Characterizing an Ink on Paper Four Color Print Process

Richard Fisch* and Sharon Bartels*

Keywords: Characterization, Color, Ink, Paper, Printing, Specifications

Abstract: This paper discusses the use of characterization to describe the colorimetric output of a printing press. Every press is a device dependent entity.

Standards writing groups are considering ink on paper specifications which recognize the synergy between the use of gamut mapping plus raw material selection to produce ink on paper output images that are not restricted by a particular printing process.

To insure proper color management for present and future needs the characterization technique must be understood and standarized.

Introduction

Yesterday, we thought in terms of printing processes. The output from each was unique. Standards, therefore, were specifically written for the Offset, Gravure, and Flexographic processes and not for color gamut and file reproduction. Today, we see print output quality as a continuum. The differences between the individual processes' ouput gamuts is both process and raw material dependent. A series of selectivly placed "referenced" color gamuts and the empty space between them can be defined (Zawacki, 1999).

The synergy between these two seemingly interrelated concepts has the potential to revolutionize the way the industry specifies ink on paper

* Imation Corporation

printing. The synergy allows specifications to be written for a set of referenced color gamuts that are not specific to any particular ink on paper printing process. The term gamut is used to describe the shell, or box that contains all the color combinations that can be rendered by a given set of primary and secondary ink colors. Additionally, in the digital age, image files can be repurposed to provide given tone values. Repurposing the contents of a gamut includes the use of tone value adjustment and/or color management. The synergy promotes printing process independence.

Initial work within the standards community, indicated the possibility that a single specification could be written to encompass most all the various printing processes used. The specification would facilitate, in effect, printing "process independence." The use of ink color strength and selected paper attributes in conjunction with color management permit appearance matching, thus separating image reproduction from a specific printing process.

Discussion

This paper will discuss four topics related to characterizing 4-color printing:

- The use of referenced printing gamuts to specify print output.
- Specific steps to characterize any 4-color printing process.
- Statistically robust methodologies to measure printing lots.
- Current practices.
- Suggestions for improvement.

Referenced Gamut Printing

The referenced gamut concept allows a printer to manipulate ink, substrate and files to produce quality printing divorced from the printing process used. Several ways have been proposed for achieving referenced gamut printing.

The first, is one in which a set of specific referenced outer gamuts is chosen such as a hi-fidelity(HiFi) print process. In this implementation, ink color, substrate and file repurposing, including color management, allow print processes, ink sets or tone manipulation to be used to fill the referenced color spaces. A series of inner gamuts that differ by perhaps 50 units of chroma exist as nested gamuts within the HiFi gamut.

The second is somewhat more restrictive than the first. In this implementation the outer gamut is technique dependent, i.e., gravure printing with high ink solid density and the best of paper. The boundaries of the internal gamuts are determined by ink solid density plus paper selection.

A derivative of both of these uses a series of "nested" color gamuts within a larger gamut like children's nested play boxes. A set of internal gamuts can be individually referenced to the output of widely used printing processes. The nests might represent the quality now produced by newsprint printing (SNAP), web offset publication printing (SWOP), commercial printing (GRACOL), or special quality work such as corporate reports.

The space between nests would be filled by combinations of raw material selection and image file adjustment. Paper quality, ink properties and file manipulation are among the available choices available to any printer. The gap distance between nested gamuts, i.e., between SNAP and SWOP, could be filled by gravure printed on newsprint base with the appropriate file adjustment.

The flexibility of the new technique allows a printer to compete for any print job regardless of the printing process formerly used. Not everyone wants to buy a Cadillac. Pocketbook and budget dictate what consumers buy. A master color gamut restricts the printer's ability to produce a given job for a given price. Maximum gamut could mean minimum choice and box a shop into an economic nightmare. A choice of gamut levels each with a different price allows the printer to sell up or down according to customers needs. The differences between a Chevrolet and Buick offer the consumer a choice at a price. Matching the gamut and tone values to selected referenced gamuts enable printers to effectively use equipment at hand to differentiate themselves from competition. The proper use of this concept can provide a means to improve economic profit. Characterization is central to the implementation of this concept.

Steps of Characterization

There are many things to consider in the characterization process to reduce uncertainty and properly sample the press sheets. Space does not permit a thorough discussion of all points. However, a step-by-step procedure is put forward in the General Procedure below. Elaboration of the Test Plan and Press Run follows the General Procedure.

