CGATS RECOMMENDED INDUSTRY PRACTICE

Color characterization data set development — Press run guidelines

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Introduction

As the industry continues its accelerated transition to digitized processes from traditionally craft-oriented processes, digital color management takes on a more prominent role in the movement of press-ready material. Digital color management requires data that defines the relationship between the CMYK values used to prepare the printing form and the colorimetric output produced by the printing process. This data is commonly called color characterization data and is derived from press runs designed to correlate process parameters and raw materials with output color.

Traditionally, printers use established process specifications to ensure consistency in their printing and between multiple prepress and printing locations. By ensuring that input variables, i. e., raw materials and process parameters, conform to specified norms, consistent output color is maintained. In some cases, industry trade groups like SNAP [26], GRACoL [6], SWOP [27], FIRST [5], GAA [7], and others have provided standardized printing and proofing specifications to produce market wide color consistency.

A completely digital approach uses colorimetric data for both prepress and printing aims rather than specifications surrounding process parameters and raw materials. In practice, characterization data from production presses are used with reference data to create the transforms necessary to map input data to the intended color through the use of digital color management systems. In the digital approach, the reference characterization data becomes the colorimetric interface between prepress and printers as well as the interface between printers.

In the transition from traditionally to digitally controlled processes, both the standards community and various industry trade groups have conducted carefully controlled press runs to produce characterization data for a variety of printing conditions. The data derived from these press runs facilitate the use of digital color management systems in prepress. In this transition, process specifications enable consistency between printers, and characterization data (typically in the form of ICC profiles) provides the interface between prepress providers and printers.

The difference between the two color control paradigms is that traditional process specifications implicitly define color whereas characterization data is used to explicitly define color for digital systems. In the digital approach, color is explicitly controlled via characterization data and process specifications of wide scope are not defined. In any case, process specifications must be selected based on careful study of the printing requirements, equipment and practical issues relating to the materials to be used – whether they represent industry wide specifications or a local site. Also, regardless of whether the source of a process specification is an industry specification or a local specification, press runs intended to establish characterization data must be compliant with the selected specification. Process specification and control topics will be discussed in more detail in a planned process control document.

The objective of this CGATS Recommended Industry Practice is to facilitate the execution of press runs with the purpose of deriving color characterization data. To this end, this CGATS Recommended Industry Practice defines key steps necessary to conduct those press runs. This document is intended to be used as a reference and checklist for standards and industry groups developing reference color characterization data, as well as by individual printing organizations as they develop their own internal procedures. The sections that follow describe the key steps needed for the successful execution of a characterization press run and are organized into the chronological sections:

— Planning,

— Preparation,

— Printing, and

— Postprinting.

In addition, this CGATS Recommended Industry Practice incorporates the knowledge gained from lessons learned by early adopters. For example, the need to be sure that printing processes demonstrate repeatability and reproducibility within specified tolerances is often overlooked during press run planning. Also important, but often overlooked, is the need to maintain adequate documentation of materials and procedures so that the printing can be replicated and/or unexpected results can be analyzed. Of course, good manufacturing procedures must be followed for this to occur. The steps described in this document encompass the general execution of the press run.

The analysis and measurement of the printed sheets, development of individual characterization data sets, and the procedures to be used to evaluate and create average characterization data sets to represent groups or classes of presses is not part of this document but is covered in another CGATS Recommended Industry Practice, *Developing a color characterization data set - Analysis and reporting*, which is under development.

CGATS RECOMMENDED INDUSTRY PRACTICE

Color characterization data set development — Press run guidelines

1 Scope

This CGATS Recommended Industry Practice defines the key steps necessary to prepare press sheets that can be measured to enable the creation of color characterization data for a given printing condition. This document assumes that process aim points have been established and validated, that printed results have been demonstrated to be repeatable and reproducible within agreed upon or specified tolerances, and that good manufacturing procedures are being followed.

2 Definitions

2.1
aliasing
phenomenon associated with sampling where the sampled data does not represent the signal that was sampled due to differences between the frequency of the sampled signal and the sampling frequency

2.2
dryback
change in color, gloss, or density of an ink film as it dries and penetrates the substrate

[ISO 12637-2]

2.3
make-ready
portion of a press run from initial startup of the press through the point that the printed sheets meet the process specification

2.4
retains
raw material samples drawn from the actual materials used during the press run

3 Planning

3.1 Define documentation needs

Documentation is essential for:

1) ensuring that process control aims and the characterization data derived from the press run are correlated;

2) allowing the exchange of data with suppliers or other vendors; and

3) enabling the press run to be reproduced within reasonable tolerances by a party not involved with the original press run.

Annex A provides a sample checklist that may be used as a guide. An editable electronic version of this checklist may be downloaded from http://www.npes.org/standards/tools.html.

During the planning stage, a documentation plan must be developed and all necessary information must be identified.

