CGATS RECOMMENDED INDUSTRY PRACTICE

Color characterization of a printing system

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Introduction

The objective of this CGATS Recommended Industry Practice is to identify and define key steps and processes necessary to color characterize a printing system (press, inkjet, electrostatic, etc.).

Color characterization of a printing system is the relationship between input data (CMYK, RGB, etc.) and the color result as measured on a specific substrate using a specific set of colorants (ink, toner, etc.) for a particular machine production condition. Such data can be used to fingerprint a device, develop output profiles for that device, create calibration adjustments, etc. Color characterization is typically created by printing a target which includes many combinations of input data (e.g. IT8.7/4 target) and measuring the color of the printed results

This document is not recommended for use by groups who are developing color characterization data sets that may be used by a broad industry segment. For this use CGATS has the following series of Recommended Industry Practice documents:

- CGATS Recommended Industry Practice, *Color characterization data set development - Press run guidelines*
- CGATS Recommended Industry Practice, *Color characterization data set development - Procedures for color measurement system process control and for inter-lab coordination*
- CGATS Recommended Industry Practice, *Color characterization data set development - Analysis and reporting*

The color characterization data set development series, which has a different focus, may provide additional information that could be of benefit for the user of this document.

CGATS RECOMMENDED INDUSTRY PRACTICE

Single Device Characterization

1 Scope

This CGATS Recommended Industry Practice defines the key steps necessary to prepare a printing system for color characterization. It is not recommended for use by groups who are developing color characterization data sets that may be used by a broad industry segment. This report includes recommendations for:

— Process setup

— Specifications

— Target selection

— Sheet evaluation

— Measurement and collection

— Analysis

2 Definitions

2.1
calibration
the method used to bring a printing system to a defined repeatable state

2.2
color characterization
determining the relationship between input tone values and resulting colorimetric output from a printing process

2.3
colorant
Material that changes the color of the surface it is applied to for example: ink, toner, dye or pigment

2.4
color management
method for the controlled conversion of color data from input to display or print output by means of device profiles, which provide the information necessary for the conversion between native device color space and device independent ones

2.5
in-control
when all output characteristics measured fall between upper and lower control limits.

2.6
out-of-control
when one or more output characteristics measured are above upper or below lower control limits.

2.7
process control
The use of process analysis results to monitor and adjust a system to maintain a set of operating parameters within a defined range of values using mechanical, mathematical and/or statistical methodologies, so as to ensure a repeatable and reproducible output. It provides a means for making decisions regarding the state of the process relative to the specification.

3 Process setup

There are common conditions that must be met prior to printing for characterization to ensure a stable, repeatable operating condition of the printing system, and they are summarized in this section. A printing system consists of a printing device and the components associated with that device. Those components might include a RIP, an image-carrier, a set of colorants, and a family of substrates.

Whenever these components change control conditions should be verified.

Those changes may require settings appropriate to the components used and may require a new system setup procedure that considers the differences that these components bring to the print process.

3.1 Maintenance

Since a printing system that has not been properly maintained is unlikely to print consistently, that system will not be suitable for characterization. Manufacturers of printing systems specify the procedures and conditions that they require for meeting their definition of a properly maintained printing system. This document assumes that the printing system and associated devices are properly maintained and in good working order according to manufacturers recommendations. For a complex system like a printing press, this can be an extended procedure that requires the on-going involvement of experts. For an inkjet proofer this may be as little as normalizing the system by checking head alignment or cleaning clogged nozzles.

3.2 Material selection

Printing systems may use multiple colorant sets and substrates. Characterization of a printing system requires that the colorants and substrate are known and have been kept the same for any printing that will use the associated characterization data. These materials should be inspected before use to verify that they are appropriate for use with this characterization data, and also are considered to be free of obvious defects. Caution is urged when using characterization data for colorant sets and substrates that have not been verified to be similar in nature to those that were used in recording the characterization data.

3.3 Incoming inspection

Each batch of materials should be verified compliant with their specifications. There are many strategies used to perform this verification. Some companies perform what is commonly called incoming inspection. Incoming inspection involves the testing of materials as they are received by the end-user. Other companies require their vendors to provide certificates of analysis that describe the types of test and the results that prove that materials delivered are compliant with the specifications.

3.4 Production Settings

Production settings can vary by process and by material. Nominal equipment production settings should be recorded for use in future production that will use the associated characterization data.