General Procedure

1. Review the relevant specifications for the printing process to be characterized. These include the standards listed in Appendix A as well as other pertinent ones not presented.
2. Produce a test plan. See Test Plan section below.
3. Assemble and test raw materials.
4. Assemble print test form including IT8 SCID image set and process control print bars. Bars should horizontally flank the press form, SCID images should be between the bars. See Test Plan and Press Run sections below.
5. Check operation of measuring device and calibrate to certified reference material.
6. Check operating condition of press.
7. Start the press.
8 Adjust make ready.
9. Sample press sheets when press temperature and run length indicate press readiness.
10. Measure both sets of press bars. Adjust keys to provide cross press uniformity.
11. Measure YMCK solids and tint values in IT8 basic set to determine correlation to press bar values.
12. Adjust press to improve correlation if possible.
13. Make go-no go decision based on correlation between IT8 values and that of the press bar averages.
14. Release press for production testing.
15. Sample production press sheets at a pre-determined frequency for a given press run size. Follow plant statistician or ASQC sampling plan recommendations to provide statistically significant samples.
16. Measure sheets and store data. Determine colorimetric and density values per sample.

Test Plan

Communication is facilitated by a Test Plan. The Test Plan must contain information concerning these nine points.

1. Precise description of what is being characterized.
2. Specifications and availability of raw materials.
3. Availability of the press, operators and QC individuals.
4. Use of a meaningful device independent test fixture such as IT8.7/3 plus an in-process press control bar.
5. Sampling plan that provides a statistically significant representation of the population being characterized.
6. Measurement device parameters.

7. Uncertainty of measuring device.
8. Uncertainty of the data.
9. Analysis and articulation of the data.

The nine points of the Test Plan are detailed below.
1. A precise description of what is to be characterized is imperative. Is one press or all presses, one shop or several shops, one process or more being characterized? This will help determine the needs for raw materials, sampling plans, etc.

2. Once the description has been written, check availability of raw materials such as ink, paper, fountain solution, etc. Materials should be tested in advance to ensure conformance to specifications. Do not scrimp on supplies. Last minute substitutions can invalidate the characterization.

3. Schedule sufficient press, operator, and QC time to assure proper characterization. Proper press balance is critical and can not be cut short.

4. Precise characterization depends on cross web uniformity. Therefore both the top and bottom of the test form used for press characterization must contain process control bars. Typical suppliers include Gretag, Sigg, RIT, GATF and FOGRA.

In addition, to be ISO compliant and device independent one must use a standard test form either as a digital file or film separations. ISO 12640(Appendix A) includes images designed to be used for characterization purposes commonly called SCID(Standard Colour Image Data) images which include natural images and synthetic images. Synthetic SCID images S7-S10 are grouped together to form a single page 8x10 layout of the cymk data set as defined in ANSI Standard IT8.7/3-1993 (Appendix A) and referred to as the IT8.7/3 target. When film separations of the IT8.7/3 target are used, the films need be individually measured and compared to the numerical values in the IT8 file.

The IT8.7/3 target includes a basic set and an extended set of colors for a total of 928 measurable patches. The basic set includes one and two color overprinted solids, halftone tint scales and selected two, three and four color overprint patches. The extended color set includes a series of grids of 3 and 4 color overprints. Data from the IT8.7/3 target is used to produce characterizations and verify color output.

5. The accuracy and precision of the characterization are affected by the sample size and frequency. It is important to obtain a statistically significant sample. Some knowledge of statistics is necessary to ensure that statistically significant samples are chosen. The QA person in charge of plant operations must define the sample size and analyze the data obtained. During press runs, samples should be taken to insure that a statistically signifiant sampling is obtained. Best practices, including those of GATF, use the ANSI/ASQC Z1.4(1981), a.k.a. Military Standard 105D Sampling Tables to determine sampling procedure and sample size (Juran, 1988) (Prince, 1999).

6. Densitometric and spectrophotometric measurements are made using appropriate specifications. ISO 5/3-1984 and CGATS.4-1993 specifies filtration for densitometers. ISO 13655-1996 and CGATS.5-1993 specify the measurement protocol and computations using CIE Lab 1976. Measurement is discussed in more detail in the methodology section of this paper.

