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Graphic technology — Guidelines and recommendations for multicolour (CMYKOGV) print characterization

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Contents

Page

Foreword

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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).

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Multicolour process packaging printing

Print technology and quality has improved in the past decades. Mechanical print characteristics perform at a higher level, as have customer expectations. For cyan, magenta, yellow, and black (CMYK), colour standardization has been adopted and customers expect a specific colour gamut and conformance to a characterization data set when printing with CMYK. The result of technology integration in all print processes has provided improvement in productivity and print quality. The research of Neugebauer (1937)[18], Murray (1936)[17], and Yule (1967)[22] presented a view of colour reproduction, which has evolved from imaging systems based on silver halide photography technology leading to today's digital pixel-by-pixel access to colour image data.

Print systems have also evolved from four-colour (CMYK) on four unit presses to CMYK plus additional colours as noted in research and recognized patents. Often called multicolour process printing (MCPP), additional terms used are Extended Colour Gamut (ECG) printing, Expanded Gamut Printing (EGP), Fixed-palette (FP) printing, N-colour printing, High-Fidelity (HiFi) printing. Examples of research include Kueppers (1989), Mills Davis/HiFi project (1991), Ostromoukhov[20], Boll[9], Mahy & De Baer[16], Bernasconi (1998), Herbert and DiBernardo (1998), Lo (1997), Viggiano and Hoagland[21], and Ingram and Simon[14]. In most of these references, additional colours were added to enhance image elements of the selected CMYK ink set. Viggiano and Hoagland provide methodology for colourant selection. Package printing often requires spot colours to be matched to aims within tolerances, with colour remaining consistent throughout the print run. This document describes insight concerning the selection of colourants to expand or enhance colour print gamut with orange, green, and violet (OGV) and recommended characterization procedures. The colourant selection may be restricted by the print process characteristics[12].

Previous efforts recommend adding an ink containing pigment Green, an ink containing Violet, and an ink containing an orange pigment. Due to ink curing systems, difficulty remains making a specific recommendation on a single orange pigment. Clemson University studies by Ingram and Simon[14], and Zeleznik[23] were able to recommend Colour Index International (C.I.)[10] pigment Orange-16 and C.I. pigment Orange-64. C.I. values are a common database reference for manufactured colour products, which can be communicated based upon a specific source. The recommended CMYKOGV pigment set provides increased colour gamut as seen in the colour gamut comparison as follows.

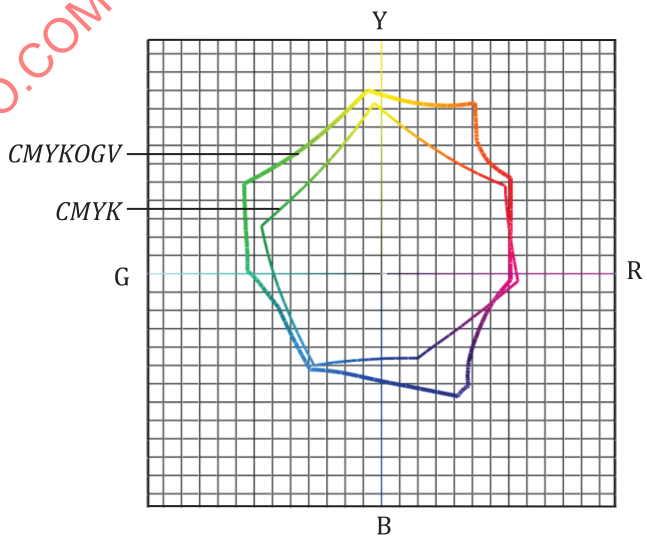


Figure 1 — CIELAB Colour Boundary Comparison of CMYK to CMYKOGV Hue Aims[15]

Use of a standardized multicolour printing target is required. Previous efforts have used an IT8.7/3 or IT8.7/4 colour characterization target. Four data sets are produced: 1. CMYK, 2. CMVK–complementary substituted ink, 3. CGYK–complementary substituted ink, and 4. OMYK–complementary substituted ink. The measured spectral data sets were combined to produce a master CMYKOGV data set. A custom seven-colour characterization target may also be used. The colour data set is then analysed to calculate the colour gamut fit. Lastly, a technology capable of producing a compatible ICC n-colour profile is needed to complete a colour-managed workflow utilizing the CMYKOGV data.

