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A Technical Report

Prepared by

Committee for Graphic Arts Technologies Standards (CGATS)

Graphic technology — Color reproduction and process control for packaging printing

SECRETARIAT

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TECHNICAL REPORT

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Any questions regarding this Technical Report should be addressed to the CGATS Secretariat, APTech The Association for Print Technologies, 450 Rev Kelly M Smith Way, Nashville, TN 37203.

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Foreword

Publication of this Technical Report has been approved by the ANSI Accredited Standards Committee for Graphic Arts Technologies Standards (CGATS). This document is registered as a Technical Report according to the *Procedures for the Registration of Technical Reports*. This document is not an American National Standard and the material contained herein is not normative in nature. Comments on the contents of this document should be sent to the Committee for Graphic Arts Technologies Standards, APTech The Association for Print Technologies, 450 Rev Kelly M Smith Way, Nashville, TN 37203.which was responsible for this work.

This report was prepared by the members of CGATS Special Task Force 2 (STF2), Color Reproduction and Process Control for Packaging Printing. At the time of its approval, the following were the Participating Members and Observers of CGATS Special Task Force 2:

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Introduction

Consumer Product Companies are becoming increasingly aware that color reproduction variability between printers and within printers adversely affects their brand images and thus their sales. They also want to maximize the benefits of a color managed workflow for all printed packaging whether it is printed by gravure, flexography or lithography. Printers also want to minimize waste of materials, time and money in starting new press runs that meet customer requirements.

Even though each organization (and product that is printed) follows a unique workflow based on individual needs, there are many elements that are common, and there are certain fundamentals of printing that are common to all. This technical report, CGATS TR 012, is intended to provide a guide to the steps necessary to perform process control, fingerprinting and characterization independent of the organizational structure of the companies involved or the particular properties of the product being printed. It deals with the issues of color control and, in particular, the development of representative color characterization data to support both the preparatory steps in package development as well as the ongoing production requirements.

CGATS TR 012 is part of a series of technical reports and standards being developed by the ANSI-accredited Committee for Graphic Arts Technologies Standards (CGATS) to facilitate communication among all participants in the supply chain involved in the design, preparation and printing of packaging materials. It builds upon CGATS TR 011, the first technical report in this series. CGATS TR 011, *Graphic technology — Package development workflow — Design concept through approved production file,* provides guidelines to bring a packaging project from concept through an approved production file. It establishes tools, recommends roles and responsibilities of participants, provides default specifications for communicating color issues, and identifies guidelines and standards that can be used to further define required parameters. For the purposes of these technical reports and associated workflows, the division between preparation and printing has been chosen to be an approved one-up production file. Other future technical reports will deal with additional steps in the process through final print production and finishing.

As color management, digital data, and digital proofing play a larger role in the preparation of press ready material, the need for and importance of color characterization data becomes more significant. Too often, color characterization data is measured, or selected, that is not representative of the expected printing conditions that will be actually used for the live work. The recommendations and steps included in CGATS TR 012 help ensure that the characterization data prepared will properly represent real printing conditions and thus will facilitate valid digital proofing aims and data preparation that matches the expected printing condition.

While the primary focus of CGATS TR 012 is the issue of color control and the development of representative color characterization data, it also provides a common language for communicating color problems, issues and solutions. It sets expectations of a better workflow. It identifies the roles and responsibilities of the various participants in the process, thus bridging many communication gaps that currently exist between participants. While current customer satisfaction may ultimately be the most important of the benefits, the concepts outlined in this technical report also set the stage for further process improvements as color management and color proofing tools become more effective. The concepts outlined in this technical report are a basic requirement to tap into these powerful tools today or in the future.

All improvements to process consistency ultimately translate into greater customer satisfaction. A more efficient operation coupled with greater customer satisfaction often leads to greater capacity and additional business. Further, once a process is stabilized and consistent, then it is possible to optimize parameters. This step-wise process improvement is the best way to achieve the full capability of a process and facility.

However, it must be remembered that in addition to printing, package manufacturing may involve several manufacturing processes that contribute to the final product. When integrated, the requirements of these processes may place constraints on the printing process. In addition, manufacturing processes downstream of the printing stage may affect the color appearance of printed materials. Some of the concerns relating to these processes would be appropriately identified at one of the Project Planning Stages (see CGATS TR 011-2002, sections 5.5 – 5.8, for a description of these stages).

The need for testing usually becomes evident as a design progresses toward completion and production requirements are identified (equipment, substrate, colors/inks, materials for finishing or converting treatments). During this period, production concerns will surface, usually leading to identification of testing parameters. Thus, the determination of testing parameters for process control, fingerprinting, and characterization for a given project necessarily requires collective input from the various involved parties.

Further, the scope and depth of the testing should balance acceptable predictability of results and budgetary considerations. Available historical data may preclude the necessity of some aspects of the testing. These judgments are generally made by the group, guided by the printer/converter, with the customer's input and expectations in mind.

The members of the task force believe that the principals described in this technical report will have applicability well beyond packaging printing, and urge the consideration of these principals by other segments of the printing industry.

Graphic technology – Color reproduction and process control for packaging printing

1 Scope

This Technical Report outlines the steps necessary to understand and objectively define the color and tone reproduction capabilities (and limitations) of a printing process. These steps include optimization, fingerprinting, process control, and characterization, which provide the information required in the package development workflow defined in CGATS TR 011.

This report also suggests steps that may be taken to control the printing processes to achieve consistent and predictable color.

2 Terms and definitions

For the purposes of this technical report the following terms and definitions apply:

2.1
bearer bars
narrow strips on either side of a flexographic plate meant to promote stability by providing continuous contact between the plate, anilox and substrate along the entire image area

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

2.3
chromatic colors
color possessing a clearly defined hue

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
fingerprinting
act of benchmarking the performance of a press or a proofing system under known conditions at a given point in time

2.6
metameric match
two-colored areas that have the same color appearance but have different spectral reflectances

2.7
metamerism
spectrally different color stimuli that have the same tristimulous values (color appearance)

2.8
optimization
use of process analysis to determine the preferred printing conditions that balance the trade offs between customer requirements, manufacturing requirements, printing quality, printing stability, and efficiency/economy of operations

2.9
process colors
the three chromatic colors (yellow, magenta, cyan) combined with black used to produce reflection full-color images in the printing process

2.10
process control
use of process analysis to maintain a specific operating condition through the measurement of control targets

2.11
protection bars
bars that run across the lead and/or tail edge of a flexographic plate and are meant to promote stability by protecting the image from "bounce" near the lead/tail edges of a plate

2.12
pull bands
bands generally used for some direct-print corrugated presses to ensure that there is continuous plate surface contact with the substrate as it moves through a print station

2.13
spot color
color (ink) not intended to be used in combination with other colors to create full color images

2.14
takeoff bars
used in lithography to promote stability by removing a large amount of ink near the lead edge of the image

2.15
targets
arrays of small patches containing different combinations of C, M, Y, K tints used to characterize or calibrate a printing process

3 Roles and responsibilities

In addition to their roles as described in CGATS TR 011, the participants in the package development workflow also play a significant role in setting the aims for and evaluating the results of the procedures outlined in this Technical Report. These participants were defined in CGATS TR 011 as:

- Consumer Products Company
- Design Firm
- Illustrator
- Ink Supplier
- Mechanical File Production Provider
- Substrate Supplier
- Package Converter
- Photographer
- Prepress Provider
- Printer

It is recognized that in some situations these may be separate organizations, and in other situations different parts of the same organization. For the purposes of this Technical Report their organizational relationship is not considered critical.