7. An understanding of the uncertainty attributed to the measuring device is critical when setting aimpoints and tolerances during the characterization process. This issue is addressed in a soon to be released ANSI/CGATS.11-199x.

8. There is always a degree of uncertainty when one collects data. No two presses in the same shop are the same. No two press runs are identical even on the same press using the same raw materials. The level of precision and accuracy of the data derived is a function of the sampling plan and the uncertainty of the measuring device. Recognition and control of the process helps minimize the combined uncertainty. To some degree the sampling practice can reduce uncertainty.

A large contributor to uncertainty is additivity failure of overprints. Colors produced by printing two to four overlaying process color inks are called overprints. Overprint image color is affected by the uncertainty contributed by both the raw materials used and aspects of press operation. Largely this includes, but is not limited to, the ability of one color layer to fully adhere to previous layers (additivity) as well as substrate properties. To avoid moiré each color of a four color image is laid down using a different screen angle. A portion of the color may go down on paper and another portion applied directly to a previous ink layer. When the ink solid densities do not add up , additivity failure occurs.

Three color overprints are most sensitive to additivity failure. Specifiers and print buyers tend to accept the final ink on paper image on the basis of overprint color. Bruno (1986) says "...the overprint colors are more significant in color reproduction than the actual colors used for printing since most of the picture consists of mixtures or overprints of the colors rather than the pure colors themselves."

There is no knob on a press to correct overprint color rendition and consistency. Overprints change within a run, between runs, and between presses(Dolezalek, 1994). Because of the variability of overprint reproduction, the values obtained from measuring the latest SWOP Certified Press Run could be used as a realistic target for SWOP printing. This is especially important if a visual match is used to confirm compliance to the pictures in the SCID (Standard Image Color Data) image suite.

9. Systems that are considered characterized contain measured values traceable to agreed on specifications determined by accredited international and national organizations. The use of data and techniques from drafts, revisions, expired standards or non-accredited documents are not acceptable except where no blessed standards are available. Shop preferred mixtures of proprietary and open standard techniques and metrics are not permissible. Nothing, however, prevents a shop from deriving a proprietary technique, calculation procedure, and company dependent characterization for internal purposes. Revelant standards documents are found in Appendix A. Terms and descriptions used to quantify color difference also contribute to uncertainty. This topic is discussed in the Methodology section of this paper.

Press Run

The press run used to produce the characterization must be in control. An unbalanced press will not produce valid results. A balanced press is determined by the use of press control bars and the characterization target itself.

The IT8 7/3 ISO 12640 must be used in combination with process control printing bars. Place print bars on both sides of the web or the horizontal portion of press sheets. During process control, measurements from both print bars must be within the specifications of the printing process used. When these conditions are met, measure the patches in the basic color set of the IT8.7/3 target. If measurements from selected color patches

agree with those of the press bars the form is balanced and the press run is in control. This is an important item. The resultant characterization is made using the IT8.7/3 target. If it differs from the press bars, the characterization is flawed.

During makeready one should:

1. Check top and bottom press bars and bring them within process specifications.
2. Rebalance the press and discard accumulated samples if a comparative density check of both sets of bars indicates that they do not match.
3. Retest the press bars. If still different, abort test efforts until cause of difficulty is found and corrected. If they are within specifications they must be averaged and stored.
4. Measure YMCK solids and tints in the IT8.7/3 target. More than one press sheet must be used and they should not be consecutive sheets.
5. Average the measurements from the press bars and IT8.7/3. The average must be within specifications of the particular printing process being characterized.
6. Adjust ink keys on press if needed to bring within specifications.
7. Abort characterization process if the press cannot be brought into specification according to above procedure.

Methodologies

Color Assessment

MacAdam discovered that in many cases where measurements using CIE 1931 predicted a color match between the samples, they appeared visually different (Wyszecki and Styles, 1982). MacAdam(1942) and others proved CIE color space was not truly uniform. Two attempts to produce a uniform space were made in 1976 resulting in CIE Lab and CIE Luv. The graphic arts industry has embraced the use of CIE Lab 1976. However Rich and Billmeyer have proven that it is not uniform (MacAdam, 1942) (Rich and Billmeyer, 1979).