Graphic technology — Guidelines and recommendations for multicolour (CMYKOGV) print characterization

1 Scope

This document provides guidelines and a procedure to generate a multicolour characterization dataset. Specifications for colour printing with CMYK + Orange, Green, and Violet are presented. Also, this document provides a recommendation on CMYKOGV ink pigment selections to produce an optimum colour gamut for specific printing processes or use cases. The recommended CMYKOGV ink pigment selections might not be suitable or available for all printing or digital processes or use cases. The procedure in this document is also applicable for CMYK plus any subset of O, G or V.

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 3664, *Graphic technology and photography — Viewing conditions*

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

ISO 17972-1, *Graphic technology — Colour data exchange format — Part 1: Relationship to CxF3 (CxF/X)*

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

ISO/TS 19303-1, *Graphic technology — Guidelines for schema writers — Part 1: Packaging printing*

3 Terms and definitions

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

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

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

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

3.1
calibration
comparison and adjustment between printing systems – one of known behaviour or correctness, made with a set of reference colours, and another printing system made to print in as similar a way as possible with the reference device

Note 1 to entry: The G7 methodology is one form of printing system calibration where the reference colours are 3-colour overprints made to match as closely as possible the optical properties of a series of black-only prints.

Note 2 to entry: ISO/PAS 15339-1 describes another process for calibration of a printing system to a Characterized Reference Printing Condition.

Note 3 to entry: Often, the first step alone in the above definition is perceived as being calibration.

3.2
colour characterization data
tabulation of data that represents the relationship between device code values (e.g. CMYK, CMYKOGV) and the colour (spectral and CIELAB values) produced on the printed sheet by those values in a specific printing process

Note 1 to entry: The colour characterization data may be used to create an ICC profile as in ISO 15076.

3.3
Colour eXchange Format
CxF/X
format for the communication of colour and process control data and the associated metadata for its proper interpretation detailed in ISO 17972-1

Note 1 to entry: For example, CxF/X-1 is used to communicate process colour information and other metadata related to the colour data including tone values, ink amounts and spectral data. CxF/X-4 files are used to communicate spot colour ink data that requires spectral data and transparency metadata.

3.4
hue angle
angular component of the polar representation of a colour based on CIELAB, calculated by h_{ab} = arctangent(b*/a*)

3.5
printing condition
set of primary process parameters that describe the conditions associated with a specific printed output and defined colourimetrical and/or densitometrical aim values

3.6
packaging
process of designing, evaluating, and producing packages

Note 1 to entry: For this document, use of the term specifically refers to the materials used to produce colour graphics and information displayed on the substrate.

Note 2 to entry: Methods for production may include direct printing, lamination, or labels.

3.7
primary process colour
colour that is the outcome of a colour separation process (typically CMYK)

Note 1 to entry: A process colour reproduction typically requires one or more printing units and process inks to be reproduced.

Note 2 to entry: The ink set is specified in the ISO 12647series.

Note 3 to entry: The colours OGV are typically added in MCPP.

3.8
characterized reference printing condition
CRPC
identified printing condition (3.11) and its colour characterization data used as the aim for a particular printing task (job)

Note 1 to entry: ISO/PAS 15339-1 provides 7 Characterized Reference Printing Conditions (CRPC).

3.9
spot colour tone value
SCTV
value that describes the apparent halftone area for a non-process ink as described in ISO 20654

3.10
multicolour process printing
MCPP
printing with more than a single colour ink with a multi-unit printing system

Note 1 to entry: It is also called expanded colour gamut printing where process colour printing uses more than 4 primary inks, for example orange, green, and violet inks, so as to increase the volume of colour space which can be reproduced using halftone combinations of the primary plus extra inks.