However, their functional relationship to the process is the critical factor being identified. The aspects of their responsibilities that impact on Color Reproduction and Process Control are summarized (from CGATS TR 011) in the following paragraphs.

3.1 Consumer Product Company

Ultimately, the customer defines how much effort is expended to reach satisfaction. Since the customer defines expectations, they also must drive integration within their supply chain.

3.2 Printer

The role of the printer is to consistently reproduce the packaging design to the satisfaction of the customer. They must provide and document the process controls to ensure that consistency. They must work with the other partners to define the capability and characteristics of the printing process.

3.3 Converter

Many packaging materials have process steps after printing. These steps are often referred to as Converting. Converting may or may not alter the appearance of the printed colors. In cases where the appearance may be affected by the finishing process, the converter must be involved in the definition of the capability and characteristics of the printing process. In any case, the Converter must employ process control to ensure that their process remains consistent.

3.4 Prepress Provider

The prepress provider must work with the printer, and others as necessary, to understand the capability and characteristics of the printing/converting processes employed. Based upon this understanding the prepress provider provides image information that enables the printer to meet the expectations of the Consumer Product Company. They must document the controls that ensure the consistency of the image exchange media.

3.5 Ink Supplier

The ink supplier's primary responsibility is to provide ink compliant with color and functional requirements. They must provide and document the process controls to ensure consistency of their product. They must work with the printer to understand the capability and characteristics of their printing process.

3.6 Substrate Supplier

The substrate supplier must supply materials consistent to defined specifications. They must provide and document the process controls to ensure consistency of their product. In terms of support for graphic image reproduction, special emphasis should be given to process control of colorimetric values, absorption, hold out characteristics, and brightness.

4 Overview of color control steps

As a part of the design workflow process, the printer must be able to provide information that describes his capability to reproduce the proposed package design to the customer's satisfaction. The choice of substrate, ink, specialty colors, and design elements interact to produce the final product. The printer must be able to evaluate his process to determine if he is able to meet the color and tone reproduction requirements of the job, identify areas of potential problems, and provide input needed to ensure that the final design can be printed satisfactorily. In addition, the printer must maintain the process in a stable condition.

The steps the printer will need to follow will depend upon a number of things, including past experience with the identified ink and substrate combination on a specific press, requirements for a color or combination of colors not before printed on that press; and design elements in the job that may produce unexpected results (e.g., knockouts, special effects, etc.). See Figure 1.

The steps that need to be addressed include:

Optimization of starting point is the first step. It involves the use of process analysis to determine the preferred operating parameters that balance the trade-offs between customer requirements, printing quality, printing stability, and efficiency/economy of operations. It may or may not require special printing trials.

Fingerprinting is the second step. It is the act of benchmarking the performance of a press or a proofing system under known conditions at a given point in time. It involves the printing of image elements with known characteristics to help in establishing standard operating conditions (aim specifications). Process analysis is a key tool in generating the fingerprinting data. Fingerprinting is done to quantify the results for a given set of materials and printing conditions. It provides the baseline against which both production printing and future improvements are measured.

Process control is the use of process analysis to establish and maintain specific operating conditions through the measurement of control targets. It is a tool for monitoring the process with respect to control limits, and it is an ongoing activity that uses measurement and assessment to ensure that production printing is consistent with established aims and tolerances determined during fingerprinting.

Characterization is the step that measures printed results, and provides color and tone reproduction data (color characterization data) for communication and coordination with prepress and designers, as specified in CGATS TR 11. The printed results used to generate characterization data must meet the aims and tolerances used for process control.

Process improvement is an ongoing effort and should not be treated as a one-time activity. It provides a scientific methodology of evaluating process improvement changes that affect color and tone reproduction.

The following changes require an assessment of the impact of the change on printing performance, and/or color and tone reproduction:

- new press;
- new copy;
- new color;
- new ink;
- new substrate;
- new finishing requirements (structure, laminate materials, etc.);
- new customer requirement;
- any change in printing equipment or components;
- any change in image carrier suppliers;
- significant maintenance;
- process change;
- any combination of the above.

Whenever there is insufficient experience to provide the necessary data, print trials need to be initiated. The point of entry to the above process steps depends upon a wide range of factors.

While these steps are discussed here as a sequence of operations, in many practical situations they are done together and/or as an interrelated set of tests. For example, optimization and process improvement are often part of the start up and/or shut down for similar types of production work where process interactions can be studied and documented without requiring special tests. In other situations, optimization, fingerprinting and/or characterization are all part of the printing test where all of the necessary targets and/or test patches are on the same printing form and the key differentiation of steps is the data collected and decisions reached based on that data.

It should be noted that these discussions are focused on 4-color (or less) process color printing and single-color spot colors. Some packaging processes make use of more than 4-color process printing and/or manufactured colors involving combinations of spot and/or process colors. Although these procedures are not directly applicable, many of the procedures and recommendations do apply by inference.

While the CGATS Recommended Industry Practice *Color Characterization Data Set Development — Press Run Guidelines* is aimed at press runs for the development of color characterization data, the principles apply to any press run including print trials for optimization of starting point. Annex A of that industry practice also includes a summary of appropriate documentation requirements and a sample report form for such documentation. (Once the CGATS Recommended Industry Practice document has been finalized, it will be made available in the CGATS section of the APTech Standards Workroom at https://www.printtechnologies.org/standards/

In addition to printing, package manufacturing may involve several manufacturing processes that contribute to the final product. When integrated, the requirements of these processes may place constraints on the printing process. In addition, manufacturing processes downstream of the printing stage may affect color appearance of printed materials. Some of the concerns relating to these processes would be appropriately identified at one of the Project Planning Stages (see CGATS TR 011, sections 5.5 – 5.8, for a description of these stages).

The need for testing usually becomes evident as a design progresses toward completion and production requirements are identified (equipment, substrate, colors/inks, materials for finishing or converting treatments). During this period, production concerns will surface, usually leading to identification of testing parameters. Thus, the determination of testing parameters for Process Control, Fingerprinting, and Characterization for a given project necessarily requires collective input from the various involved parties.

The scope and depth of the testing should balance acceptable predictability of results and budgetary considerations. Available historical data may eliminate the need for some of the testing. These judgments are generally made by the group, guided by the printer/converter, with the customer's input and expectations in mind.

