DATABASE OF DENSITOMETRIC DATA

Anthony P. Stanton*
John P. Sweeney**

ABSTRACT

This paper presents a proposed structure for a database of print attributes for the graphic arts industry. The need for the database and its potential uses are given. The hardware and software requirements are explained. The administration and access to the database are examined.

INTRODUCTION

There is a growing need in the graphic arts industry for an industry-wide public domain database of print attributes. This need is founded on several factors. The use of color reproduction continues to increase, and a more diversified group of printed products are utilizing color. However, color reproduction requires a more thorough knowledge of the printing process than monochrome reproduction since color images consist of four carefully balanced halftone images. The tone reproduction and trapping characteristics of each of the primary ink colors must be known.

---

* Graphic Arts Technical Foundation
** X-Rite Corporation

The quality expectations of customers are increasing. The printing process needs to be in good control to meet these heightened expectations. Customers are frequently participating in press-side color approvals during the makeready process. The approval process is shortened when the first makeready sheet is representative of good printing conditions.

The costs of materials and labor are rising, and thus, the printer is under pressure to reduce waste and increase productivity. Furthermore, the expense and difficulty of disposing of waste materials from the printing plant has increased dramatically. This factor further pressures the printer to have the printing process in good control. An accurate knowledge of the printing characteristics of a press system is necessary to reducing waste in that system.

The graphic arts industry is widely segmented; frequently, color separations are made outside of the printing plant. Often a single image is printed at multiple sites. There is increasing use of data transmission via satellite and other nontraditional delivery systems. Therefore, there is greater need for compatibility of printing conditions at various plants. In order to gain the needed compatibility, print attributes must be measured and brought into compliance with standard or specified values.

The activities of graphic arts standards committees has steadily been increasing. The Committee for Graphic Arts Technology Standards (CGATS) has been granted accreditation by the American National Standards Institute (ANSI). The first digital data exchange standards (DDES) for the graphic arts have been adopted by ANSI (IT8.1 - 1988). Specification committees are providing recommendations for the preparation of color advertising materials for publication by heatset web offset (Specifications for Web Offset Publications, SWOP) or by nonheatset web offset (Specifications for Non-heat Advertising Printing, SNAP). Both the SWOP and the SNAP specifications contain target values for selected print attributes within their industry segments. Souter (1989) reported on the

activities of an industry committee, the Gravure Association of America (GAA)/SWOP Task Force, in its efforts to develop colorimetric specifications for SWOP and Group VI proofing and production inks.

There is increasing activity in the area of international standards and specifications. The International Standards Organization (ISO) has issued graphic arts standards that are widely adhered to in Europe. The International Federation of the Periodical Press (FIPP) has published specifications (FIPP, 1984) for the preparation of advertising materials for heatset web offset magazine printing. The FIPP committee is comprised of 23 member associations representing 31 countries. In the introduction to the 1984 FIPP Specifications the authors acknowledge the success of the SWOP specifications in the United States. The various activities taking place in setting international standards reflects the growing need to have compatibility among the printing conditions worldwide. This requires that the print attributes be known and communicated to all involved parties.

The use of statistical process control (SPC) in printing companies is on the rise. The implementation of SPC requires knowledge of the printing characteristics of the process. SPC techniques demand that printers form a database of the measurements taken during the production cycle. Traditionally, density measurements made at press-side have not been recorded. When a database is formed, trend analysis techniques can be used to examine cyclical anomalies in the data. An international database would take advantage of the growing trend toward recording data, and it would further the possibilities for analysis based on the composite data.

These and other factors combine to form a climate wherein graphic arts professionals are striving to better understand, and more accurately characterize, the printing process. Their efforts are complicated by the fact that the print attributes of a given printing system are restricted to that system. The printing system encompasses the equipment and materials that are employed for a

given job. The press, plates, blankets, paper, inks, dampening solution, and even press crew all affect the characteristics of the printing system. Jorgensen and Lavi (1969) have identified 71 factors that can affect print quality on a lithographic press. It is difficult, therefore, to establish a valid print characteristic profile for even a single press, let alone an entire industry segment. It is helpful to be consistent in the consumable materials that are used in a printing system, but the printing process still relies on minor corrective adjustments by skilled press operators during makeready to obtain optimum results.

PAST ACTIVITIES

Traditionally, the measurement of print attributes has been performed by individual printers striving to improve their quality and competitiveness. The data collected under these conditions has not been available to the public. Researchers have also made measurements of print attributes to support a particular study. In these situations, the data collected is determined by the hypothesis of the study. An example can be seen in Jorgensen's (1977) study of black-and-white tone reproduction, where only attributes necessary for the study were measured. In many cases, data collected for individual studies is not applicable to other printing conditions. The poor interinstrument agreement of densitometers has also deterred the interchange of measured print attributes.