3.11
identified printing condition
printing condition documented in a national or international standard or industry publication in a way that allows it to be replicated by an industry practitioner. Also, a set of primary process parameters that describe the conditions associated with a specific printed output and defined colourimetrical and/or densitometrical aim values

4 Guidelines and requirements associated with specific tasks

4.1 Basic support requirements

4.1.1 Viewing conditions

The viewing and illumination conditions used for visual assessment of printed products shall be in accordance with ISO 3664.

4.1.2 Measurement and colour computation

The measurement of colour shall be made with instruments, standardized according to the manufacturer's guidelines and capable of producing data in accordance with ISO 13655. Further, it is recommended that ISO 20654 should be used to determine tonal values, also CMYK near neutral or TVI methods are applicable. When substrate corrections are necessary, calculations should follow ISO/PAS 15339-1. When the OBA content is high or moderate and the expected viewing condition contains UV, measurements shall be made with M1 measuring mode. When the OBA content is low or faint (i.e. UV-UVX ≤8 when measured D65 Brightness with UV and with UV cut-off filter), M0, M1 or M2 may be used since comparable results are expected. Where the expected viewing condition doesn't contain UV, the use of M2 is recommended.

NOTE When viewing in a UV free environment the use of M2 provides measurements consistent with viewing.

4.1.3 Data evaluation tools

Colour data, resulting from the characterization print run, should be analysed to confirm its fit to the determined colour aims. Software tools for determining these colour differences may include commercial software tools, spread sheets or 3D gamut applications. Tone values for the CMYKOGV ink prints may also be analysed with such tools.

4.2 Colour definition

4.2.1 Process colours

Prior agreement on identified reference printing conditions and their tolerances shall be obtained between all stakeholders of the characterization materials and procedures before beginning characterization work.

In the case of flexographic printing, Table 1 provides an example of the specifications for CMY process colour inks and overprints for flexographic printing. For other printing technologies, refer to the appropriate parts of ISO 12647.

Table 1 — Example metric hue angle (degrees)[a] [13]

Colour	Traditional inks	Light-fast inks
Cyan	233°	233°
Magenta	357°	12°
Yellow	93°	100°
Red[b]	36°	40°
Green[b]	160°	162°
Blue[b]	290°	296°

[a] Metric hue angles are taken from ISO 12647-6 for primary process colours.

[b] Red, Green and Blue are two colour builds from the CMY components (not to be confused with the additional primaries added to the process set).

Stakeholders should determine tolerances based on the printing technology and ink systems used, as specified in the appropriate part of ISO 12647.

4.2.2 Pigment Selection

In ink specification, it is desirable to select pigments that will most likely permit printing the greatest colour gamut, whilst retaining the four primary process colours defined in the appropriate part of ISO 12647. Tables 2 and 3 show example of ink pigments, based on colour attributes and printability for analogue printing (offset lithography, flexography, and gravure). Other printing technologies and substrates within the substrate colour range may require different ink selection and hence produce different CMYK and OGV values.

Table 2 — Example colour pigment and hue angle[12],[14]

Cyan - PB 15:3 / 233°	Orange - PO 16 / 54°
Magenta - PR 57:1 / 357°	Orange - PO 64 / 55°
Yellow - PY 14 / 93°	Green - PG 7 / 181°
Black - PB 7 / na	Violet - PV 23 / 310°

Table 3 — Example CIELAB aims for OGV[12]

Ink	L*	a*	b*	C*	h_{ab}
Orange	70	56	80	98	55
Green	66	-73	-1	73	181
Violet	24	46	-55	71	310

The recommended CMYKOGV ink pigment selections are intended to produce an optimum colour gamut, they might not be suitable or available for all printing processes or use cases.

Annex C provides guidance for selecting pigments for expanded gamut applications.