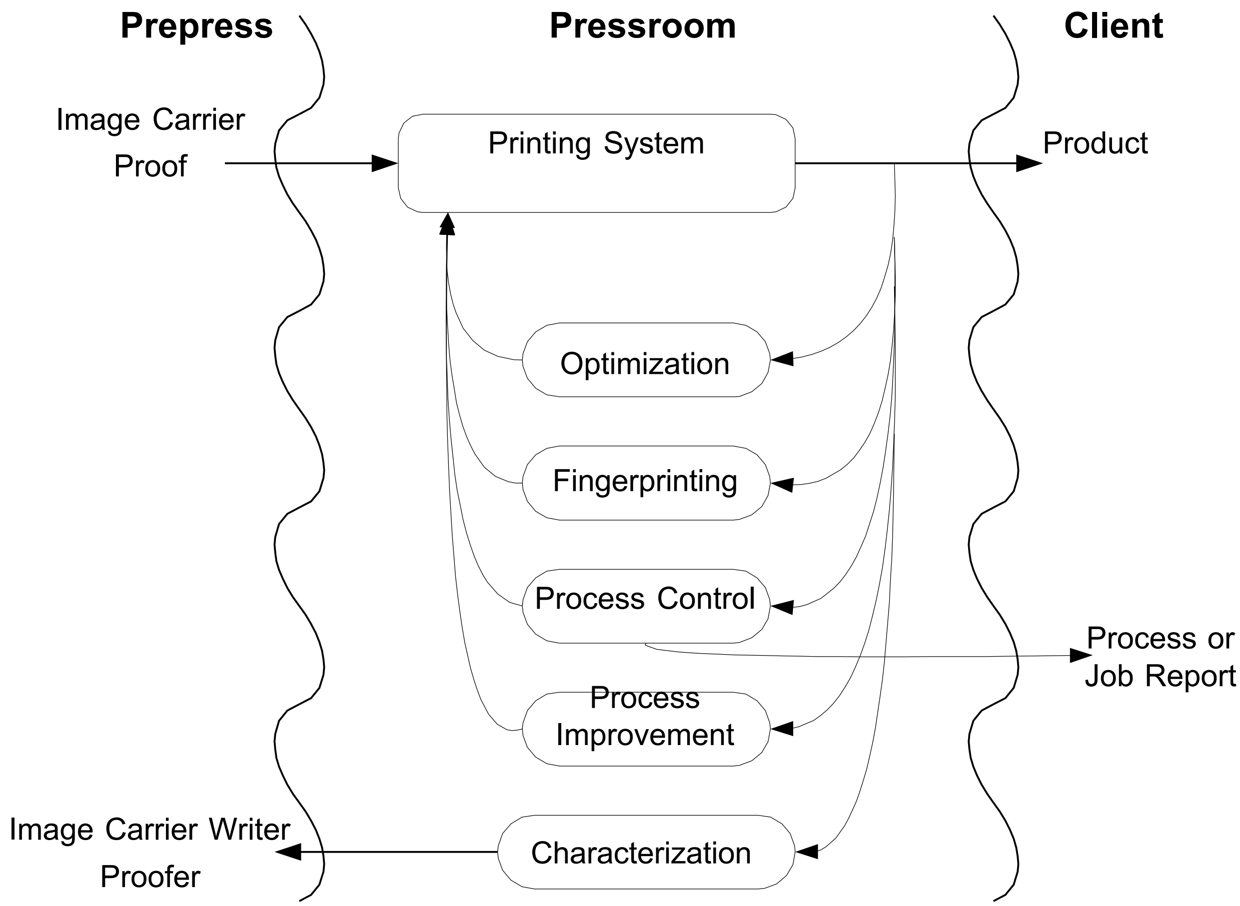

Figure 1 — Typical Workflow

5 Optimization

5.1 Introduction

Optimization is used to set up a new process, stabilize a changed process or improve an existing process. It seeks to identify the best combination of printing conditions based on the preliminary process specifications. These must represent normal production behavior and quality, and be attainable consistently under routine production conditions. However, before any optimization is started, there must be assurance that the materials to be used are consistent and fit for the intended application.

As part of the package development workflow, as defined in CGATS TR011, the printer is expected to offer advice and recommendations during the initial phases of the design process. Once the Package Prepress Process Phase defined in CGATS TR 011 begins, the printer is responsible for providing the printing specifications. This can only be done well if the starting point has been properly optimized.

Prior to fingerprinting, the optimization step must identify the preliminary process control aim points that will produce the desired results with the materials to be used for the customer's product. These materials include substrate, inks, coatings, glues, applied finishing materials such as films, foil, etc. It also must identify any potential areas of instability or incompatibility between the materials to be used, the printing aims selected, and the specific combination of printing/ finishing equipment available to the printer.

A complete listing of the issues that should be evaluated quickly becomes very printing process specific and is beyond the scope of this document at this time. However, one of the more subtle issues that is often overlooked (and is therefore specifically highlighted here) is the fact that the inks that we print with, particularly the cyan and magenta inks, absorb light in spectral regions that the ink should ideally not absorb light. The result is that the cyan and magenta inks change hue at higher densities. Depending upon the particular ink and substrate used, this change in hue (commonly called hooking) may occur at densities at or near those used for package printing. In some extreme situations, density does not change appreciably even though ink strength and or thickness are increased. The initial part of the optimization test must determine if hooking is occurring at the proposed printing aims. If hooking is occurring, and if density aims cannot be reduced, the trade-offs between process color gamut (i.e., colors that can be achieved as single or two-color solids) and the impact on process stability, must be evaluated. Figure 2 shows a typical CIELAB a* vs. b* plot for an ink set that exhibits severe hooking of the magenta with a lesser degree of hooking of the cyan. Most dramatic is the difference in the blue two-color overprint scale at lower tone values compared to the blue solid.

The optimization step must be completed for all combinations of process colors to be used (often in package printing these are not the traditional CMYK, but arbitrary combinations of three chromatic colors and a dark color depending on the spot color needs and the available impression cylinders) as well as any single-color spot colors.

It may not be necessary to perform an optimization test for every material or element of the process if sufficient history or data is at hand to eliminate the possibility of problems or incompatibilities between materials or parts of the process. The customer may also have packaging specifications, which, if followed, may provide the same certainty of compatibility.

ADD SCTV for Spot Colors

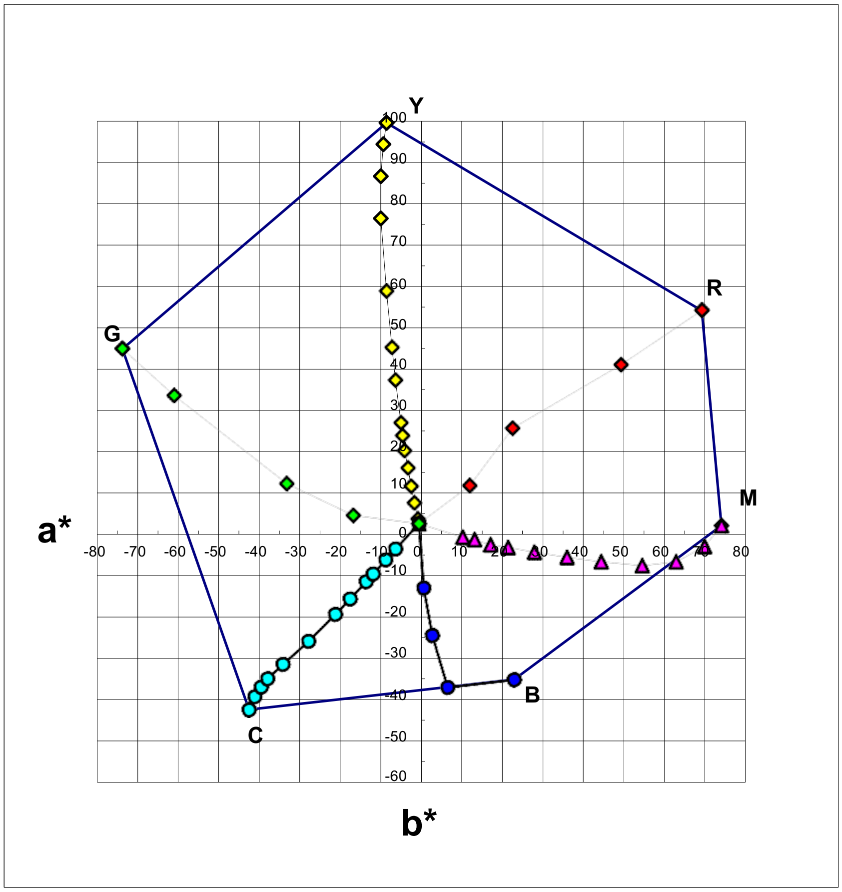

Figure 2 — Typical CIELAB a* vs. b* plot for an ink set that exhibits severe "hooking" of the magenta ink

5.2 Preparation

In preparation for the optimization step, the printer must review the preliminary designs, layout and printing requirements provided by the Consumer Products Company and Design Firm. Comparing these requirements against the knowledge base of prior work will determine if printing tests are advisable and the extent required.