3.2 Choose established process aims and tolerances

Process aims and tolerances should be chosen based on one of the following three scenarios:

1) Process specifications exist and they are exactly followed. These process specifications have been developed and published by trade organizations. Examples are SWOP, SNAP, GRACoL, FIRST, GAA, etc.

2) Reference printing conditions (often associated with industry process specifications) exist, and individual printers need to match those references. A printer that can satisfy the colorimetric gamut requirements of a reference printing condition using digital color management, but has different print characteristics than those associated with an industry process specification, may choose this option.

3) Process specifications are unique and/or private. This includes house standard processes, alternate process colors, special substrates and/or unique customer requirements.

Aims and tolerances (specifications) should be selected based on average process operating conditions (e.g., multiple press runs, multiple presses or multiple printing locations where applicable). They can be chosen based on industry norms for practical and usable input variables (e.g., line screen, etc.), as well as on normally achievable print properties to be expected as output assuming a properly controlled printing process. They are usually chosen because they "will" work properly and "can" be achieved in a normally controlled environment of printing. Refer to other CGATS documentation, such as CGATS TR 012 *Graphic technology — Color reproduction and process control for packaging printing*, or a CGATS Recommended Industry Practice on Process Management (currently under development). Also refer to the part of the ISO 12647 series of standards that is appropriate to your process (see Bibliography for listing).

3.3 Identify equipment

Identify the press(es) that will be used and insure that preventative maintenance is current. The objective is to collect data that reflects the performance of the press in its normal mechanical condition for production. Special treatment should not be applied to the press for the characterization press run. Also consider items (for example, blankets and form rollers) that should be run for a brief period before they stabilize.

Identify the parameters that must be measured during the press run, and verify that appropriate measurement equipment and calibration materials are available to meet these measurement needs. (See CGATS.4, *Graphic technology — Graphic arts reflection densitometry measurements — Terminology, equations, image elements and procedures*, and CGATS.5, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*.)

3.4 Identify inks and substrates

Inks and substrates used should be those used in establishing process aims and tolerances in 3.2. Consideration should be made for using inks in conformance with one of the parts of ISO 2846.

NOTE The various parts of ISO 2846 document the color and transparency of four-color process ink sets for printing processes. See the Bibliography for a listing.

3.5 Sampling plan

Sampling is critical to the quality (accuracy and precision) of the resultant color characterization data as well as to the recovery from unexpected problems that may be encountered after the press run is performed. Accuracy and precision are addressed by accounting for both between-sheet and within-sheet variability. More in-depth discussion of accuracy and precision relative to characterization is contained in Annex B.

3.5.1 Sheet selection

The minimum length of the press run in terms of the number of impressions after make-ready should be determined before performing the press run. This length should be long enough to allow the process to stabilize at the selected process aims. Historical process data from the press on which the press run is performed should be used as guidance in determining the minimum run length necessary for the printing process to stabilize. The press run should also be long enough to provide several hundred samples for validation and to provide a good pool from which samples can be drawn for the generation of characterization data. Typically, a minimum of 500 impressions after make-ready are needed.

The sheet selection strategy should be considered relative to the objective of the particular press run. There are several strategies that satisfy various needs. The following describes the utility of three sampling strategies:

— Use random sampling in cases where the sources or contributions of variability are unknown, or known factors are not being individually investigated. Random samples are selected by generating scaled random numbers from random number generators, such as those found in common office suite software, or from tables of random numbers found in the appendices of most statistics textbooks.

— 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. Uniform sampling frequencies should be high enough to prevent aliasing.

— CGATS uses a specialized sampling strategy in which sheets that are very tightly grouped around the specified aims for solid ink density (SID) and tone value increase (TVI) are chosen. Use specialized sheet selection strategies only in cases where process aims and uniformity can be validated in the area being used for development of color characterization data (the area encompassed by the characterization target).

A coding schema that uniquely identifies each sheet pulled should accompany the sheet selection plan. The coding schema should identify:

— press run identification;

— sheet number relative to all sheets printed;

— printing sequence (Does sheet #1 correspond to the first or last printed sheet?); and

— sample location on the test form (in the case where impressions are cut by the delivery system).

3.5.2 Test form design

Test form design encompasses content, layout and construction.

The test form content should include standard characterization elements (ISO 12642, IT8.7/3 and IT8.7/4) and/or similar vendor-specific elements. For standards work where data is intended to be shared, either the ISO 12642, IT8.7/3 or IT8.7/4 element should be used.

In addition to addressing the press run objectives, design of the test form should minimize errors due to within-sheet variability. This is accomplished by using multiple individually randomized elements in the test form. If space limitations do not permit the use of multiple elements, a single randomized element will help reduce the bias associated with some effects. Neither ISO 12642 (IT8.7/3) nor IT8.7/4 specify a standard layout of the patches as a requirement. IT8.7/3 only provides a default layout organized to assist in visual identification of the patches while IT8.7/4 provides both an organized and a randomized default layout. However, a number of randomized versions of IT8.7/3 have been developed by individual vendors, and IT8.7/3 is currently under revision to include a randomized version.