Attempts to characterize the print attributes of broader segments of the graphic arts have been made by suppliers and trade associations. DuPont, for example, has combined data from large samples of printing companies and calculated average printing conditions for product development purposes. The **North American Print Survey** (Muirhead and others, 1985) measured the print attributes of heatset web offset printing, and the **North American Commercial Print Survey** (1988) focused on sheetfed printing conditions.

The Print Properties Committee of the Graphic Communications Association (GCA) has made an extensive study of the printing characteristics of heatset web offset for the magazine publications industry. Scharpf (1983, 1984) reported on this study. The voluminous data generated by the Print Properties Committee has been used by the SWOP Committee in producing the 1986 revision of the **SWOP Specifications**. The SNAP Committee performed a study (Stanton, 1987) of the characteristics of nonheatset web offset printing. The 1988 revision of the **SNAP Specifications** incorporates the data from this study.

For a variety of reasons, the data collected by these groups is not widely available to individuals doing research in the graphic arts. There is no central location acting as a repository for the data, so the individual researcher encounters difficulty in attempting to access the results of various studies of print attributes. The data is not often in easily accessible form. Much of it is not resident in computer databases. Some of the groups that have collected the data are hesitant or unwilling to share their findings with potential competitors. The data is flawed in many cases. The complex mechanical and chemical interactions occurring during the lithographic process lead to a host of uncontrolled conditions that taint the data. Measurements of print attributes have been made with densitometers with a variety of spectral response characteristics. The poor interinstrument agreement of densitometers has prevented the comparison and combination of various data sets.

This paper proposes the formation of an industry-wide database of print attributes to be administered by the Graphic Arts Technical Foundation (GATF). The database will be used by researchers, printers, suppliers, and graphic arts educators. Specification groups, such as SWOP and SNAP, and standards committees, like CGATS and IT8, could benefit from the proposed database. The newly formed SPC User's Group at GATF is another potential benefactor from the existence of a print attributes database. GATF, a nonprofit technical

foundation, is ideally suited for a repository for an international database.

The advent of a standard spectral response for graphic arts densitometry, ANSI Status-T (1984), has led to a higher degree of interinstrument agreement between densitometers. The standard calibration reference, T-Ref, further improves the confidence that densitometers will agree. It has, thus, become feasible to make density readings in a variety of different locations, with instruments of different manufacturers, and to treat the readings as a single population from the perspective of spectral response.

The interface of densitometers with personal computers is easily accomplished today. This speeds the acquisition of data and provides a convenient medium for transferring that data into a central database. Also, the development of new software programs, like Hyper Card, allow for flexible sorting of the information in a database. This is of particular importance for a database of print attributes that encompasses more than one type of printing.

STRUCTURE OF THE DATABASE

The proposed database would initially reside in a personal computer at GATF. Enhancements, such as additional memory or a more powerful computer, could be added as the size of the database grew. The database management program would allow for flexible sorting of the data and for selected mathematical and statistical manipulations.

Data input would be accomplished with the aid of an interactive data entry program, which would be distributed to participating printers. The data entry program (accessible from DOS) would be made available on 3.50-in. or 5.25-in. floppy disks. It would prompt the user through a series of responses and store the information for transfer to the database. Information transfer could also be accomplished by modem (300- or 1200-baud). The software will allow for direct entry of density readings via RS-232. Direct interface between the

densitometer and the computer will greatly speed data entry and will eliminate transcription errors, although measurement errors may still occur due to misalignment of the reading head of the densitometer.

The program would contain three sections: General Information, Printing Materials, and Densitometric Data. Appendix A outlines the information that would be solicited from the participants in the data entry program. The General Information section would gather facts about the printing plant, job description, printing process, press, densitometer, and the measuring target. The Printing Materials segment gathers information concerning the substrate, inks, dampening solution, printing plates, and blankets. This information would be used to access a particular sub-population of the data. For example, a researcher could examine the print attributes recorded for 40-in. six-color sheetfed presses printing on 100-lb. coated stock with compressible blankets. In the early stages the database would not have a sufficient sample size to provide valid data for such a specific request, but validity would be gained as the sample size of contributing companies increased.

In the Densitometric Data section, the user would enter the densities of solids and tints from the color bar. The paper densities are also recorded. The readings from all four densitometer filters are retained. Input is made from the single-color and two-color overprints at four levels -- 1/4-tone, mid-tone, 3/4-tone, and solids -- if the appropriate patches are available on the color bar.

PRINT ATTRIBUTES

The program would initially be restricted to the following print attributes:

Density -- the densities of all inks colors with or without paper

Dot Gain -- using both the Murray-Davies and the Yule-Nielson equation, at three levels, 1/4-tone, mid-tone, and 3/4-tone

Ink Trapping -- using the Preucil, Brunner, or Hamilton formulas for red, green, and blue overprints

Print Contrast -- between the 3/4-tone tints and solid ink coverage

Hue Error, Grayness, and Saturation -- of cyan, magenta, yellow, and of the two-color overprints red, green, and blue

The Data Entry Program would report the calculated print attributes to the participant at the time of data entry. In addition, the mean, range, and standard deviation of the measured samples would be given.