The term JND (just noticeable difference) gained universal acceptance and is generally thought to be equal to one deltaE. Wyszecki (1982) did not agree and wrote, "Wright's (1941) data constitute the main body of experimental evidence collected on just-noticeable chromaticity differences. The color-matching ellipses of MacAdam (1942), Brown and MacAdam (1949), Brown (1951, 1952a,b, 1975), and Wyszecki and Fiedler (1971) are often considered to be directly related to just-noticeable chromaticity differences, but strictly speaking, the color-

matching ellipses are standard deviations derived from repeated complete color matches and not just-noticeable chromaticity differences."

Unfortunately, few recognize the nature of the MacAdam experiments which last produced the values incorporated as the CIE Standard Observer. Three-color matching experiments of MacAdam etal. were done under viewing conditions using targets very different from those used for judging graphic arts images. The viewed field in graphic arts subtends a greater angle than that in the color matching experiments. The color matching work used a back illuminated, nested circular bipartite field in which additive color (RGB) was used as the color stimulus. The color stimulus was bandwidth limited artificial light viewed in a darkened room. However, graphic arts images are larger than those used in the bipartite experiments. In addition, ink on paper graphic arts color images are produced by subtractive color mixing composed of a mixture of broad band reflective colorants.

Recognizing that observers place a different weighting on the attributes of lightness, chroma and hue when judging color differences, the British Textile Industry introduced the CMC color difference formula (Clark, 1984). Work on determining new weighting factors were initiated and resulted in CIE 131-1998.

Color Measurement

Characterization data must be device independent. The measured values should be traceable, without additional comment concerning which machine or device is used.

Densitometer values are device dependent. None of the densitometer filter sets match the visual response of the CIE Standard Observer. Standards do exist for three different RGB densitometer filter sets. Status E is used by those adhering to European process control standards. Status T is used by those adhering to US process control standards. The third filter set, is called either Status I or DIN NB(narrow band) and used for situations when narrow bandpass (10nm) are necessary.

Video cameras are being used for measuring printed color images. The color separation filters used in video cameras can be either additive RGB plus an additional green or subtractive yellow, cyan and white from which RGB is interpolated. In either case the filter response is not

matched to the spectral characteristics of printing inks and are device dependent.

The values associated with output of the measurement device must be traceable to national or international standards. The uncertainty connected with the data collection device must be available. The uncertainty of measurement values is addressed in ISO/FDIS 12645:1998(E), "Graphic technology - Process control - Certified reference material for opaque area calibration of transmission densitometers."

The values obtained are technique dependent as well. Improvisation, for example, the use of another CIE Standard Observer, print viewing condition, or backing material in place of the standard condition is not acceptable.

ISO and CIE color measurement standards specify black paper be used under printed sheets measured by optical means (densitometry and spectrophotometry). When a thin paper stock, is printed on both sides, optical measurements made on one side of the sheet will be influenced by the image printed on the other side. Using black sheeting under the stock being measured eliminates the difficulty. Measurements obtained with white backing cannot use black backing aim points.

Statistics

The arithmetic mean is the most generally used measure in quality control work, for example; average size, average yield, average percentage of defective, etc. The arithmetic mean, aka the average, is used for symmetrical or near symmetrical distributions, or for distributions that lack a clearly dominant single peak.

Good statistical practice dictates the data being studied must be checked to assure it is distributed normal, that is, equally distributed forming a bell shaped curve around the arithmetic mean. Central tendency describes one type of data distribution in which most of the data is distributed equally on either side of the Arithmetic Mean.

If the distribution of the data around the central tendency is normal, conclusions can be derived from the data. The term sigma, describes differences in data distribution between the average value and portions on the normal distribution. The mathematical definition of sigma may be applied to any data set, but it is only accurate in the determination of probability when the data is normally distributed. Therefore, the

term sigma can be used to express differences between skewed population if no attempt is made to draw conclusions related to normality, a standard distribution.