Control patches should be strategically placed in the test form. These patches should surround characterization test elements and/or be contained within the test elements themselves. The inclusion of control patches in and around the characterization elements permits the evaluation of printing uniformity and validation of the printing conditions in the immediate vicinity of the characterization test element.

Test form images should be printed such that, whenever possible, there is no printing on the reverse side of the elements to be measured. However, where substrate tracking through the press is an issue, there may be a need for printing on the back side of the substrate. If printing behind a test element is necessary, flat tints of balanced gray should be printed for cyan, magenta and yellow inks. The black ink value should approximate the gray level of the CMY gray. Printing on the reverse side of the substrate may have an impact (e. g., show through, etc.) on measurement data of the characterization target.

When designing a test form, mechanical printing issues that may affect color must be considered. In offset lithography, for example, printing tone scales across ink key boundaries can cause inconsistencies in tone rendition when adjacent ink keys are not perfectly balanced. In this case, tone scales should be positioned in the sheet or web direction with the solids toward the lead edge. In gravure it has been noted that highlights print lighter if there is no process ink immediately preceding the patch. In this case, the standard remedy is to position tone scales such that the solids lead. These are examples of mechanical printing issues that need to be considered when designing the test form.

3.5.3 Raw materials

In addition to validating the substrate and ink before the press run is performed, samples of the materials should be retained for a length of time after the run for future reference in the case that further analysis of these inputs becomes necessary. Provisions should be made for collecting and storing material retains. Twenty-five virgin sheets of the substrate should be collected. Several hundred milliliters (500 ml minimum) of each ink should be collected from the ink fountain or sump. All retain samples should be uniquely identified in a manner that clearly links them to the press run.

4 Preparation

4.1 Procedures

The following steps should be taken in preparation for the press run:

— Assemble documents, reporting forms, checklists, templates and media as identified by the documentation plan.

— Assemble the test form as specified by the test form design.

— Make image carriers (plates, films, cylinders, etc.) as necessary.

— Generate a proof (from either or both digital data and film if used) to validate positional and functional requirements of the test form.

— Validate the image carrier against process control requirements.

— Validate that inks are compliant with manufacturing specifications.

— 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.

Caution: While process specifications are typically based on dry samples, subsequent characterization is always based on dry samples. On-press process control, however, may be based on measurement of either wet or dry samples. If the ink is not dry at the time of measurement, dryback needs to be considered. Dryback is the difference between ink density measurements made immediately after printing and measurements made after the ink has had time to dry. Ink densities measured immediately after printing will be higher than the densities measured after a few hours have passed. In the case that specifications are based on dry samples, dryback values must be added to the aim values at press side.

— Validate that the substrate is compliant with manufacturing specifications.

— Distribute procedures for press setup and on-press control aims to the team responsible for conducting the press run. This ensures that the press operator clearly understands the objective of the press run and the process aims to which the press should be set.

4.2 Press preventive maintenance validation

Calibration and timely maintenance of all equipment is required; special care should **not** be given to equipment for the characterization press run because the press run should be conducted under conditions representative of production conditions.

Press maintenance per manufacturer's guidelines and press set up conditions should be verified prior to the start of any press run. Areas to address include, but are not limited to:

- ink distribution and sequence (forms, impression rollers and blankets);
- substrate path (tensions, pressures and cleanliness of rollers);
- image transfer (correct blankets, rollers and cylinders);
- chemistry (fountain solution, inks, solvents);
- drying (temperature and humidity).

5 Printing

5.1 Make-ready

Verify that:

- measured printing parameters satisfy all process aims and tolerances;
- mechanical artifacts (doubling, slur, etc.) are not present or minimized; and
- ink contamination has not occurred (see Annex C).

Important: Contrary to normal operating procedures, during the press run for characterization there should be no effort to match a color proof. Verification that the process is compliant with the process specification should be based on a comparison of measured values against their specified aims and tolerances.

Due to the nature of variations within and between press sheets, several areas on several sheets should be tested to determine that the printing meets the desired aim points within and between sheets. This requires that not only press control bars are measured, but also control elements in and around characterization elements from several randomly selected sheets are measured. In addition, several consecutive sheets should be examined for mechanical artifacts.

Make-ready is complete when all process parameters are at specified aims values and within specified tolerances within the image area of multiple sheets, and mechanical artifacts are not present or are at an acceptable level. In other words, characterization elements and mechanical artifacts are compliant with the process specification and the process has stabilized. This marks the beginning of the actual press run.

5.2 Perform the press run

Run as specified including:

— the number of impressions,

— flagging,

— live sampling,

— ink sampling,

— ink contamination evaluation during make-ready and at the end of the run (see Annex C),

— virgin substrate sampling,

— sheet identification.