3.5 Calibration

While calibration has many different meanings depending on the audience, for the purpose of this document calibration is defined as the method used to bring a printing system to a defined repeatable state. Operators who are accustomed to setup on a job-by-job basis are urged to establish and follow a series of best practices that bring the printing system to a repeatable state when setup is complete. This repeatable state is a requirement for successful use of the resultant characterization data set.

4 Printing Specifications, Aims and Tolerances

It is useful to understand the potential differences between international standards and industry specifications, house specifications and manufacturer specifications. Each of these may have different characterization data associated with them and may use the characterization data in a different workflow.

4.1 Industry Specifications

American industry practices include CGATS reference printing conditions TR002, TR003, TR005 and TR006. ISO has printing standards embodied in the ISO 12647 series, which are separated into parts by printing process or use. These standards are the foundation upon which many industry specifications are built.

There are a number of existing printing industry specifications. These specifications are often based upon international standards and represent a narrowing of scope and provide specific aims for these implementations.

Some of these relate to the method of printing and some relate to the final use of the printed material. The advantage to using industry specific aims is that many files are prepared with these aims in mind and this will make preparation of the files for printing easier and should result in fewer surprises for the purchaser of the printed work. In addition, the process specific printing specification usually provides realistic aims and tolerances for the user to follow. Industry specifications include:

- GRACoL® – General Requirements and Applications for Commercial Offset Lithography
- SWOP® – Specifications Web Offset Publications
- FIRST – Flexographic Image Reproduction Specifications and Tolerances
- SNAP – Specifications for Newsprint Advertising Production

4.2 House Specifications

Many printing facilities have developed “house” specifications over time. These are internal to the specific organization and in general are not interchangeable. Additional reasons for house specifications include:

- Unique printing technique
- Non-standard printing inks or substrates
- Colorants extending beyond traditional CMYK or RGB printing

4.3 Manufacturer Specifications

Certain printing equipment, substrates or colorants may be supplied with aims from the manufacturer. These aims are usually supplied for materials or processes where no existing industry specification exists, or where the manufacturer is controlling the entire workflow and may have specific requirements at particular stages of the process.

4.4 Customer Specifications

Separate from the above are customer specifications. Often the customer specifications incorporate Industry specifications with unique requirements for brand color, quality or other metrics. These contractual requirements are outside the scope of this document.

5 Target selection and imaging

5.1 Partial characterization targets

There are times when full color characterization of the printing device is not required. A target that contains a subset of the values in the full characterization target is one example of a target that may be used to validate to a characterization data set (IDEAlliance control wedge, FOGRA media wedge, etc.).

5.2 Full characterization targets

CGATS has developed two targets for CMYK device characterization that are in widespread use. These targets are the IT8.7/3 (ISO12642-1) and IT8.7/4 (ISO12642-2) used in many characterization applications and are available for individual use. When using standard targets the user must include all values of the data set and not selectively remove or alter values. Today the IT8.7/3 is deprecated in favor of the IT8.7/4, which contains all of the patch values of the IT8.7/3 with additional patches to better define critical reproduction areas.

There are times when these targets are not directly applicable:

— RGB process (photographic printers and many printers connected directly to a computer without a RIP)

— Hexachrome or extended color models that use CMYK and additional colorants

— N color printing (printing that may have more or less than 4 colorants and are not restricted to CMYK)

In addition many characterization software packages offer targets that the manufacturer believes optimizes the characterization process through either a unique patch set or through an iterative process where additional targets are produced by the data gathered in reading the preceding target.

The target must be formatted properly both for the press output and the measurement device that will be used to read the resultant print. Resizing of a target to fit the output device is not recommended without consideration of the measuring instrument.

5.3 Multiple targets

In processes that are known to have spatial non-uniformity (printing is not even across the sheet) it is recommended to place more than one target in the printable area, ideally at different rotations. On devices where page size does not allow this but where multiple images are reasonably accomplished orienting targets in various positions is advised.

6 Sheet evaluation

6.1 General information

In *Color characterization data set development - Analysis and reporting* considerable care was given to provide different methods of evaluation including; sampling procedures, how to validate a press run, and how to select the sample to be used for full measurement and development of color characterization data. This document will not duplicate that effort but will highlight some simple evaluation criteria.

6.2 Printed sheet evaluation

Sheets are evaluated first for printing artifacts (e.g. hickies, scratches, voids, doubling, etc.). Sheets that do not have any artifacts are then verified to be within the specified aims and tolerances established under section 3. The purpose of this validation is to determine whether or not the printed sheets meet the required aims and to pass or fail the print run or operational condition of the printing device.