HARDWARE REQUIREMENTS

A printer would need two pieces of equipment in order to participate in the database.

1. An IBM PC or compatible computer, with MS DOS operation system, and either 3.50-in. or 5.25-in. disk drive. A serial interface (RS-232) is recommended as it will allow for direct data entry. This will avoid transcription errors and yield significant time savings.

2. A color reflection densitometer, with Status-T response conforming to ANSI 2.18 - 1984. Since data from all four filters is required for each measurement, it is most convenient to use an instrument that measures through all filters simultaneously. An instrument with an RS-232 serial interface is needed for direct entry of measurements to the personal computer.

It is recommended that the densitometer compliance with Status-T be verified with a GCA T-Ref, a standard color reference available from the Graphic Communications Association.

TEST TARGET

Participating printers will need to print a color control bar appropriate to their printing process. The screen ruling of the color bar should be the same as the production screen ruling. Color control bars of any manufacturer can be used.

Initially, the Densitometric Data section of the interactive program would allow for the input of readings from the following measurement patches of a color bar:

one-color solids
two-color solids
one-color 1/4-tone tints
two-color 1/4-tone tints
one-color mid-tone tints
two-color mid-tone tints
one-color 3/4-tone tints
two-color 3/4-tone tints

The GATF/SWOP Proofing Bar, a 133-line/in. color bar designed for press-proofing color separations made for web offset publications, contains all of the necessary elements to complete the information requested in the Densitometric Data section of the interactive program for four-color printing. The GATF Six-Color Control Bar (150-lines/in.) provides all of the needed targets with the exception of the 1/4-tone and 3/4-tone overprints for six ink colors. This color bar would be a good choice for commercial sheetfed printers. If a color bar that does not contain all of the needed target values is used, the database will ignore the missing data while retaining the available data.

FUTURE DEVELOPMENT

The database would be modeled on a modular concept to allow for the creation of new categories of print attributes, graphic arts processes, and measuring techniques. For example, the Data Entry Program could be expanded to incorporate measurements from the remaining elements of the GATF/SWOP Proofing Bar. These include three- and four-color

overprints of solids and 25%, 50%, and 75% tints; a 300% four-color patch, and 25%, 50%, and 75% levels of three-color gray patches.

Initially, the database would be limited to densitometric measurements. The expansion to accommodate colorimetric data (in C.I.E. L*a*b* space) would be a natural extension of the database. It is conceivable that spectrophotometric data would be input into the database although this would require more memory than is currently practical.

More complete statistical analyses could be performed from the data by enhancing the statistics capability of the database program, or by exporting the data to an existing statistics program such as Custom/QC (Holmes, 1988).

The proposed database could be managed by an Expert System program, such as Goldworks (Goldhill, 1987). The expert system could provide rules to guide the user through a data search, and an interpretation of the information which the database provided.

REFERENCES

American National Standards Institute, **User Exchange Format (UEF00) for the Exchange of Color Picture Data between Electronic Prepress Systems via Magnetic Tape (DDES00).** ANSI IT8.1 - 1988, New York; 1984.

American National Standards Institute, **Photography (Sensitometry)--DensityMeasurements--Spectral Conditions.** ANSI/ASC PH2.18 - 1984, New York; 1984.

DuPont Imaging Systems Division, **North American Commercial Print Survey.** E.I. Du Pont de Nemours and Co., Wilmington, DE; 1988.

Goldhill Computer Co., **GOLDWORKS.** Cambridge, MS; 1987.

Holmes, Donald, **Introduction to SPC.** Stochos Inc., Littleton, MS; 1988.

Jorgensen, George W., "Improved B&W Halftones, Part II." **Research Project Report, no. 110.** Graphic Arts Technical Foundation, Pittsburgh, PA; 1977.

Jorgensen, G.W. and Lavi, A., "Press Interaction Chart," **Research Project Report, no. 82.** Graphic Arts Technical Foundation, Pittsburgh, PA; 1969.

Maurer, R.E., "Customized-Color Computer Printing Analysis." **TAGA Proceedings, 1982.** pp. 518-550.

Muirhead, A.R., Burgstein, M. and Fahr, R.H., "North American Print Survey." **TAGA Proceedings, 1985.** pp. 585-601.

Scharpf, Norman W., "Further Analysis of Factors Contributing to Variability in Web-Offset Color Advertising." **TAGA Proceedings, 1984.** pp. 78-92.