6 Postprinting

6.1 Sampling and sample validation

— Select sheets according to the sheet selection plan.

— Allow sheets to thoroughly dry. For non-heatset samples, drying time should be a minimum of 48 hours.

— Validate that all samples satisfy mechanical artifact specifications.

— Validate that all samples achieved the desired density and/or color aims and tolerances after the sheets are thoroughly dry. Densitometric and colorimetric measurements should be made in accordance with CGATS.4 and CGATS.5.

— Validate that ink contamination (see Annex C) has not occurred for any sample.

6.2 Postprint handling

The following should be considered when handling samples after printing:

— Store samples in a cool, dark, dry location.

— Samples should be kept flat or rolled, but not folded unless the test form accommodates folding

— Deliver samples as soon as reasonably possible.

— For extended periods of storage or shipping, shrink wrap samples to a pallet if possible.

6.3 Raw material samples

— Properly label the ink and substrate retains. Labeling should clearly identify the press run.

— Store retains as determined during planning.

6.4 Documentation

— Review documentation to ensure that it accurately reflects all materials, procedures and last minute changes.

— Assemble and verify the completeness of documentation package.

— Distribute the documentation package.

7 Measurement and analysis

Refer to the CGATS document, *Developing a color characterization data set – Analysis and reporting*, for guidelines for measurement and analysis of the printed samples. (This document is currently under development.)

Annex A

Documentation

The information shown in Table A.1 should be provided. Any additional information that may be helpful in the definition of the press run should also be provided.

NOTE This list is not all-inclusive; information is process-specific.

Table A.1 — Information that should be provided

- Site
- Date
- Coordinator
  – Name
  – Contact Information
- Color Objective (i.e., SNAP, GRACoL, SWOP, FIRST, GAA, other)
- Tone Reproduction Curves (Linear or Other)
- Process Parameters (i. e., SID, TVI, Trap, etc.)
- Color Sequence
- Press
  – Make
  – Model
  – Serial Number
  – Age
  – Number of Impressions
  – Preventive Maintenance
- Ink
  – Manufacturer
  – Type
  – Lot Numbers
  – Physical Properties
- Substrate
  – Manufacturer
  – Type
  – Basis Weight
  – Lot Numbers
  – Physical Properties
- Image Carrier
  – Manufacturer
  – Type
  – Plate Setter or Engraver
  – Physical Properties
- Fountain Solution
  – Manufacturer
  – Type
  – Physical Properties
- Blankets
  – Manufacturer
  – Type
  – Physical Properties
- Sampling
  – Test Form (Designed and Validated)
  – Run Length
  – Sampling Plan Documentation
  – Raw Material Retains

A sample format for providing this information for offset lithography follows. The sample format is also available as a separate file from http://www.npes.org/standards/tool.html.

Sample Documentation for Offset Lithography

Planning - Who and Where

Site:	**Date:**
Coordinator:	**Phone:**
Contact information:	

Planning – Color Objective

Check below			Guideline version and description
☐	**SWOP**	☐	**GRACoL**
☐	**SNAP**	☐	**ISO 12647, Specify Part Number**
☐	**FIRST**	☐	**Other** (describe fully)

Planning - Press

Press manufacturer:		
Model:		**Press ID:**
Age:	**No. Units:**	**Estimated total number press impressions:**
Maintenance Required:		

Planning - Materials

Ink manufacturer:	
Ink type:	**Color sequence:**
Substrate manufacturer:	
Type and basis weight:	
Fountain solution manufacturer:	
Type:	
Blanket manufacturer:	
Type:	
Plate manufacturer:	
Type:	

Planning - Status

Sampling plan document name:		
Location:	**Check below**	
	☐	**Sampling plan complete**
	☐	**Test form design complete**
	☐	**Retains plan complete**
	☐	**Documentation plan complete**

Preparation – Test Form

Test form description:		
Production notes:		
	Check below	
	☐	**Form assembled**
	☐	**Design validated**

Preparation – Prepress

Output curves:	☐	**Linear**	☐	**Other** (describe below)
FM (name):	**FM spot Size:**			
Halftone screen ruling:	**Halftone angles:**			
Halftone dot type (round, square, eliptical, euclidean, etc.):				

Preparation - Materials

Ink Specification Referenced:	☐	**SWOP**	☐	**GRACoL**	☐	**SNAP**	☐	**ISO 2846-1**
☐	**Other** (describe)							