4.2.3 Substrate selection

Substrates should be light (typically CIELAB L* > 85) and reasonably neutral (-3 < CIELAB a* < 3, -6 < CIELAB b* < 5).

4.3 Colorimetric/spectral data reporting

Colorimetric data shall be communicated as referenced by ISO 17972-1 Colour eXchange Format or ISO 28178.

4.4 Printing for the development of characterization data

4.4.1 Input data for characterization of multicolour printing

Printing the selected CMYK and OGV inks shall be performed on a verified calibrated device (described in 4.4.2) using a defined multicolour characterization input data set such as the "Global Expanded Colour Gamut (ECG) Characterization Target". A method for utilizing ISO 12642-2[8] is also suitable as described by Ingram and Simon[14].

4.4.2 Printing device setup

Printing devices shall be calibrated and said calibration verified and documented. A near neutral calibration or TVI technology is recommended for press calibration of CMYK colours. For ECG inks, specifically OGV colours, the SCTV based calibration is recommended. In that case a linear (1:1) reproduction is recommended for the SCTV calibration. Annex A provides an example of process steps to develop characterization data.

4.4.3 Printing device verification

For packaging use case, measurement and documentation referenced in ISO/TS 19303-3[14] should be consulted for print device verification.

4.4.4 Colour Communication

Print process colour qualification should be made with spectral data measurement described in ISO 13655. For press qualification, given reference Lab values for a specified ink film thickness or ink quantity, control during characterization process can be performed by press operators by CIELAB measurements. Once the colour is correct, maintain with any suitable process control to meet the process colour aims. Colour difference (CIEDE2000) may be used for process control.

Non-CMYK process colour qualification should be made with spectral data measurement. Colour differences may be analysed from colorimetric data derived from the spectral data to determine the precision and accuracy of the results and therefore acceptability of the results.

4.4.5 Verification and reporting

ISO/TS 15311-1[10] provides details regarding verification and reporting of data for materials. Specifically, the Certificate of Analysis (CoA) and Certificate of Conformance (CoC), as defined in ISO/TS 19303-1[14], should be used to confirm that the specifications and deviations or tolerances that were agreed upon by all involved suppliers of the characterization data, have been met. For packaging use case, measurement and documentation for the CoA provides all the required specification and test results about a particular material [a description of the test or examination method(s) used; limits of the test or examinations; and actual results of the tests or examinations], to demonstrate that end user/customer requirements are met. The CoC is a document certifies that the supplied services or goods meet the required specifications.

The CoC for materials used in the colour characterization shall be kept on file to be used as reference for communication and confirmation that specified materials were acquired for the colour characterization. Items described include substrate(s), inks, and additives specific to the print process used.

The CoA details outcomes produced by the colour characterization process. Procedures for actions and analysis of the following shall be documented and kept on file:

— name of organization(s) producing the colour characterization;

— name(s) of individuals responsible for producing the analysis;

— operating procedures for preparation and execution of colour characterization;

— sampling procedures;

— testing and measurement equipment and measuring procedures;

— colour data acquired from the colour characterization test charts;

— comparison of colour characterization data to colour aims;

— information specific to the printing process used for the colour characterization.

This is not an exhaustive list. It serves as example for reporting critical information necessary for replication of colour characterization process.

Annex A provides guidance for decision points when developing colour characterization procedures.

Annex B provides guidance for the colour characterization process.

Annex A
(informative)

Example of colour characterization procedures

A.1 General

The characterization of the print system requires using the inks to produce a colour target provided by the anticipated profiling algorithm provided by the colour profiling software manufacturer, which is then measured to verify colour aims are achieved[11]. Figure A.1 provides a general overview of process steps.