6.3 Sheet selection

Many users are tempted to characterize a device using one “representative” print from the device. It is recommended that at least 3 and preferably 5 or more targets be evaluated in creating characterization data. There are 3 preferred methods of sampling, particularly for devices that have known variability in the process. These three methods, with additional supporting material are covered extensively in the document: CGATS Recommended Industry Practice, *Color characterization data set development - Analysis and reporting*

6.3.1 Random sampling

Use random samplings in cases where the sources or contributions of variability are unknown, or known factors are not being individually investigated.

6.3.2 Uniform or sequential sampling

Use uniform or sequential sampling in cases where known factors are being investigated. Examples of known factors are start-up effects and periodic between-sheet fluctuations.

6.3.3 Specialized selection strategies

This sub-sampling strategy requires identifying the criteria associated with a particular printing specification (such as solid ink density (SID), gray balance, color, tone value increase (TVI), etc.) and then establishing a set of weighting factors against these criteria. Evaluating individual printed sheets using these criteria results in a subset of the overall sample population.

7 Measurement and data collection

During the data collection step, color characterization target(s) from selected sheets are measured. The actual number of targets and the specific data recorded will depend on the specific applications.

Printed sheets or proofs need to be evaluated shortly after their production. Some materials have a stabilization period that can take up to 24 hours. Measurement should not occur prior to establishing that the print has stabilized. Conversely, printed sheets can also have a relatively short lifetime before changes begin to occur such as color changes of the paper and inks. It is important to attempt to complete all measurements within a

short time period depending on how rapidly changes occur to the samples (i.e. ink color change, paper color change, etc.).

8 Data analysis

8.1 General

After the selected sheets have been measured, the resulting pool of data must be evaluated to look for outlier data points and/or extreme (suspect) data. This ensures that the final data set is as statistically sound as possible and that sufficient information is included with the data set to allow confident use.

8.2 Patch specific evaluation

Before multiple measurements of individual patch samples (either repeat readings of the same sample or readings from different samples) can be combined they must be evaluated to determine consistency of the data.

Many commercial software characterization programs or measurement tools allow you to review and compare the measurement data on a patch-by-patch basis. These packages may also allow you to perform edits or subtract suspect patches from subsequent data sets.

The method currently used by CGATS is to compute CIELAB data for each sample, and the CIELAB ΔE between each sample and the average CIELAB for that patch. The statistics of the CIELAB ΔE population can then be used to identify potentially bad data. Samples with significantly larger CIELAB ΔE values can indicate either measurement errors or printing anomalies that were missed in earlier evaluations. See Annex A.

Suspect patch measurements should be identified and removed from the data before further evaluation.

NOTE See CGATS Recommended Industry Practice: Color characterization data set development — *Procedures for color measurement system process control and inter-lab coordination* [9] for further information on this topic.

9 Data reporting and exchange

If the characterization data is for in-house use, the requirements for data reporting may be minimal with no requirements for data exchange. In all cases however it is important that data is kept for later analysis or comparison purposes if problems arise. If all of the data collection, analysis and averaging was done as part of a commercial profile creation application the same tool may have reporting capabilities and will ensure that the data is prepared in a manner that can be used within that program.

9.1 Exchanging Data

Many applications recognize the ISO 28178 (CGATS.17) data format in ASCII format. For this reason data that needs to be communicated outside of a single workflow application should conform to one of the data reporting formats defined in CGATS.17. Two formats are presented in CGATS.17, an ASCII keyword value file format or a XML format. These include header information to identify the originator of the data, the date of creation, a description of the purpose or contents of the data being exchanged, etc.

Annex A

Composite data set evaluation

Once outlier points have been removed, new average values and CIELAB ΔE values can be computed. The total population of CIELAB ΔE values can then be pooled and histograms and cumulative probability plots prepared. Histograms and cumulative probability plot can be easily prepared using any of the typical spreadsheet tools.

Note: removal of outliers may be a subjective decision. ASTM E178 *Practice for Dealing With Outlying Observations* can provide guidance. In general where one data point has a much larger deviation from the average of the data points being combined that data point is probably an outlier.

A simplified way to create a cumulative probability plot is as follows:

1. Sort all the CIELAB ΔE values from smallest to largest and number the resulting list from 1 to N (where N is the number of samples).

2. Plot the resulting data (rank number vs. CIELAB ΔE values) using CIELAB ΔE values as the abscissa and the sample number divided by N as the ordinate.