Ink Verification:		
Ink# 1 name:	**Tack:**	**Grind:**
Viscosity:	**Emulsification:**	**Batch #:**
Ink# 2 name:	**Tack:**	**Grind:**
Viscosity:	**Emulsification:**	**Batch #:**
Ink# 3 name:	**Tack:**	**Grind:**
Viscosity:	**Emulsification:**	**Batch #:**
Ink# 4 name:	**Tack:**	**Grind:**
Viscosity:	**Emulsification:**	**Batch #:**
Ink# 5 name:	**Tack:**	Grind:
Viscosity:	**Emulsification:**	**Batch #:**
Ink# 6 name:	**Tack:**	**Grind:**
Viscosity:	**Emulsification:**	**Batch #:**
Substrate verified:	**Basis weight:**	**Brightness:**
Lot #	**Opacity**	**Caliper**
Fountain solution verified:		**Type:**
Blanket verified:		**Type:**
Plate verified:		**Type:**
Lot #		
Production Process Notes:		

Preparation – Press

Preventative maintenance verified:	☐	**Date:**
On press control aims: (describe)		
Check when complete:	☐	**Established**
	☐	**Documented**
	☐	**Distributed**

Preparation – Documentation

Documents complete:	☐	**Date:**	**Initial**
Forms complete	☐	**Date:**	**Initial**
Templates complete:	☐	**Date:**	**Initial**
Materials available:	☐	**Date:**	**Initial**

Printing – Preparation

☐	**Spectrophotometer/Densitometer calibrated**		**Date:**
Manufacturer and Model:			**Serial #:**
Fountain solution validated:		☐	**Temperature:**
		☐	**pH**
		☐	**Conductivity**

Printing – Prior to Sample Collection

Check samples for:	
☐	**Slur**
☐	**Doubling**
☐	**Ink contamination**
☐	**Press speed**
☐	**Number of Impressions**
☐	**Retain samples collected**
☐	**Process Compliant with Specification**

Printing – Verification of Solid Ink Density (SID)

	Aim	Low Limit	High Limit	Actual (Average)
Ink 1				
Ink 2				
Ink 3				
Ink 4				
Ink 5				
Ink 6				

Printing – Verification Midtone Tone Value Increase (TVI)

Ink	Aim	Low Limit	High Limit	Actual (Average)
Ink 1				
Ink 2				
Ink 3				
Ink 4				
Ink 5				
Ink 6				

Printing – Verification Hue Error and Grayness

Type:	Hue	Gray
C		
M		
Y		

Printing – Verification Trap

Type:	Aim	Low Limit	High Limit	Actual (Average)
R				
G				
B				

Printing – Verification Colorimetry

Illum/Obs:	L*	a*	b*	C*	h_{ab}
K					
C					
M					
Y					
R					
G					
B					
CMY					

Printing – Sample Collection

Sample selection plan reviewed	**Reviewer's Initials:**
Interval of collection:	
Interval of sheet verification:	
Number of samples collected:	
Notes:	

Annex B

Accuracy and precision in press run results

B.1 Introduction

As stated in the introduction to this document, the need for characterization data has been driven by the increasing use of digital imaging technology. While color management is not exclusive to digital imaging technology, mechanical color measurement is a requirement of digital color management whereas traditional color management largely relies on visual "measurement" of subjective imagery. In traditional color management, human observers perceptually "sample" hundreds and thousands of points and form "average" opinions about the appearance of color images. Due to the large number of points sampled, results of the traditional method are generally very accurate and precise. In digital color management, however, economic forces prohibit mechanically sampling a similar number of points, but, levels of accuracy and precision are expected to be similar or better than that achieved traditionally.

Within economic constraints, the quality objective of a press run for characterization is to compile the most accurate and precise data. In this context, this annex summarizes the variables and strategies to consider when developing a sampling plan for press characterization.

B.2 Separating press run variables

Since characterization data accuracy and precision are functions of the variability found in press runs, it is necessary to account for all sources of variability. The literature documents several variables and their affect on measurements of printed samples. Ink take-off and target configuration have been shown to affect ink starvation and tone reproduction in offset lithography (Siljander, et. al., 2000). Another well known factor in offset lithography is the effect of ductor timing on sheet to sheet consistency. The effects of wipe-back by the doctor blade in gravure printing have been shown to depend on the target layout. Lateral diffusion of light in the ink and substrate is a phenomenon associated with the measurement process, but is also significantly responsive to the test target layout (Spooner, 2000). In practice, there are multitudes of variables and each printing technology has its own set of caveats.

To simplify and to make the analysis method independent of the printing process used, variables may be roughly separated into within-sheet and between-sheet categories. This separation groups spatial effects with within-sheet variables and temporal effects with between-sheet or press run variables. Even though particular variables depend on several factors including the printing technology (e.g., flexography, lithography, gravure, etc.), this division of the variables is process-independent, reduces the amount of knowledge required for each specific source of variation, and facilitates the sampling of all variables.

B.3 Measuring accuracy and precision

Consider, for example, a single measurement from a single press sheet. The result of this measurement will be a value that is descriptive of the press run, but biased toward the condition that existed in that particular location of the test form at that particular point in time. To evaluate and/or improve accuracy and precision, multiple measurements are required and the manner in which these measurements are taken affect the result in different ways. Accuracy is improved by sampling more variables while precision is improved by replicating measurements of the same variable (Siljander, et. al., 2001). Using the process-independent method to separate the variables described above, various sampling strategies for measuring accuracy and precision are available.