If prior test data that includes the preliminary aim densities for the ink and substrate to be used is not available, it is strongly suggested that a simple test be run that includes all single-color and two-color scales to allow the overall color gamut to be evaluated, as well as any hooking that occurs (primarily seen in the cyan, magenta, and blue scales). Additional tests at different aim densities may be appropriate, based on initial tests. The comparison of colorimetric plots at multiple density levels can then be used to select initial density aims for the subsequent optimization, fingerprinting and characterization testing stages.

If printing tests are to be accomplished, it is important that a test plan be created. This plan must identify the specific color and/or resolution requirements of the project and should define the minimum set of parameters to be evaluated (defined by process control strategy), the equipment to be used (press and coating or finishing equipment), the materials (inks, substrates, plates, etc.), aim process parameters (dryer settings, screens, speed, etc.), and measurements to be taken.

5.3 Print trials

Print trials are performed to provide physical samples for evaluating the performance of printing systems in various conditions. As such, print trials must be carefully controlled and be driven by test plans. In most cases, several different combinations of inputs will be evaluated to maximize the balance between the client's requirements and printer's productivity needs. It is important that the variation of individual parameters is carefully controlled and measured so that an optimum condition can be identified.

1. **Planning**
   a) Documentation: The print trial should be documented to a level such that an uninvolved person can reproduce the print trial.
   b) Equipment: Identify the press(es) that will be used and verify that maintenance activities are up to date. Special maintenance, however, should not be performed because the print trial is intended to reflect normal operating conditions.
   c) Materials: Identify the materials (inks and substrate) to be used, and verify their availability.
   d) Sampling: Develop a sampling plan that addresses test form design and sheet selection.
   e) Retains: Raw material samples (e.g., inks and substrate) should be collected and saved for ad hoc analysis if needed.

2. **Preparation**
   a) Assemble and distribute documents, reporting forms, checklists, templates and media as identified by the documentation plan.
   b) Assemble the test form as specified by the test form design. Proof the test form to verify positional and functional requirements of the test form.
   c) Make and validate image carriers (plates, films, cylinders, etc.) as necessary.
   d) Validate that inks and substrate are compliant with manufacturing specifications.
   e) Produce laboratory prints of each ink color at the aim density on the press run substrate for use during ink contamination evaluation and to determine dryback.
   f) Finish any needed press maintenance, again, remembering not to make any special provisions for the print trial.

3. **Printing**
   a) Measure printing parameters to evaluate and/or refine initial process aims and tolerances.
   b) Evaluate mechanical artifacts (doubling, slur, etc.).
   c) Verify that ink contamination has not occurred.
   d) Measure several areas on several sheets to evaluate and account for natural variations. In addition, several consecutive sheets should be examined for mechanical artifacts and short period cyclical effects.

4. **Postprinting**
   a) Select sheets according to the sheet selection plan.
   b) Measure test forms being sure to accommodate drying characteristics.
   c) Store samples in a cool, dark, dry location. Samples should be stored flat or rolled but not folded unless the test form accommodates folding.
   d) Finalize and distribute documentation package.

Refer to the text in the CGATS Recommended Industry Practice, *Color Characterization Data Set Development — Press Run Guidelines*, for more detailed discussion.

5.4 Data collection and documentation

The product of the optimization step is a document that describes critical control elements for the start of the fingerprint trial. This document should include initial trial data (preliminary aim points) such as:

a) Preliminary aims and tolerances for process parameters defined by the process control strategy
b) Raw materials description
c) Ink specification
d) Substrate specification
e) Initial press settings – dryer settings, impression roller hardness, doctor blade setting, etc.
f) Environmental conditions
g) Date and time of initial data collection
h) Prepress variables specifications – screen, gamma, diamond angle, plate material

In addition to data that identifies the proposed aim points, the optimization step should provide the printer with an understanding of the relationship between (sensitivity to) the selected aim points and the customer requirements (e.g., color variability vs. solid ink density, density and/or color variability vs. press speed, etc.).

The CGATS Recommended Industry Practice, *Color Characterization Data Set Development — Press Run Guidelines*, provides process specific checklists of representative data to be collected and reported.

6 Fingerprinting

6.1 Introduction

The term "fingerprinting" has been used for a number of years in the printing industry. How this term is interpreted may be very different from one location to another. It may simply be a capabilities test of the press under a given set of conditions, a snapshot of the running conditions at a given point in time, finding the centerline performance of a press with a given set of materials, a determination of the optimum reproduction capabilities of a press or all of these combined!

For the purposes of this document, "fingerprinting" will be used to define the process step that verifies that the process control aims selected produce an acceptable and reproducible result that matches the customer aim specifications for image quality, color, and reproduction of the product design. It will also result in data which can be used to define the printing process specification, including aim values, and tolerances. Further, it provides the definition of the characteristics of the raw materials and equipment operating parameters to which the printing characterization data will be referenced.

Fingerprinting involves the sampling and analysis of two types of parameters. Parameters that are used for process control and parameters that are used to document the condition of the printing process. The fingerprint must be run at production speeds and conditions for the determination of acceptable ranges for both process control and operating parameters. The goal of the fingerprint should be to document the conditions necessary to produce the best image quality across the sheet, under stable and repeatable conditions.

Fingerprinting provides the reference against which production printing will be compared and provides the printing specifications defined in 6.2 of CGATS TR 011. As such, this step must be completed for all combinations of process colors to be used as well as any single-color spot colors.

Although most package printing involves unique combinations of ink, substrate, color aims, etc., there are situations where a separate fingerprinting test is NOT required. When the same combinations of materials have been used in previous printing applications, or previous fingerprinting tests have provided an overlap of aim conditions, a fingerprinting test to develop new data may not be required (this is an example of the value of good data reporting and a reason that all test data should be included and reported as part of a fingerprinting test). Sometimes process control data from previous live production may be analyzed to provide fingerprinting information. However, the fingerprinting function is always required (verification that operating conditions produce result that match customer aims) to summarize the known data and document the aims and tolerances to be used for the printing specification.

6.2 Preparation

Before a fingerprinting test is initiated (or a printing specification is prepared), a process control strategy and the process control parameters to be used must be identified. The process control strategy defines the metrics, and therefore, the calculations, that will be used for process control while the parameters selected define the "control handles" of the process.