The graph in Figure 1 TR001 , "A Histogram of the Distribution of deltaE Values" indicates a skewed distribution of deltaE values obtained from the data collected for CGATS.6 Type 1 Printing. Generally sigma is applied to normal distributions. However, sigma can be used on the skewed distribution if one applies some restraints. The most important restraint is that normal statistics cannot be used to describe it. Rank order and cumulative summation techniques are allowed. The parameter of choice may be a Chi Square distribution. "The statistics of color distances from the center of production (the mean) is not gaussian. Gross errors may result especially in the one- and two- dimensional cases if gaussian statistic formulae are used for calculating confidence intervals or the probability of values well beyond the median value." (Dolezalek 1994)

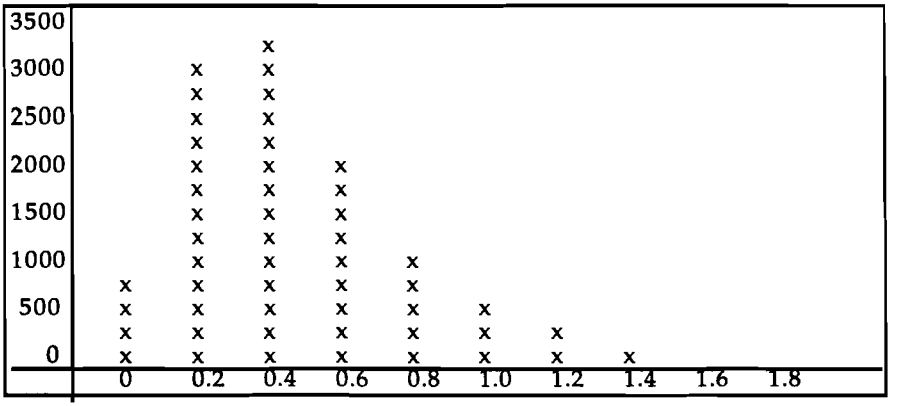

Figure 1. A Histogram of the Distribution of deltaE Values

Current Practices

This section will discuss commonly used targets, specifications, images, and standards. In some instances these are standards. In others, they are de-facto standards. Current practices become entrenched eventhough difficulties may exist. This paper will discuss the following practices. Suggestions for improving them are given in the last section of this paper.

- Certification Process - SWOP
- Aimpoints and Tolerances - TR001

- Uncertainty - ISO 12647-2
- Standard Images - SCID(Standard Color Image Data of ISO 12640)

- Certification Process - SWOP Current Practices

Industry brands are the creation of independent industry associations. The brand name is promoted by the association to denote the product made used a process that insures specified acceptance. One such brand is SWOP® (Specification Web Offset Publication). Trade shops or printers who meet the specifications use the SWOP® brand name and gain the marketing value it provides. Initially the specification disseminated best practices information but recently The SWOP specification has been incorporated in ANSI/CGATS.6 and ISO 12647-2 standards and include more precise information.

The integrity of an industry brand is strongly correlated with the integrity of enforcement. The SWOP specification is widely enforced by print specifiers and advertising agencies for advertisements placed in periodic publications. To their credit, SWOP was the first to formally characterize their print process. Printed copies of the specification can be obtained from SWOP, Inc.

Three SWOP press runs have been done to date. SWOP Press Run 1 was made in 1993 and eventually resulted in the TR001 report. SWOP Press Run 2 was made in 1995 and certified sheets are sold to customers. The latest press run was recently completed in 1999 and will be released for sale.

In mid 1993, the SWOP Committee printed a single lot of that included the following two test images.

-GATF (Graphic Arts Technical Foundation) print process control bars
-ISO 12640 a.k.a. IT8.7/3, Input data for characterization of 4 color printing

Pre selected sheets (8, 9, 10, 12, 14 and 16) from the 1993 press run were sent to three off-press proof vendors as well as two vendors of portable spectrophotometers for measurement. These sheets have been recognized by SWOP as being in compliance with their set of written specifications. The data was compiled and published in ANSI/CGATS.6 TR001.

After characterizing ANSI CGATS.6 Type 1 Printing, the remaining press sheets from Press Run 1 were sold individually, incorporated into SWOP® Calibration Kits, or discarded. The SWOP® Calibration Kit consists of halftone separation films and a "Certified Press Sheet".

SWOP Certified Press Sheets are a product. The individual sheets in a press run of Certified Press Sheets are discrete units which collectively constitute a "lot" (Juran, 1974). Lot acceptance is dependent on agreed upon measurements that adequately describe the product. In the case where the press sheet is used only as a visual reference, a lot acceptance is sufficient. In those cases where a discrete sheet is used as a visual reference to a pooled numerical lot characterization such as TR001, problems can occur.