Statistics for within-sheet variables describe the central tendency and spread of data observed within a single sheet. The average and standard deviation of density are examples of statistics for within-sheet variables. Because multiple test elements within a test form increase both the number of variables sampled and the number of replications, accuracy and precision of within-sheet statistics are both improved when test elements are replicated on a test form. The most accurate and precise results are obtained from test forms that include replicated test elements each of which are individually randomized. Without replicated test elements or without a varying test element layout, results will be biased to varying degrees due to the spatial conditions that exist in the particular region of the test form where the test element is positioned.

Also relative to sampling within-sheet variables is the use of replicated and individually randomized test elements versus the use of a single test element layout that is rotated with each replication. Since research has only been performed using randomized test elements, only conclusions from individually randomized elements are discussed in this annex. The use of a single test element layout that is rotated with each replication is an improvement over the use of a single test element and may produce results of sufficient accuracy and precision.

Statistics for between-sheet variables describe the central tendency and spread of sheet averages from a single press run. Examples of between-sheet statistics are the average and standard deviation of sheet averages. While accuracy and precision can be improved by sampling multiple sheets, the lower bound for between-sheet accuracy and precision has the same magnitude as within-sheet statistics. Also, between-sheet variables can only be resolved from within-sheet variables if multiple measurements are taken from within each sheet.

Total statistics reflect the within press run central tendency and total spread of the data. Total statistics may be directly measured or mathematically determined through the combination of statistics for within and between-sheet variables. As a function of within and between-sheet variables, the accuracy and precision of total statistics are directly related to the accuracy and precision of within and between-sheet statistics. The functional relationship is always additive, i.e., less accurate and precise than the within and between-sheet components, although, the final form of the relationship depends on the type and size of the distribution for the particular metric (e. g., density, L*, delta E, etc.) in question.

Research also indicates that the use of data from multiple press runs further improves accuracy and precision; that is, that results converge closest to the process specification when data from more than one press run are combined. The inclusion of more than one press run allows further increase in the number of variables sampled. In particular, the affects of different lots of ink and substrate, press crew and environmental conditions as well as random fluctuations in press conditions can be accounted for in the resultant characterization data. Again, with more replication and more variables sampled, accuracy and precision are improved. Conversely, results from a single press run are biased towards the conditions that existed during that press run only, and gauging the reproducibility of those results is impossible. The criticality of the color output should govern the decision to use more than one press run.

B.4 Applying the appropriate strategy

With respect to the quality objective of the press run for characterization, accuracy and precision, an exhaustive sampling plan ensures the most accurate and precise data but may be economically prohibitive due to the substantial amount of measurement and analysis resources required. The compromise between accuracy and precision and resources is found by focusing the sampling plan on the particular needs of the press run. In the case of press characterization, the need is accuracy relative to intended aim values, which is found most efficiently through the use of directly measured total statistics so long as the press run is compliant with process specifications *on average*. The direct measurement of total statistics requires that measurements be taken from several within-sheet locations and from several sheets. However, the measurement of all test elements on all sampled sheets is not necessary. That is, total statistics can be adequately determined by measuring a few different elements from a few different sheets.

The direct measurement of total statistics using this optimized sampling plan means that within- and between-sheet effects cannot be resolved from the resulting data set. But since total statistics are functionally related to within- and between-sheet statistics and since the total statistics are less accurate and precise than within- and between-sheet statistics, so long as the total statistics satisfy the process specification, their use satisfies the quality objective of the characterization press run. In the case that total statistics do not satisfy the process specification, it may be necessary to measure more samples such that within- and between-sheet variables can be resolved and the problem identified. This allocation of resources, however, would only be required if a problem was encountered.

B.5 Summary

The strategies outlined in this annex should provide reliable and efficient means of digitally achieving levels of accuracy and precision similar to those achieved traditionally. The idea is to understand the variability of the printing system in terms of within- and between-sheet variables, to design the test form and sampling plan to accommodate the sources of variability, and to minimize measurement requirements. While the most exhaustive sampling plans allow resolution of all the variables, as long as the steps in this CGATS recommended practice are followed, most characterization press runs will require only the direct measurement of total statistics.

Annex C

Ink contamination evaluation

C.1 Introduction

Printed inks should be evaluated for contamination both during make-ready and at the end of the press run. Performing the evaluation during make-ready ensures that any problem found can be corrected before proceeding so that press time and materials are not wasted. Performing the evaluation at the end of the press run ensures that samples collected for characterization do not exhibit ink contamination.

Potential sources of ink contamination include the ink delivery system and back trap of inks printed on previous units. When the contamination is due to ink back trapping, it will be encountered in the 2nd down ink or later. This is because back trapping occurs when ink that has been printed onto the substrate, transfers back onto a subsequent blanket and mixes with this subsequent ink. Therefore, when checking for contamination, the color sequence that is being printed will indicate the most likely source for the contamination.