The fingerprinting test form should contain those control elements that will be used for production process control. (See Section 10 for a discussion of test targets.)

The amount of new testing required is largely a function of the knowledge database that exists within the printing organization. The key goal of any fingerprinting test must be to develop data for the specific task, validate the proposed aims and tolerances, and add to the existing knowledge database upon which future work will be based.

While in many cases a special fingerprinting test may be required, in other situations the collection of fingerprinting information can be an integral part of production printing. The use of process control elements, and careful record keeping can develop data that can help define within sheet and between sheet variability that is characteristic of the printing equipment and similar types of ink and substrate. When such data is combined with more limited testing of the specific materials and or aim points to be used an overall set of aims can be developed more efficiently than starting over for each job.

6.3 Fingerprinting press runs

Fingerprinting press runs are performed to provide physical samples to be used for determining normal operating conditions. While in many cases special fingerprinting press runs may be required, in many other situations fingerprinting can be an integral part of production printing, or, they may be integrated with characterization press runs. The amount of new testing required is largely a function of the knowledge database that exists within the printing organization and the level of experience the printer has with a given set of process parameters.

The key goals of fingerprinting are to finalize proposed aims and tolerances, develop process data for troubleshooting and add to the existing knowledge database upon which future work will be based.

The fingerprint must be run at production speeds and conditions for the determination of acceptable ranges of ink formulations, viscosities, blade angles, blade pressure, register, impression, gray balance, maximum ink coverage, and line and type thickness (positive and reverse). The execution of fingerprinting press runs require the same level of exactitude as do print trials for optimization and press runs for characterization. See the CGATS Recommended Industry Practice, *Color Characterization Data Set Development — Press Run Guidelines*.

6.4 Data collection

For process control parameters, data should be collected from process control elements. These are ideally extrapolated from live work from several jobs printed at the intended aim values. This ensures that within and between press run variables are adequately sampled and accounted for. In other situations, special tests will be required specifically aimed at the current printing requirements.

It is important to remember that every test must measure and validate a set of “troubleshooting” parameters to insure the validity of characterization and process control parameters. These are the slur and doubling type of printing parameters and the ink and substrate characteristic, etc., that are often taken for granted during production printing.

6.5 Data analysis

For all parameters measured, central tendency and the spread of data should be determined and recorded. For process control parameters, aim values and tolerances (decision intervals) should be calculated based on the process control strategy used.

6.6 Data reporting

The Fingerprinting Report should contain at least three parts:

— a summary of data collection that includes information regarding the press tests, test methods and instrumentation;
— a process specification containing aim values and control limits for each process control parameter; and
— a summary of the results for additional parameters tested.

7 Process control

7.1 Introduction

Process control employs process analysis to maintain a specific operating condition through the measurement of control targets and the comparison of measured values against established aims and control limits. It is a self-contained monitoring loop until a change in the process occurs. When a change is discovered, the process must be reset to the aim values specified in the printing specification. As long as these aims can be reproduced, additional fingerprinting and characterization are not required.

The details of process control and the associated use of statistical data are the subject of many courses, texts, and articles and will not be covered in detail here.

7.2 Control target

Integral to process control is the use of a process control target(s). Because of differences between print processes, customer requirements, and characteristics of the particular equipment being used, a single standardized target is not feasible or even appropriate. Instead, the following elements have been prioritized for use, as space is available for the target on the specific printing form:

- the minimum is a solid for each print color – primary color control (colorimetric);
- single-color tint of each print color;
- two-color chromatic overprints (traps) – secondary color control;
- job-specific gray balance.

See Section 10 for a more complete discussion of target requirements.

7.3 Control data to be analyzed

The analysis of process control data falls into several categories. First in importance and priority is the evaluation of the current printing to determine whether it meets the established process specifications (if not, corrective action may be necessary).

Next, established aim points and tolerances must be evaluated to determine whether they should be adjusted to provide either tighter tolerances (i.e., more rejections) or more stable operating conditions (i.e., printing that is more consistent with tolerances).

Finally, it must be determined whether current printing process control information should be added to the existing knowledge database as an aid to establishing aims for future printing jobs or additional print runs of the current job.

7.4 Deliverables

In any printing job, a process control summary should be prepared to compare the actual printing against the printing specification. This should include at a minimum, aims, tolerances, and a summary of the measured values for each specified parameter. There are many ways that this can be accomplished using varying levels of statistical analysis. The detailed specification of requirements for such a report is best left to discussions between the customer and printer.

8 Characterization

8.1 Introduction

Characterization is the use of test targets, color measurement, and statistical analysis to define the relationship between input data and the result (color) on the printed sheet. Characterization data is essential for the use of modern color management tools.

A key issue is that characterization data is of little value unless the printing condition being characterized is known and can be repeated. Thus, characterization tests should never be conducted until fingerprinting has been completed, a printing specification has been established, and process control is in place to ensure that the process can be replicated. Some thoughts on repeatability and reliability that apply here are included in Annex A.

It is important to note that in package process color printing, ink colors are used that are often not the traditional CMYK colors. Characterization data therefore may represent combinations of three chromatic colors and a dark color. In fact, some printing requirements may involve several combinations of chromatic and dark colors in the same printing job. Where such combinations occur it is best if they are all printed on the same sheet at the same time so that all data is prepared at a common set of printing conditions.

8.2 Characterization test target

While many characterization test targets have been offered by different software vendors it is recommended that any characterization tests involve the use of either the ANSI IT8.7/5 or IT8.7/5 characterization targets. Other targets may also be included but the open exchange of data is greatly enhanced by standard targets and data sets that result from their use.

8.3 Characterization press run

It is important that any press run used to develop characterization data be conducted at aim conditions of press operation as well as being as close as possible to the printing specification aims.

See the CGATS Recommended Industry Practice, *Color Characterization Data Set Development — Press Run Guidelines*.

8.4 Data collection

See the CGATS Recommended Industry Practice, *Color Characterization Data Set Development — Press Run Guidelines*.

8.5 Data analysis

The CGATS Recommended Industry Practice, *Developing a color characterization data set - Analysis and reporting* will address the issues of data analysis for the development of characterization data in detail and readers are directed to that document when it becomes available. (This document is in the early stages of preparation. When it has been finalized, it will be made available for download from the CGATS section of the APTech Standards Workroom at https://www.printtechnologies.org/standards/.)

8.6 Deliverables

The report of characterization data testing must include the characterization data itself, reported in the appropriate format for the target, as well as a detailed description of the printing specification aims, materials used, and compliance of test data to these established aims.

It is also important to summarize the data collection and data analysis steps followed and to identify any actions taken with respect to anomalous data points, etc.

9 Process improvement

Process improvement is the use of process analysis to improve quality, efficiency, and production yield. Among the many drivers are market competition, industry trends and technology change.

Process improvement depends upon constant monitoring of process control data for every printing job, which allows evaluation of process aims and tolerances as a function of substrate type, ink type, operating conditions, etc.

Although data for any particular set of printing specification aims cannot be directly related to other aims, an understanding of trends observed, and cause and effect relationships in one printing job, can be used to effectively build a knowledge database that can allow future work to be more efficiently specified and/or higher quality products to be produced with existing equipment.