Juran (1974) uses the term certification as a form of product assurance centered around a formal test method and signed certificate. In the case of SWOP the product is certified as conforming to SWOP specifications. Currently the dated SWOP Certified Press Sheet or package, as delivered, does not include test data.

- Aimpoints and Tolerances - TR001 Current Practices

In the United States the cooperating official standards writer is CGATS, the ANSI Committee for Graphic Arts Technologies Standards. ANSI/CGATS.6 is widely used as an example of a characterization process. SWOP Inc. is not an officially recognized standards making authority such as ANSI. However the SWOP specification was, with negotiation, incorporated into a national and then an international standard document. The official designation for the specification for offset printing for publications is ANSI CGATS.6 Type 1 Printing. Halftone 133 line per inch hard dot separation films were produced from the ISO SCID image file for this purpose. The use of a 133 line screen ruling is predicated on its presence in the SWOP specification.

ANSI CGATS TR 001-1995 documents the data collection procedure for SWOP Certified Press Run 1. Colorimetric data from the IT8.7/3 target is also included in TR001. As stated in the TR001 document "This document is not an American National Standard and the material contained herein is not normative in nature." In ISO language that statement tells the reader that the information included is not a standard and is only incorporated to educate and inform.

Many who desire to make color management profiles or determine adherence to SWOP specifications are now directed to TR001 for standardized aim points. As seen in Figure 1, the distribution of deltaE values obtained from SWOP Run 1 is not a normal distribution. Although sigma can be used to describe data that is not normally

distributed, the probability statistics related to a normal distribution cannot be applied. Several alternative techniques for obviating the normal distribution aspects when using sigma for a non normally distributed population used a Chi Square distribution. (Dolezalek, 1994) (Rickmers and Todd, 1967).

A technique referred to as the Donnelley Initiative recognizes the use of the IT8.7/3 Extended Color Set to study color differences produced by additivity law failure. R.R.Donnelley chose to use Percent Cumulative Sum versus deltaE as a means of defining, displaying and quantifying overprint color differences from the TR001 aimpoints.

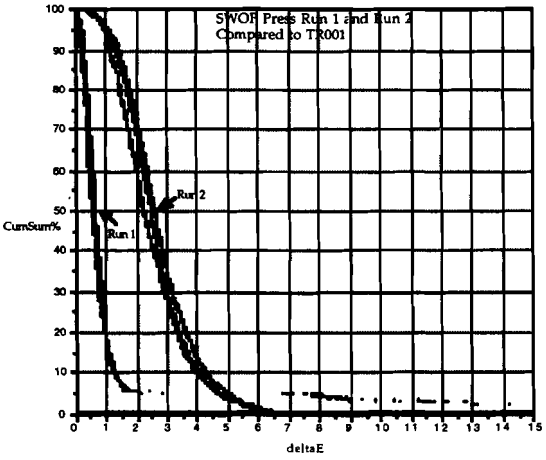

Figure 2. CumSum% graph of SWOP Run1 and Run2

Figure 2 illustrates the use of CumSum% to compare the color difference of overprints between SWOP Certified Press Runs 1 and 2. For all 928 patches of the IT8.7/3 target, deltaE was computed as compared to the TR001 values. The Run 1 sheets were those measured as part of the CGATS study that made up the TR001 values. Fifty percent of the 928 patches for Run 1 sheets are within 0.5% deltaE of TR001 (In other words, the actual measurements for one site versus the average). The 0.5% deltaE could be thought of as the tolerance for measurement uncertainty. The second set of curves is the deltaE values obtained by comparing random Run2 press sheets with TR001. Fifty percent of the patches fall within 2.5% deltaE of TR001. Additional applications of this technique can be found in "A Colorimetric Test for Reflection

CMYK Colorant Output" by Bartels and Fisch in this volume, 1999 TAGA Proceedings.

A form of standard deviation which does not require the data to be distributed normally such as Chi Squared distribution, probability function or CumSum% must be used to specify achievable tolerances. A statement in the update to SWOP booklet, Eighth Edition entitled "Digital Specifications and Requirements" includes the statement that "Output device calibration procedures should be used where available from the manufacturer. When color management is employed, the characterization data in ANSI CGATS TR001 must be used as the aim point." An aim point without tolerances is misleading and TR001 does not include tolerances.