Comparing the shape and values of the resultant histogram and cumulative probability plots with those of other data sets can help evaluate the consistency of the composite data set. Figures 1 and 2 show the histogram and cumulative probability plots of the ΔE statistics of two sets of press characterization test data. While the two types of plots show similar characteristics of the data, each has advantages and disadvantages. The histogram shows the distribution of the ΔE values and can be useful in understanding what realistic variations are. The shape of the cumulative probability plot helps provide an insight into how tightly grouped the data is. For example the 50th percentile point for the data set of the tightly distributed data set correlates well with the peak of the histogram. On the other hand the wider distribution has a peak that occurs before the 50th percentile point. In general, the steeper the cumulative probability curve, the tighter the data distribution. However, any evaluation of the distribution of the ΔE values of a data set must also take into account the size of the data set.

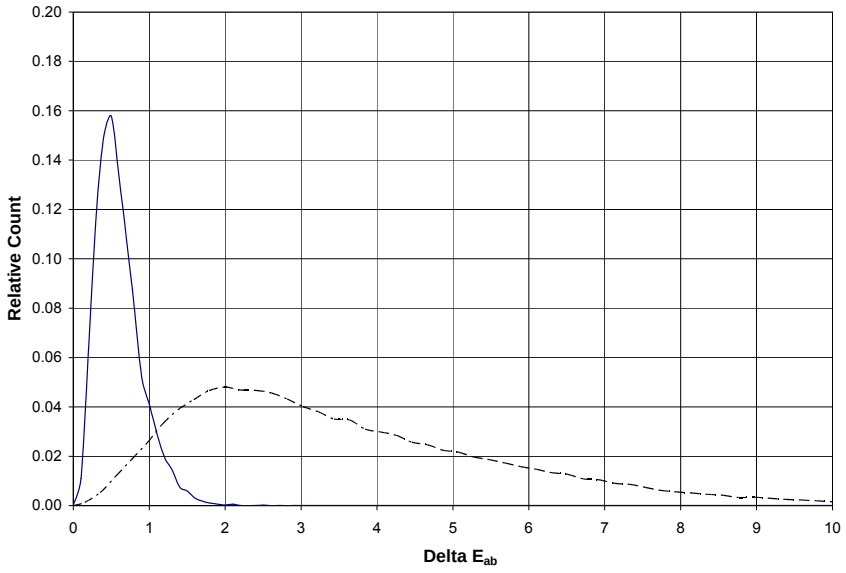

Figure 1 — Typical histograms

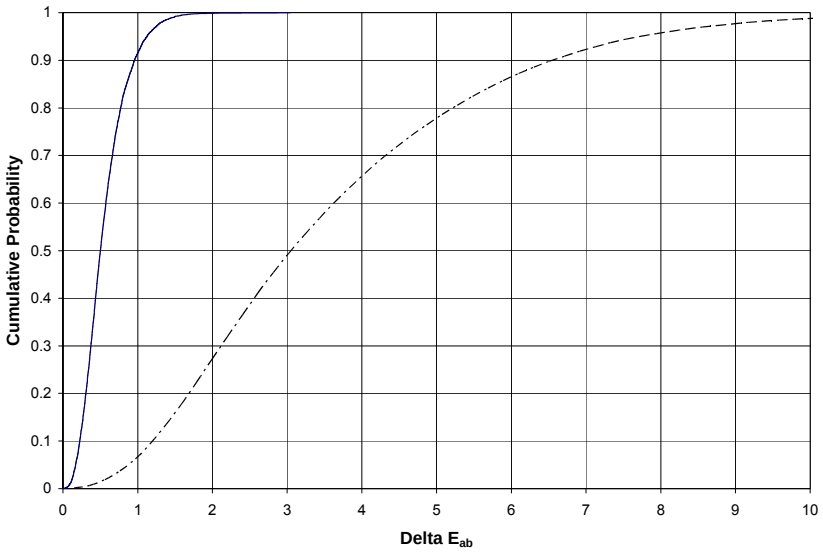

Figure 2 — Typical cumulative probability plots

Where plotting tools are available, additional visual representations of the data set can assist experienced practitioners in evaluating the symmetry and smoothness of the data set, particularly by comparison to data sets of known quality. Typical plots used for such evaluation are 3-dimensional plots of CIELAB data, 2-dimensional plots of CIELAB data projected on the a*b* plane, L* C* plots of selected data (e.g. single color scales and single color solids with varying black, and L* and/or C* vs. input tone value.

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