C.2 Spectrophotometric evaluation

Printed samples should be measured with a spectrophotometer and spectral curves examined for signs of contamination. Contamination can be detected by comparing the curves of the substrate and cyan, magenta and yellow solids in the printed output to the curves from laboratory prints of the inks made at the aim density on the same substrate.

In evaluating the spectral curves, evaluate the following.

- The yellow and magenta curves should exhibit high reflectance portions that are within 2% of the reflectance level of the unprinted substrate. (For example, see how in Figure 1, the spectral curves of the yellow from 530 – 730 nm and the magenta from 630 – 730 nm are within 2% of the paper.)

- Look particularly for contamination from the previously printed color(s) by checking for a dip in the spectral curve at the maximum absorption point of those colors. For process inks, the maximum absorption points are approximately: Cyan - 630 nm, Magenta - 560 nm and Yellow - 400 nm.

Figure C.1 illustrates a process ink set with no contamination. The high reflectance portions of the spectral curves for the yellow (530 – 730 nm) and magenta (630 – 730 nm) are within 2% of the paper.

Figure C.2 shows the same yellow ink with magenta ink contamination compared to the uncontaminated ink. The spectral curve of the contaminated ink has an inflection point in the curve from 550 – 580 nm that corresponds with the maximum absorption point (lowest point) of the magenta curve. Also, the high reflectance portion of the curve for the contaminated yellow is 4 - 5% lower than the curve of the uncontaminated yellow.

Figure C.3 shows the same magenta ink with cyan ink contamination compared to the uncontaminated ink. The spectral curve of the contaminated ink has inflection points in the curve from 620 – 640 nm and 690 – 720 nm that correspond with the absorption points of the cyan curve. Also, the high reflectance portion of the curve for the contaminated magenta is 4 - 5% lower than the curve of the uncontaminated magenta.