- Uncertainty - TR001 Current Practices

The effort to standardize offset printing was undertaken by the ISO/TC 130 as part of a series documenting process control for the various ink on paper printing processes. Specifications for screen ink, gravure, and flexographic printing are in process. The physical and colorimetric properties of ink set for offset printing was specified by ISO 2846-1, Unlike ANSI Type 1 Printing, which was focused specifically on Publication Printing and therefore used Textweb as its preferred substrate, the ISO effort encompassed almost all ink on paper printing. This effort used five different paper substrates. The values encompassed in ISO are applicable to almost all offset printing, including that for commercial printing. The ink set used was ISO 2846-1, the same ink set used for ANSI Type 1 printing.

Since the ISO is international, several countries participated in this effort. Characterizations were performed in at least three independent countries, US, Japan and Germany. The same ISO IT8.7/3 test fixture, ink set and measurement protocol was used by all participating countries. The parameters detailed in ISO 12647 included colorimetry of ink solid densities as well as dot gain. In this ISO standard, Type 3 paper has the same specifications as Champion Textweb. Data was obtained using, in large part, the same equipment as used for ANSI Type 1 printing. Both efforts used TC42 5/2 and 3.

The US contribution to this standard was largely the same data from the same process run made to characterize SWOP. Standards to specify instrument geometry and filtration were used. Density values are reported for Status T, Status E, and Status I (with and without polarization) filtration.

Measurements were made on the full IT8.7/3 target. Data from individual countries' IT8 results or pooled results from all participating countries have not been published. The ISO Type 3 data set is a larger pool of data from which one can draw information concerning time, location, preparation, press and overprint variability.

- Standard Images - SCID Current Practices

The SCID images are a collection of both pictorial and synthetic test images. The pictorial images were contributed by many involved in the construction of the SWOP Certified Press Sheet form. The pictorial SCID images were scanned in Japan and the form compiled there as well. Unfortunately an arbitrary gray balance was chosen for these images. The printed SCID images used for the characterization of ANSI CGATS.6 Type 1 Printing therefore exhibit a biased, cold, color balance. The synthetic image IT8.7/3 is defined in terms of CMYK color patches and therefore not subject to gray balance issues of separation techniques and color correction.

Suggestions for Improvement

This section of the paper suggests improvements for the current practices discussed in the previous section. Again, these practices are:

- Certification Process - SWOP
- Aimpoints and Tolerances - TR001
- Uncertainty - TR001
- Standard Images - SCID(Standard Color Image Data of ISO 12640)

- Certification Process - SWOP Suggestions for Improvement

A disclaimer should be included in the package containing a "Certified Press Sheet". Because the TR001 overprints from each lot of certified press sheets made to date differ, the certification process as now practiced is flawed. Only the press bars are measured when qualifying a sample sheet from a certified lot for customer distribution. Certification then only applies to press bar results not the IT8.7/3 images or practicals in the test form.

SWOP should consider offering colorimetric data from the specific press sheet IT8.7/3 target included in the SWOP® Calibration Kit. Those making profiles would appreciate having a visual, pictorial image as a reference. This would provide characterization data as well as a visual reference for profiling.

In future SWOP press runs, follow the proposed make-ready procedure in the Characterization Steps section of this paper. Both top and bottom bars must be balanced. Once balanced the revelant color patches in the IT8 Basic Color Set patches must be brought into compliance with the process specifications. The bars should be rechecked. Cross web balance must be assured. Basic Color Set values are to be given priority over in-process color bar values. If the IT8 Basic Set does not perform to process specifications the press run shall be aborted.

- Aimpoints and Tolerances - TR001 Suggestions for Improvement

SWOP must decide what the overprint aim point values should be. The aim point may be the "most recent run" or the pooled data set. SWOP should provide by website the IT8.7/3 colorimetric pooled data set as well as the data values from Runs 1,2 and 3. However, no practical images are associated with pooled data.

- Uncertainty - TR001 Suggestions for Improvement

Combine the data from ISO 12647-2 with CGATS.6 to expand the data pool, reduce uncertainty, and increase aim point confidence for SWOP printing characterization. Additional information concerning.