Scharpf, Norman W., "Test Analysis of Factors Contributing to Variability in Web-Offset Color Advertising Reproduction." **TAGA Proceedings, 1983.** pp. 276-285.

Souter, John, "Colorimetric Specification for SWOP and Group VI Proofing and Production Inks." Paper presented at the Annual Meeting of the Technical Association of the Graphic Arts, Orlando, FL; April 2-5, 1989.

Stanton, Anthony P., **SNAP: 1987 Print Test Analysis.** Graphic Arts Technical Foundation, Pittsburgh, PA; 1988.

The International Federation of the Periodical Press, **Specifications for European Offset Printing.** FIPP, London; 1984.

APPENDIX A

INFORMATION FOR DATA ENTRY PROGRAM

GENERAL INFORMATION

Printing Plant

Name of Company _____
Location (City, State, Country) _____
Date of Measurement _____

Printing Process

a. Lithography
b. Gravure
c. Flexography
d. Letterpress
e. Other (Specify) _____

Printing Press

Sheetfed / Web _____
Manufacturer / Model / Size _____
Number of Units _____
Number of Impressions _____
Dampening System _____
Auxiliary Equipment (Specify) _____
Other Features (Specify) _____

Job Information

Product Description _____
Run Length _____
Press Speed _____
Finishing Operations (Specify) _____
Coatings (Specify) _____
Waste Percentage (Measured) _____
(Estimated) _____

Densitometer

Manufacturer / Model _____
Spectral Response _____
Aperture Size _____
Computer Interface (Specify) _____

Measuring Target

Color Control Bar (Specify) _____
Quartertone Tint Values _____
Halftone Tint Values _____
Three-Quartertone Tint Values _____

PRINTING MATERIALS

Substrate

Type of Subtrate
- a. Coated Premium Grade
- b. Coated Publication Grade
- c. Uncoated Free Sheet
- d. Groundwood
- e. Paper Board
- f. Other (Specify) _____

Manufacturer _____
Caliper or Basis Weight _____

Inks

Type of Inks
- a. Heatset
- b. Drying Oil
- c. Nonheatset
- d. UV Curing
- e. Flexographic Water-Based
- f. Flexographic Oil-Based
- g. Other (Specify) _____

Manufacturer _____
Process Color / Spot Colors (Specify) _____
Tack Rated / Unitack (Specify) _____
Printing Sequence _____

Dampening Solution

Manufacturer / Type _____
Central or Individual Fountains _____
pH / Conductivity _____
Additives (Specify) _____

Plates

Negative / Positive _____
Manufacturer _____
Type (Specify) _____
Plate / Blanket Squeeze Pressure _____

Blankets

Type (Specify) _____
Manufacturer _____

APPENDIX A (cont.)

DENSITOMETRIC DATA

Note: All four densitometer filter values are entered for each reading in the order: visual, red, green, blue.

Reading Sample

a. OK Sheet
b. Production Sample
c. Other (Specify)_____

Density Readings

Densitometer Filters:	Visual	Red	Green	Blue
Paper Densities:	_____	_____	_____	_____
Solid Densities:				
Cyan	_____	_____	_____	_____
Magenta	_____	_____	_____	_____
Yellow	_____	_____	_____	_____
Black	_____	_____	_____	_____
Fifth	_____	_____	_____	_____
Sixth	_____	_____	_____	_____
Solid Overprints:	**Visual**	**Red**	**Green**	**Blue**
Red	_____	_____	_____	_____
Green	_____	_____	_____	_____
Blue	_____	_____	_____	_____
1/4-Tone:	**Visual**	**Red**	**Green**	**Blue**
Cyan	_____	_____	_____	_____
Magenta	_____	_____	_____	_____
Yellow	_____	_____	_____	_____
Black	_____	_____	_____	_____
Fifth	_____	_____	_____	_____
Sixth	_____	_____	_____	_____
1/4-Tone Overprints:	**Visual**	**Red**	**Green**	**Blue**
Red	_____	_____	_____	_____
Green	_____	_____	_____	_____
Blue	_____	_____	_____	_____
Mid-Tone Densities:	**Visual**	**Red**	**Green**	**Blue**
Cyan	_____	_____	_____	_____
Magenta	_____	_____	_____	_____
Yellow	_____	_____	_____	_____
Black	_____	_____	_____	_____
Fifth	_____	_____	_____	_____
Sixth	_____	_____	_____	_____
Mid-Tone Overprints:	**Visual**	**Red**	**Green**	**Blue**
Red	_____	_____	_____	_____
Green	_____	_____	_____	_____
Blue	_____	_____	_____	_____

APPENDIX A (cont.)

3/4-Tone Densities:	Visual	Red	Green	Blue
Cyan				
Magenta				
Yellow				
Black				
Fifth				
Sixth				

3/4-Tone Overprints:	Visual	Red	Green	Blue
Red				
Green				
Blue				