10 Test form development

10.1 General

In developing a test form to be used for fingerprinting or characterization of a packaging process, it is important to realize that there may be only one opportunity to get "on press" during the process evaluation and optimization cycle. A printing process evaluation test which starts as an optimization test, may move directly into a fingerprinting run, and the sheets for characterization may be selected from the final stages of fingerprinting. All test elements needed for each of these diverse tasks should be present in the test form. All process control elements should be a subset of the tint areas used in the fingerprinting target which in turn are a subset of the characterization target (see Figure 3). In many situations, these elements can be reproduced as individual groups to facilitate ease of understanding. In other situations where space is limited, multiple use can be made of selected elements.

In addition to the process control, fingerprinting, and characterization target elements, it is important to include test elements that will allow evaluation of the following characteristics:

- within-sheet uniformity;
- sheet-to-sheet uniformity;
- color and tone scale of any spot colors to be used either singly or as color builds.

It is also important to remember that proper characterization requires knowing the range of ink formula and viscosities, image carrier specifications, as well as press conditions to develop acceptable tolerances from the selected optimum. Restricting press evaluations to "one shot" can defeat the very purpose of the objective: consistent adherence to acceptable tolerances.

The reader is referred to the CGATS Recommended Industry Practice, *Color Characterization Data Set Development — Press Run Guidelines* for additional discussion of the issues involved in target design.

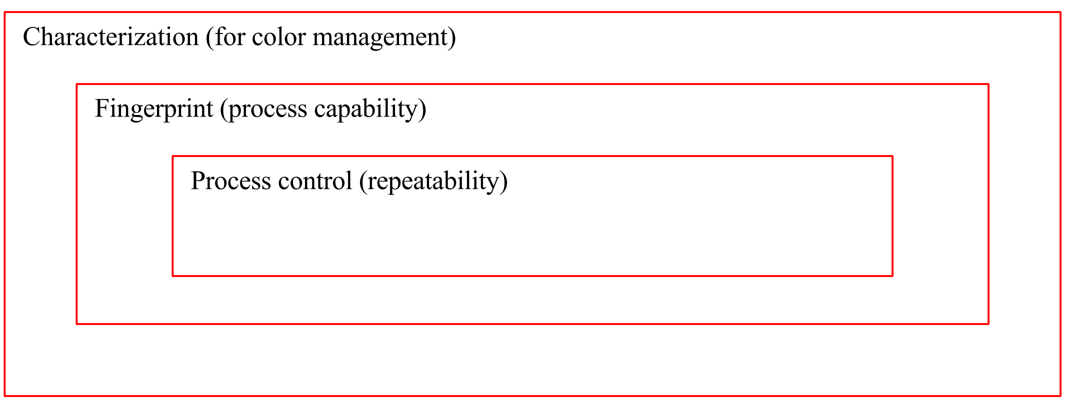

Figure 3 — Conceptual relationship of targets

10.2 Fingerprinting target

It is important to remember that any printing process evaluation and/or fingerprinting must include evaluation of mechanical issues such as slur, doubling, etc. in addition to solids, tints and overprints. Evaluation of these characteristics requires targets that have specific spatial characteristics that may necessitate either optical (film) input or targets specifically tuned to the imaging system characteristics. Mechanical target elements should also be replicated in various areas of the form to insure within sheet uniformity of these characteristics.

Supplemental elements of a fingerprint target, not included in the characterization target, may include:

- slur targets;
- lines (positive and negative);
- exposure guides;
- vignettes;
- microlines;
- registration;
- UPC codes;
- solid bars.

10.3 Characterization target

The recommended characterization data set is the IT8.7/5-2019, *Graphic technology — Input data for characterization of 4-color process printing*, or the proposed IT8.7/5, *Graphic technology — Input data for characterization of 4-color process printing of packaging materials*. Although there are default layouts for each data set, the standards do not require any specific layout and or replication of individual elements. The choice of random, symmetrical, or custom layouts along with the use of a single or multiple targets is the responsibility of the organization doing the characterization. This choice will depend on the available space, knowledge of the process being characterized, and precision required. Whatever the layout used, it is the responsibility of the organization doing the layout to provide a mapping between physical location (row-column data) and the data set ID number in the appropriate standard or the ink values of the individual components if non-standard ink value combinations are used.

10.4 Other test form elements

Whether to include additional elements such as pictures, graphics, assumed neutral gray balance patches, and proprietary test elements is the decision of the group developing the test form. Such elements can be both beneficial and detrimental: beneficial in that something more specific can be learned about the process or the result may be more accurate; detrimental because the additional elements may lead to bias in the way the test is conducted.

For example, pictorials can be reassuring to a consumer product company (the ultimate benefactor of color management), but may mislead those conducting the test into producing a “pretty picture” rather than running to established aims. This is especially dangerous if someone who is familiar with the intended appearance of the pictorials can influence the test. One outcome of press characterization is the development of color management data that allows us to make accurate proofs and color separations. Since we cannot know this information beforehand, it is unlikely that any pictorial on the test form will be correct.

It is recommended that the same “control bars” are included on each of the test forms in all phases of testing and during “live” press runs. The control bars may include solids, overprints, tints and gray balance patches. They should be a subset of the larger test form, and in everyday use provide a familiar foundation for process control.

Use careful consideration for mechanisms such as bearer bars, protection bars, takeoff bars, and pull bands. They are important when used properly, but may lead to bias in data that may not show up in live jobs.

Multiple line rulings can validate the stability of printing conditions. Many printers aspire to rulings that are higher than can be handled by the process. A successful press test will make it obvious which rulings will result in stability, with some rulings failing the selection criteria. Bear in mind, though, that multiple rulings may be an obstacle in press characterization because a large set of test elements must have the same screen ruling. This is especially important when we must consider replication on a single test form.

Again the nature of the test, the sophistication level of process control, and the ultimate goals of the group conducting a fingerprint and/or characterization determine whether it is appropriate to include additional elements on the test form. Such is not discouraged, but careful consideration must be given to whether the additional elements will lead to bias in the way the test is conducted or in the data collected from the test.

Annex A

Reliability vs. repeatability

If a test is to be reliable, it should bring about the results or ends intended. If a test is to be repeatable, it should produce the same results (within tolerances) if the test is repeated ad infinitum. It is important to note that a test can be repeatable without necessarily being reliable. However, no test can be reliable if it is not repeatable.

Consider the following example:

Employing CIE methods for calculating and communicating color, one generally expects that the data gathered from a press characterization will correlate with what we see. Such data may be used in the form of an ICC profile to produce color simulations of a printing press with an inkjet printer. In a fairly simple test, we may determine that the maximum ΔE between the inkjet simulations and the original measurement data is less than 0.5, a number so small as to be passed off as random error in the measurements. In addition, we can repeatedly obtain this same result by performing the test again, even when we begin with a different press characterization. The problem is that although the measurements show an extremely small ΔE between the press sheet and the proof, the visual color match that we see is quite poor. It leaves us asking what went wrong.

We all have learned to trust spectrophotometry as a tool for color measurement, often without carefully examining the materials that we are measuring. In the example above, the materials were not tested to be sure that the measurement procedures were appropriate. The substrate used for the printing and press characterizations had a high level of brighteners, and was quite fluorescent. The proofing substrate had a much lower level of brighteners and exhibited very little fluorescence. During measurement, no measures were taken to account for, or eliminate, the difference in fluorescence between the printing and proofing substrates. The color management system did what it was supposed to, based on the characterization data it received. This is a clear example of a situation where a test is repeatable, but not reliable.