Additional data concerning overprint reproduction, the effect of presses, press crews, and raw material lots exists in the data collected from the press runs made for ISO 12647. The specifications for the Type 3 paper within ISO 12647 is identical to that of Textweb used in SWOP. The ISO 12640 SCID images used for the ISO tests are identical to those used for ANSI/CGATS.6. A new report including the pooled data would be of value to all involved in digital color printing.

The data in ANSI/CGATS.6 TR001 is a small subset of the ISO data. Further sampling of the remaining SWOP Run 2 press sheets would only contaminate the existing data pool because ink on paper images and Textweb base change with time.

- Standard Images - SCID Suggestions for Improvement

The color balance of the SCID pictorial images should be adjusted to be more neutral. An additional SCID synthetic image should be made that has a black printer scale and an extended neutral equivalent gray scale representing a SWOP gray balance.

Literature Cited

Bartels, S.A., and Fisch, R.S.
1999 "A Colorimetric Test for Reflection CMYK Output," TAGA Proceedings 1999.

Bruno, M.H.
1986 "Principles of Color Proofing" (GAMA Communications, Salem,NH) pp. 71.

CIE (Commission Internationale del'Eclairage)
1998 CIE 131-1998, The CIE 1997 Interim Coloour Appearance Model (Simple Version), CIECAM97s

Clark R. et.al.
1984 "Modification of the JPC difference formula," J. Soc. Dyers and Colorists, vol. 100, pp. 128-132.

Dolezalek, F.K.
1994 "Appraisal of Production Run Fluctuations From Color Measurements in the Image,"TAGA Proceedings 1994, pp. 154-165.

Juran, J.M.
1974 "Quality Control Handbook" (McGraw-Hill, Inc.), 3rd ed., Sec 12, Inspection and Test.

1988 "Juran's Quality Control Handbook"(McGraw-Hill, Inc.), 4th ed., Sec 25, Acceptance Sampling.

Prince, R.
1999 Private Communication.

MacAdam
1942 J. Optical Society of America, vol. 32, pp. 247-274.

1943 J. Optical Society of America, vol. 33, pp. 18-26.

Rich D. and Billmeyer F.W.
1979 J. Coating Technology, vol. 52 Numer 650, pp. 45-47.

Rickmers, A.D. and Todd, H.N.
1967 "Statistics an Introduction" (McGraw-Hill, Inc.), Chap 5, Statisitcal inferences about vaiability, pp. 108-120.

SWOP® Inc.
1986 "Specification Web Offset Publications" (SWOP Incorporated, 60 East 42nd Street, Suite 721, New York, NY, 10165), 8th ed.

Wyszecki, G. and Stiles, W.S.
1982 "Color Science" (John Wiley & Sons, Inc.), 2nd ed., pp. 575.

Zawacki, W.F. and Steele, L.C.
1999 "Color Characterization of Various Ink, Substrate and Printing Process Combinations," TAGA Proceedings.

Appendix A - Standards

A combination of standards produced from approved standards writing associations provided the means to define a device independent metric for measuring graphic arts color appearance. The standards groups included the CIE(TC42, Photography), ANSI/CGATS and ISO/TC130, Graphic Technology. Some of the pertinent standards are listed below.

ISO 12640:1998	Graphic technology-Prepress digital data exchange-Standard colour image data (SCID)
ISO 12645:1998	Graphic technology-Process control-Certified reference material for opaque area calibration of transmission densitometers
ISO 13655:1996	Graphic technology-Spectral measurement and colorimetric computation for graphic arts images
ISO 3664:1998	Viewing conditions-for graphic technology and photography
ISO 5/3-1984	Photography(Sensitometry)-Density Measurements-Spectral Conditions
ANSI® CGATS.4-1993	Graphic technology-Graphic arts reflection densitometry measurements-Terminology, equations, image elements and procedures
ANSI® CGATS.5-1993	Graphic technology-Spectral measurement and colorimetric computation for graphic arts images
ANSI® CGATS.6-1995	Graphic technology-Specifications for graphic arts printing - Type 1
ANSI® CGATS.11-199x	Graphic technology-Certified reference materials for reflection and transmission metrology-Documentation requirements and recommended procedures
ANSI® CGATS TR001-1995	Graphic technology - Color Characterization Data for Type 1 Printing
ANSI® IT8.7/3-1993	Graphic technology - Input data for characterization of 4-color process printing