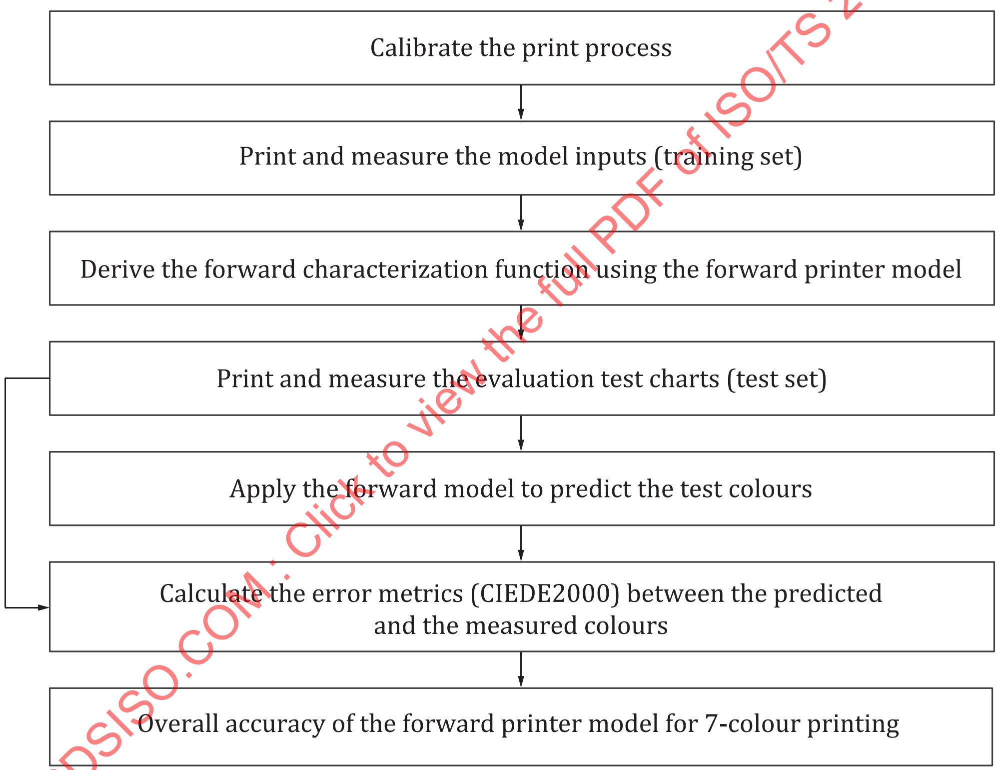


Figure A.1 — Processing steps

A.2 Preparation and planning

Colour characterization requires attention to the following points:

— screening frequency and angles;

— print sequence;

— verification of plate specifications;

— verification of substrate;

— verification of ink;

— proof;

— calibrated measuring device;

— viewing and illumination conditions;

— control strip including patches for additional inks;

— sampling method;

— verification of press-condition/maintenance;

— press room temperature and humidity.

And process specific parameters:

— blankets;

— fountain solutions;

— anilox specifications;

— doctor blades.

This list is not a comprehensive list for all printing types and parameters.

A.3 Production for characterization

Detail on reporting requirements regarding the CoA is found in ISO/TS 15311-1 and CoC in ISO/TS 19303-1 relative to printer and convertor responsibilities.

The printer should decide the colour sequence for printing the seven ink colours. This characterization print can be done using sets of four or seven colour sample sets.

The printer should decide the colour sequence taking into account other technical considerations and be aware that changing the sequence requires a new fingerprint profile to be established. A four-colour print target can be used and ink substitutions made to produce the four sample sets. A suggested ink sequence for a standard four-colour target follows[19].

A custom seven-colour target may be used with a recommended print sequence of KYOMGVC[19] (an alternative is YOMGCVK or KVCGMOY). Production run length shall be sufficient to confirm the print is produced under normal calibration conditions[19].

Sampling should be in conformance with ISO/TS 15311-1.

NOTE Surface and reverse printing can require different ink sequence.

