obtained. In severe cases, this may even arise with a $0^\circ:45^\circ$ or $45^\circ:0^\circ$ geometry. Such erroneous results are normally obvious from simple visual assessment of the samples.

It is possible to have an ink with such a high degree of transparency that the resultant overprint reflects less light than that of the black ink alone. This is simple to understand in that both the black and test inks will absorb light. It is with such an ink that the graph obtained as shown in Figure B.2 will have a negative or zero slope. However, in practice, most inks scatter light to such a degree that this scenario is not likely, particularly for magenta and yellow. Thus, if such a result is obtained, it is sensible to be cautious. It is wise to assume that such phenomena as “super-transparency” on the one hand (whereby the result appears blacker when overprinted by the coloured ink than without) or an ink seeming excessively opaque on the other hand are the result of gloss or bronzing effects which are different between the black ink and the overprint surfaces. If unexpected results are obtained, the nature of the black substrate and printed samples should be investigated to see whether these phenomena are a possible cause. Visual assessment will generally confirm whether or not the test ink is really as highly transparent or opaque as suggested by the regression coefficient and, if not, should reveal the source of the difficulty.

B.3.2 Use of sphere instruments for determining transparency

It is because the variation in surface effects is more likely to influence results obtained on an integrating sphere instrument (even with the specular component excluded) that values for transparency obtained using a sphere instrument, equivalent to those obtained using a $0^\circ:45^\circ$ geometry instrument, have not been provided in Annex D.

Nevertheless, with care, the procedure can still prove useful for the evaluation of samples of similar surface characteristics. Results obtained with such instruments give absolute values of T different from those obtained with a $0^\circ:45^\circ$ geometry instrument, but are ranked in the same order and with similar relative differences between them. The procedure can also prove useful for “troubleshooting” unexpected results obtained with a $0^\circ:45^\circ$ geometry instrument.

NOTE For a more extensive discussion of the issues raised in this clause, the reader is referred to the paper by Bassemir and Zawacki^[2].

Annex C (informative)

Spectral data

For some applications, such as calculating tristimulus values for a different observer or illuminant, it is useful to have recourse to spectral data. It is deliberately decided not to standardize such data since it can be very restrictive for ink manufacturing and the future development of ink with improved properties. However, the following data may be taken as “typical” of that which was obtained during development of this document.

Two tables of data are presented: [Table C.1](#) is for 0°:45° geometry and [Table C.2](#) is for 8°:di. The data in [Table C.1](#) are in accordance with the values in [Table 1](#). The data of [Tables C.1](#) and [C.2](#) have been used to compute the values in the tables of [Annex D](#).

For the purposes of this document, the 0°:45° and 45°:0° geometries are deemed to be equivalent to each other, as are the 8°:di and di:8° geometries. Thus, while only one of the equivalent geometries is specified in the tables of this annex, it may be interpreted that either is acceptable. Of course, the values obtained with each geometry are different.

Table C.1 — Typical spectral reflectance data for inks conforming to this document, 0°:45° geometry

Wavelength nm	Reflectance factor				
	Cyan	Magenta	Yellow	Black	Substrate ^a
380	0,094	0,245	0,113	0,019	
390	0,200	0,219	0,087	0,020	
400	0,312	0,206	0,067	0,020	0,787
410	0,409	0,208	0,053	0,022	0,814
420	0,452	0,214	0,044	0,024	0,836
430	0,522	0,228	0,041	0,025	0,850
440	0,606	0,242	0,041	0,025	0,859
450	0,664	0,237	0,045	0,025	0,869
460	0,690	0,213	0,056	0,026	0,880
470	0,699	0,181	0,060	0,026	0,889
480	0,695	0,148	0,082	0,026	0,898
490	0,679	0,119	0,168	0,026	0,905
500	0,647	0,092	0,348	0,026	0,910
510	0,597	0,068	0,584	0,026	0,914
520	0,525	0,047	0,741	0,026	0,918
530	0,436	0,038	0,803	0,025	0,923
540	0,341	0,035	0,831	0,025	0,929
550	0,245	0,029	0,848	0,024	0,932
560	0,158	0,022	0,856	0,023	0,934
570	0,102	0,018	0,864	0,023	0,936
580	0,072	0,039	0,869	0,023	0,939
590	0,057	0,177	0,874	0,024	0,944
600	0,047	0,431	0,877	0,024	0,949
610	0,041	0,653	0,881	0,025	0,952
620	0,040	0,789	0,885	0,026	0,953
630	0,041	0,852	0,889	0,027	0,954
640	0,043	0,880	0,895	0,028	0,955
650	0,051	0,895	0,900	0,030	0,957
660	0,062	0,903	0,904	0,031	0,959
670	0,068	0,907	0,906	0,032	0,959
680	0,065	0,910	0,907	0,034	0,959
690	0,060	0,914	0,909	0,035	0,961
700	0,048	0,918	0,912	0,037	0,964
710	0,043	0,921	0,914	0,039	
720	0,053	0,923	0,914	0,042	

^a Reference substrate (see [Annex A](#)).