Some interesting dictionary definitions that apply:

valid – bringing about the results or ends intended;

reliable – able to be trusted to be accurate or correct or to provide a correct result;

repeatable – results can be obtained over and over.

Annex B

Measurement of brand or special spot colors

When printing graphics for packaging, the printer is often asked to match brand or special spot colors. Brand or special spot colors (hereafter referred to as "special colors") are defined here as colors other than the normal process colors (CMYK). The special color may print only as a solid color but often the design elements such as gradients (vignettes), tints and multiple-color tonal images of the "special color" are included. While standard densitometry using primary filter readings is adequate for control of process colors, special colors are more effectively controlled with more sophisticated techniques. Special colors can be measured using spectrophotometers, colorimeters or densitometers and evaluated using several methods. Regardless of the method used, it is important to report the sample backing used during measurement as well as a description of the instrumentation used. Measurements and computations should be performed and reported in conformance with ISO 17972-4 or ISO 17972-1 with spectral reflectance data.

Colorimetric specifications are common and are the preferred method. These specifications can be in terms of one or more of the following:

– CIE L*a*b* or ΔL*, Δa*, Δb*

– CIE L*C*h or ΔL*, ΔC*, Δh

– Total Color Difference (ΔE)

CIE L*C*h is the preferred method for specifying chromatic colors since these colors are normally evaluated in terms of lightness, chroma or cleanliness, and hue or shade. C* and h can be calculated from a* and b* but this requires an additional calculation and knowledge of the mathematical formula. (See Figures B.1 and B.2.)

CIE L*a*b* is the preferred method for specifying achromatic colors (blacks, whites and grays) since these colors are normally evaluated by how light or dark and how close to neutral (a* = 0; b* = 0) they are. Since these colors are close to the neutral axis, a very small change in the a* or b* value can result in a very large change in the h value, which makes it difficult to use this value for control.

Total Color Difference (ΔE) can be used alone or in conjunction with ΔL*, Δa*, Δb* or ΔL*, ΔC*, Δh. When used in conjunction with ΔL*, Δa*, Δb* or ΔL*, ΔC*, Δh, specifications can be developed that prevent all or most of the Total Color Difference from being caused by one characteristic - lightness, chroma or hue. The ΔL*, Δa*, Δb* or ΔL*, ΔC*, Δh values also provide information that is helpful when the color needs to be adjusted.

Spectral reflectance data may also be used to specify special colors. While the spectral curve provides a precise definition of the color, it can be difficult to match the curve exactly unless the same batches of materials (substrate, inks, etc.) are used. Therefore, it is common practice to also provide tolerances in the form of total color difference or colorimetric specifications. By specifying the spectral curve, the color can be matched using colorants that will prevent metamerism. This is important if the color must match the standard under more than one light source. A color can match the colorimetric values of the standard without being a spectral match. Such a match is known as a metameric match.

When a spectrophotometer or colorimeter is not available, special colors can be controlled using densitometric methods - revise to spectro only ISO 13655

These methods include:

— Primary filter reading
— Secondary filter reading
— Primary and secondary filter readings
— Hue/grayness

The primary filter reading, the highest of the red filter density (Dr), green filter density (Dg), and blue filter density (Db) readings, will normally track changes in lightness but does not provide information about the chroma and hue of the color. While this method works well for the primary colors (CMY), a single filter reading may not be adequate to control a special color.

The secondary filter reading, the second highest of the Dr, Dg and Db readings, in some cases will track changes in lightness better than the primary filter reading. For example, a red may have a Dg reading (magenta channel) that is the primary filter reading and a Db reading (yellow channel) that is the secondary filter reading. However, over the acceptable range of light to dark, the Db reading may provide a larger density range, which would provide increased sensitivity to changes in lightness. In this case, the secondary filter reading would be the preferred reading for control. Again, while this controls the lightness of the color, it does not provide information about the chroma and hue of the color.