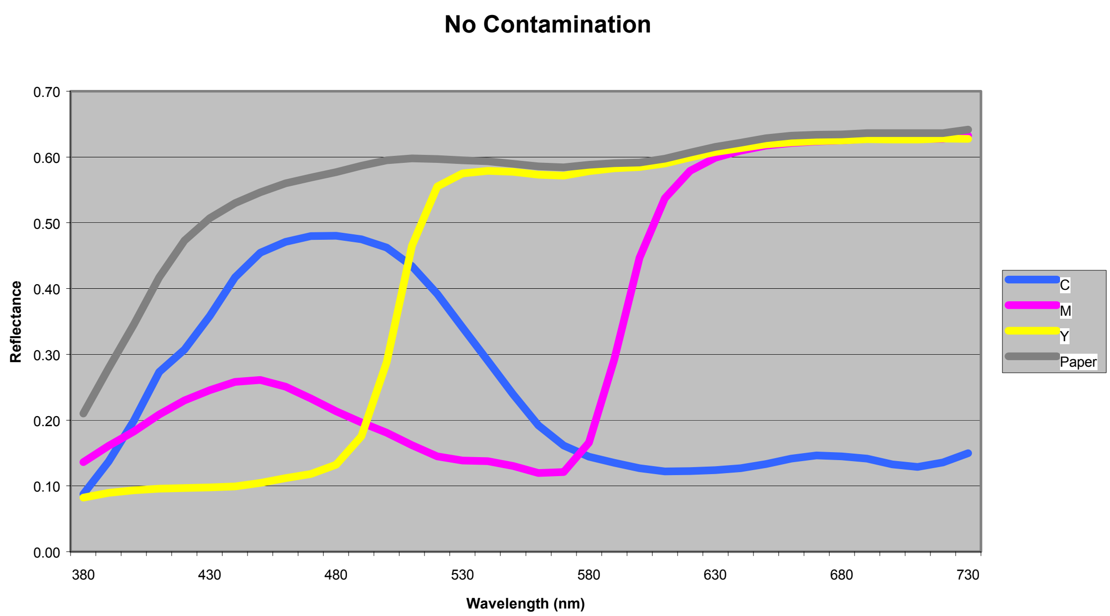

Figure C.1 — Process ink set with no contamination

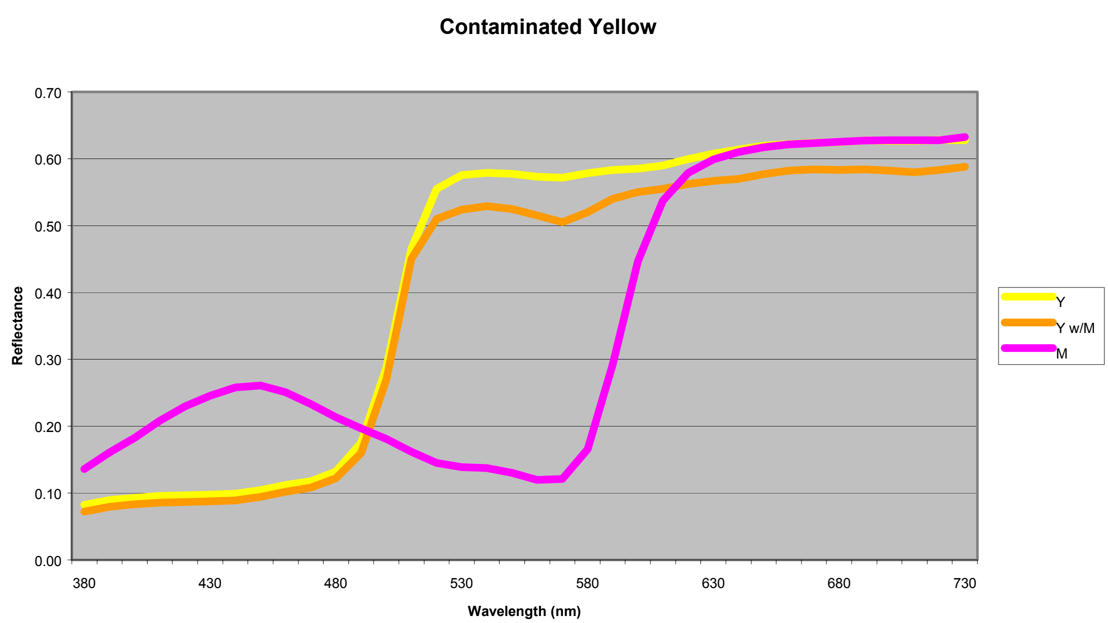

Figure C.2 — Yellow ink contaminated with Magenta

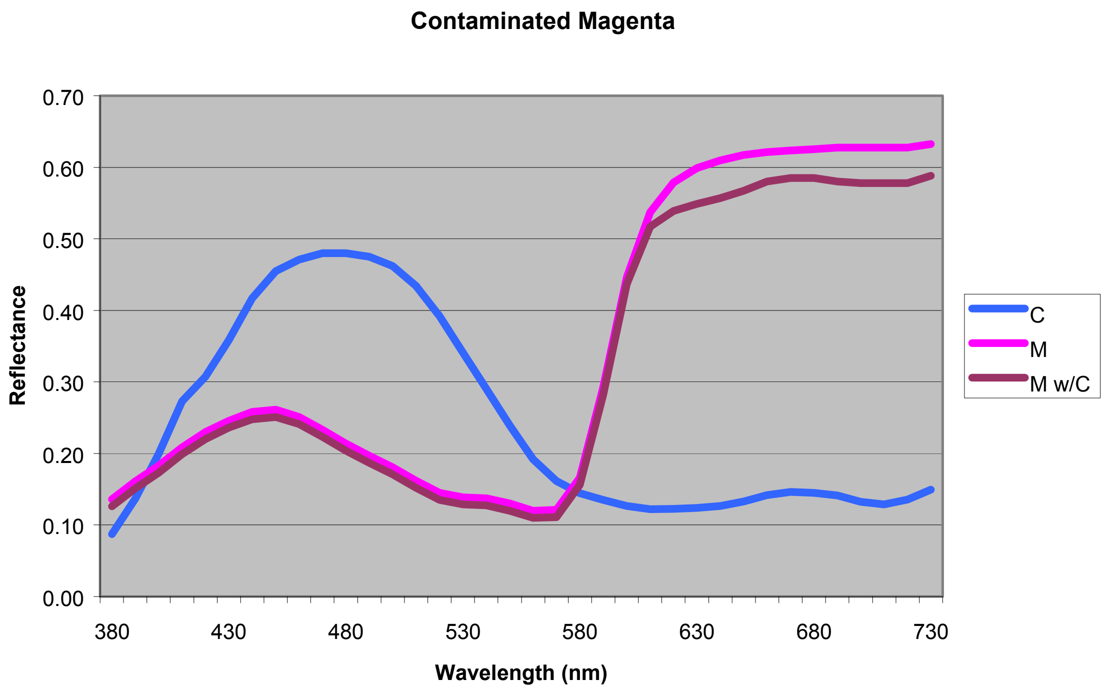

Figure C.3 — Magenta ink contaminated with cyan

C.3 Densitometric evaluation

Although spectrophotometric evaluation is recommended, if a spectrophotometer is not available, an alternate approach is to compare the hue/grayness values of the printed inks to those of the laboratory prints of the inks on the same substrate. A change of more than 2% in the hue and/or grayness indicates a possible problem that should be evaluated using a spectrophotometer. If there is contamination, the hue shifts in the direction of the ink causing the contamination. A higher grayness is an indication of "dirtiness" that comes from contamination.

A representative from the ink manufacturer should be contacted if contamination is suspected.

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