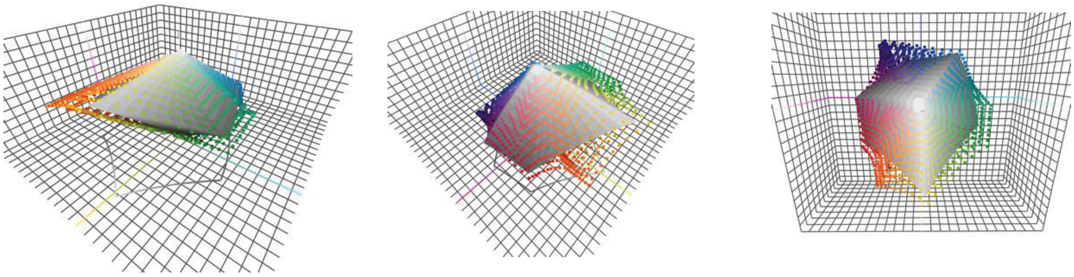
A.4 Measurement

The number of the charts measured depends on the printing variability, in every case it is recommended to measure a minimum of three charts, to control possible measurement error outliers. To calculate an optimal number of charts to be measured, refer to ISO/TS 15311-1:2020, 4.2.2 and Annex A.

The colour data acquired in the characterization and measurement activities are compared to the aims for the seven ink colours. Colour difference of solid tones compared to colour aims are calculated using CIEDE2000. Tints should also be evaluated; use of ISO 20654 SCTV is recommended.

ISO/TS 18621-11 has procedures for gamut analysis[13].

Another analysis recommendation is to use 3D rendering of the colour data. The CMYK characterization data is compared to a known characterized reference print condition (CRPC) confirming calibration. Lastly, the CMYK data may be analysed with the CMYKOGV data. If necessary, adjustments are made, and the characterization process is repeated.



NOTE Solid grey represents CMYK (CRPC6)–Points represent CMYKOGV[15].

Figure A.2 — CMYK CMYKOGV analysis example

A.5 Communicating results

Results and data should be communicated to premedia and others in the supply chain as required. Production workflows are confirmed with colour data implemented in the necessary systems.

Annex B
(informative)

Colour characterization process

The following discussion is based on a CMYKOGV set of expanded gamut printing inks. The printing sequence of inks is at the printer's discretion, although there is evidence to suggest that KYOMGVC can provide the broadest colour gamut[19]. For a given substrate and ink formulation, the press should be calibrated to a known standard, whether an internal standard specific to the printer or in conformance to a referenced printing condition such as CRPC6 (preferred).

The printer should decide on the screening resolution and angles necessary to prevent a moiré with the multiple process colours. Common solutions include placing OGV at the same screen angles as their complementary colours—orange and cyan at 15°, green and magenta at 75°. However, if violet is placed at 0° as is yellow, the resulting violet moiré is objectionable. One solution is to put violet at 45° along with black, to avoid moiré with cyan and magenta, however subtle shifts in registration can create colour shifts as the black and violet dots overprint one another to varying degrees. Stochastic screening of either the violet alone or all stations is a viable solution to prevent moiré.

In the initial calibration, the inks should be adjusted as necessary for the solids to conform to the specifications of 4.2.1 and 4.2.2. For the CMYK component of the calibration, press curves should be created to ensure conformity to neutral print density curves or TVI curves as specified by the desired referenced print condition. The OGV curves should be adjusted to meet a linear SCTV tone distribution, following the methodology specified in ISO 20654.

A set of characterization plates should be generated with appropriate press calibration curves in place. The characterization should be performed using distinct data sets for CMYK, CMVK, CGYK, and OMYK. For each data set, sheets should be pulled and measured to ensure that the solids and tints of the individual printers meet specification, and adjustments made as necessary to conform to the specifications.

Run Length – The number of the charts measured depends on the printing variability, in every case it is recommended to measure a minimum of three charts, to control possible measurement error outliers. To calculate an optimal number of charts to be measured, refer to ISO/TS 15311-1:2020, 4.2.2 and Annex A. The accuracy of the profile can be estimated using a round trip method as described in ISO/TS 23564, or thru a print run made in the same characterization conditions. In some cases, a proofing system can be helpful to estimate the relative accuracy between two or more profiles.