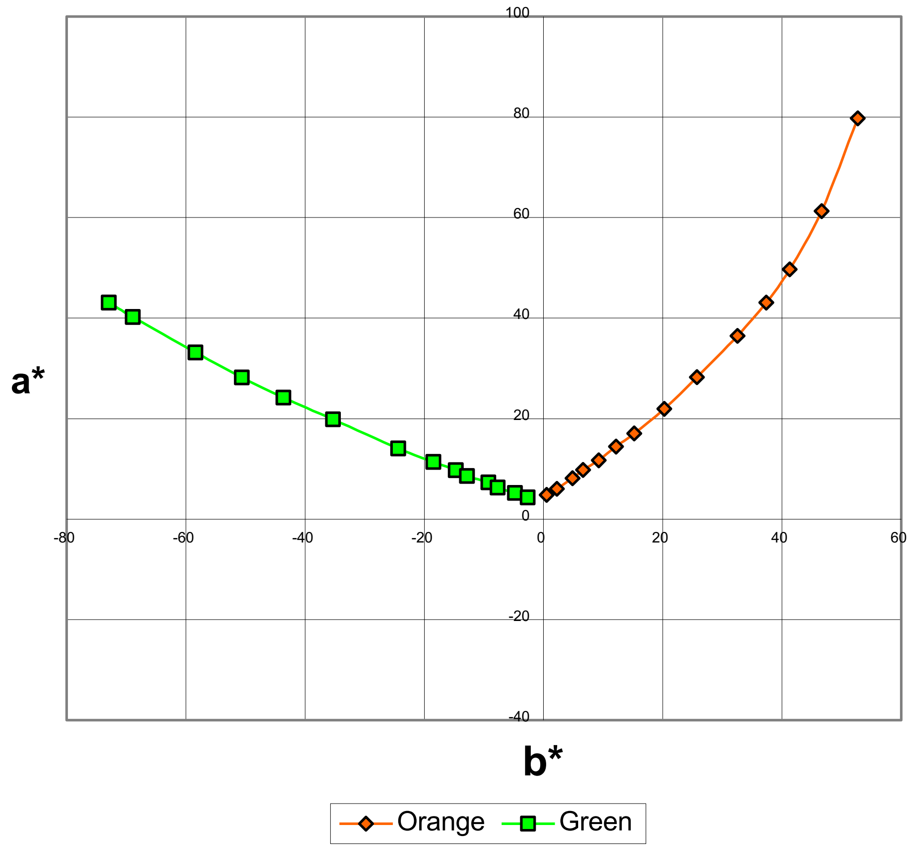

Figure B.1 — Typical a* vs. b* plot of special colors

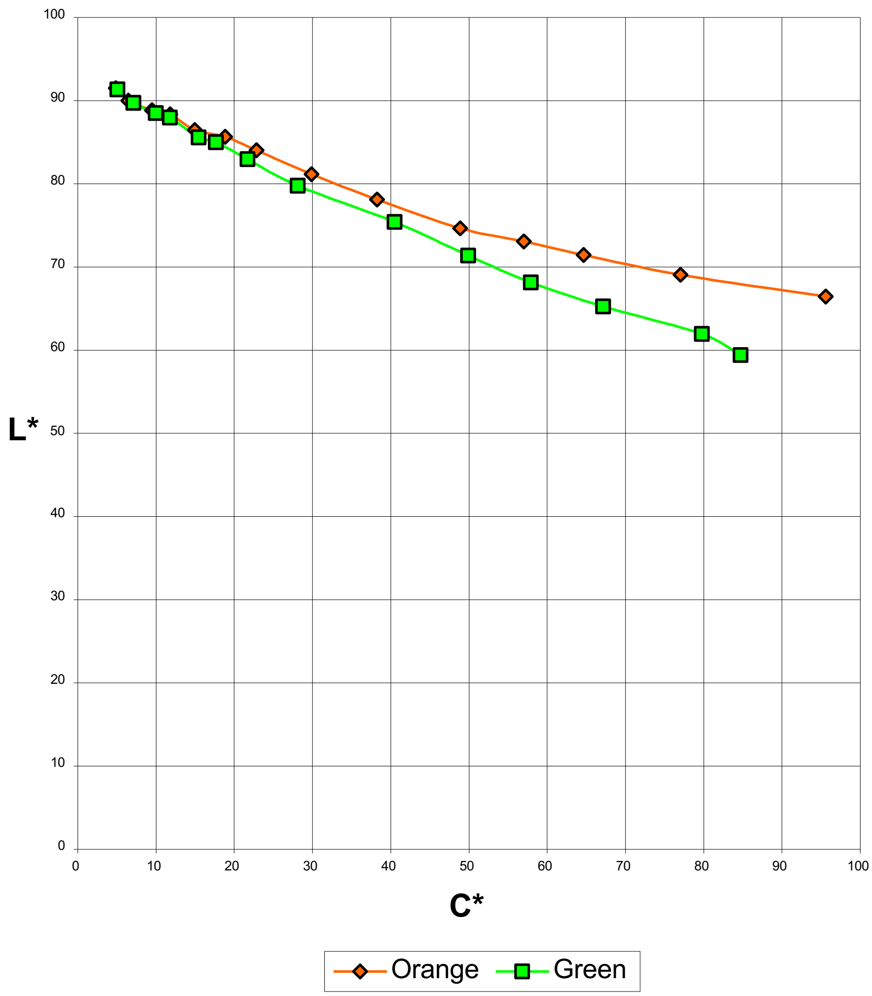

Figure B.2 — Typical L* vs. C* plot of special colors

By using both the primary and secondary filter readings, changes in lightness and hue can be controlled. This method is preferred over using just one filter reading.

Hue/grayness readings are calculated from all three filter readings. When combined with the primary or secondary filter reading, this method provides control of lightness, chroma (grayness) and hue. While densitometry may not have the sensitivity of colorimetry, this method provides control similar to L*, C* and h.

Designs that include graphic elements such as gradients (vignettes), tints, multiple-color tonal images, and use of non-process colors incorporated into process images present more complicated situations. The tonal characteristics of the supplied "target" and the press may differ considerably, creating difficulties in matching the target. Control of an image (via its reproduction curve) through measurement of values in a tonal scale printing with the image can be helpful when aligning (matching) the reproduction curve of the printed sample against the target.

Measurement of solids and their tonal values with a spectrophotometer or colorimeter and plotting a* vs. b* and L* vs. C* can be helpful in understanding and controlling special colors.

Tolerances can be developed that create a "tube" around the line connecting the various tone level measurements. Using color difference equations such as CMC, CIE94, or CIE2000 can be helpful in determining the size and shape of the tolerance tube. Depending on the color, the tolerance tube may be elliptical in shape.

Annex C – Update to SCTV

Recommendation for computing narrow-band optical density of spot color inks

There are several ways to compute the optical density of a non-process ink. The most general method is to use the narrow-band density spectral product centered at the wavelength of maximum spectral density of the measured spectral reflectance factor or transmittance factor. (Spectral density is the negative of the log10 of the spectral reflectance or transmittance factor). Only wavelengths between 420nm and 680nm, inclusive, should be examined. Table C.1 shows two examples of the use of the narrow-band spectral products, one centered at 480 nm and the other at 660 nm.

Table C.1 — Example of weighting factors for narrow band densities

Wavelength (nm)	Example 1 centered at 480 Weight Value	Example 2 centered at 660 Weight Value
400	0	0
410	0	0
420	0	0
430	0	0
440	0	0
450	-0.0064	0
460	-1.8503	0
470	15.6734	0
480	72.3666	0
490	15.6734	0
500	-1.8503	0
510	-0.0064	0
520	0	0
530	0	0
540	0	0
550	0	0
560	0	0
570	0	0
580	0	0
590	0	0
600	0	0
610	0	0
620	0	0
630	0	-0.0064
640	0	-1.8503
650	0	15.6734
660	0	72.3666
670	0	15.6734
680	0	-1.8503
690	0	-0.0064
700	0	0
SUM	100	100

For example, to compute narrow band density for an ink that has a peak spectral density at 480 nm, multiply the measured spectral reflectance factor (decimal value, not percent) of the ink by the weights shown in Table C.1 (wavelength by wavelength) and sum these individual products. Using this "sum", the narrow band density is then computed as follows:

$$\text{Density} = -\log_{10}(\text{“sum”}/100)$$

For paper relative density, apply the same table of weights to the reflectance transmittance factor of the substrate alone and subtract the paper density from the ink + paper density.

To compute narrow band density for an ink that has a peak spectral density at some other wavelength (660 nm is shown in Table C.1), simply adjust the above weighting factors so that the peak of the weighting factor matches the peak of the ink spectral density curve (i.e., the wavelength of maximum light absorption of the ink).

Bibliography

The following documents, many of which are referenced in the text, supplement this Technical Report and are recommended guides in the preparation of specific workflow procedures. CGATS maintains a registry of currently valid ANSI and International Standards that impact the graphic technology industry, as well as all referenced documents.

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[2] ANSI/CGATS.5, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*

[3] ANSI/CGATS.6, *Graphic technology — Specifications for graphic arts printing — Type 1*

[4] ANSI/CGATS.9, *Graphic technology — Graphic arts transmission densitometry measurements — Terms, equations, image elements and procedures*

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[8] ANSI/IT8.7/1, *Graphic technology — Color transmission target for input scanner calibration* (included in ISO 12641)

[9] ANSI/IT8.7/2, *Graphic technology — Color reflection target for input scanner calibration* (included in ISO 12641)

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[22] ISO 12646, *Graphic technology — Displays for colour proofing — Characteristics and viewing conditions*

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

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

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

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

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

[28] ISO 12647-6, *Graphic technology — Process control for the manufacture of half-tone colour separations, proof and production prints — Part 6: Flexographic printing*

[29] ISO 12647-7, *Graphic technology — Process control for the manufacture of half-tone colour separations, proof and production prints — Part 7: Reference printing conditions for electronic data exchange*

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

[31] ~~ISO 15930-1, *Graphic technology — Prepress digital data exchange — Use of PDF — Part 1: Complete exchange using CMYK data (PDF/X-1a)*~~

~~[32] ISO 15930-2, *Graphic technology — Prepress digital data exchange — Use of PDF — Part 2: Partial exchange (PDF/X-2)*~~

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[34] *Specifications for Newsprint Advertising Production (SNAP)*, Web Offset Association for Coldweb/Open Web, 100 Daingerfield Road, Alexandria, VA 22314

[35] *Specifications for Web Offset Publications (SWOP)*, SWOP, Inc., P.O. Box 175, Marblehead, MA 01945

