THE USE OF THE GATF SHEETFED COLOR PRINTING TEST KIT TO OPTIMIZE AND CONTROL SHEETFED LITHOGRAPHIC PRINTING

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ABSTRACT

A system of process control for sheetfed lithographic printing is described. The use of the GATF Sheetfed Color Printing Test Kit to troubleshoot, optimize and characterize a printing system is also addressed. Various tests of color reproduction are suggested, and a procedure for production control is given.

The sequence of optimization begins with a diagnostic phase where the mechanical transfer properties of the press are examined. This is followed by tests of the capacity and variability of the printing system. The color reproduction characteristics of the press system are measured next. The color scanner and proofing system are then adjusted to the conditions of the printing system. Finally, the production control aim-points are established.

Conscientious use of the GATF Color Printing Test Kit can lead to a higher quality, more consistent printing operation. Printing presses in a plant can be compared, and various printing materials -- such as inks, papers, dampening solutions, blankets, and plates -- can be evaluated. A regular program of testing will show changes in print quality that occur over time. The cumulative test results form a valuable data base of in-house printing conditions.

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INTRODUCTION

The GATF Sheetfed Color Printing Test Kit is a quality control tool designed to help the sheetfed lithographic printer achieve consistent high quality color reproduction. The test kit is designed for 38 and 40 inch presses with up to six printing units. The heart of the test kit is the GATF Sheetfed Test Form, a press form that is used to troubleshoot and characterize the printing conditions of a press. In addition to the test form, the Sheetfed Color Printing Test Kit includes three 5 x 7-in. color transparencies, color separations made from these transparencies, a Kodak Ektachrome Q60A target, an Ugra Plate Control Wedge, GATF Six-Color Control Bars, a GATF Register Test Grid, register pins, and a User's Guide with accompanying Press Test Analysis Form. The test kit is a flexible tool. The GATF Sheetfed Color Printing Test Kit User's Guide provides a complete description of the target elements and the experimental uses of the kit. This paper focuses on a testing strategy for optimizing lithographic printing and the role that the Color Printing Test Kit can play in troubleshooting and characterizing the process.

High quality lithographic color reproduction can be an elusive goal, particularly when consistency and efficiency of operations are also demanded. The difficulties arise from several sources; these include: the interrelatedness of operations in the reproduction cycle, the complex chemical interactions occurring on press, the lack of reliable predictive measurements and the subjective nature of color judgments.

As a starting point, the practitioner needs to accommodate two distinct definitions of high quality color reproduction. High quality color printing can mean conformance to specifications within allowable tolerances. This definition implies the use of objective measurement techniques and lends itself to statistical process control. The specifications for printing can be adapted from industry-wide sources (such as SWOP); they can be based on internal studies of the process, or they can be customer-imposed. Further discussion will be directed to the establishment of process specifications and tolerances within a printing company.

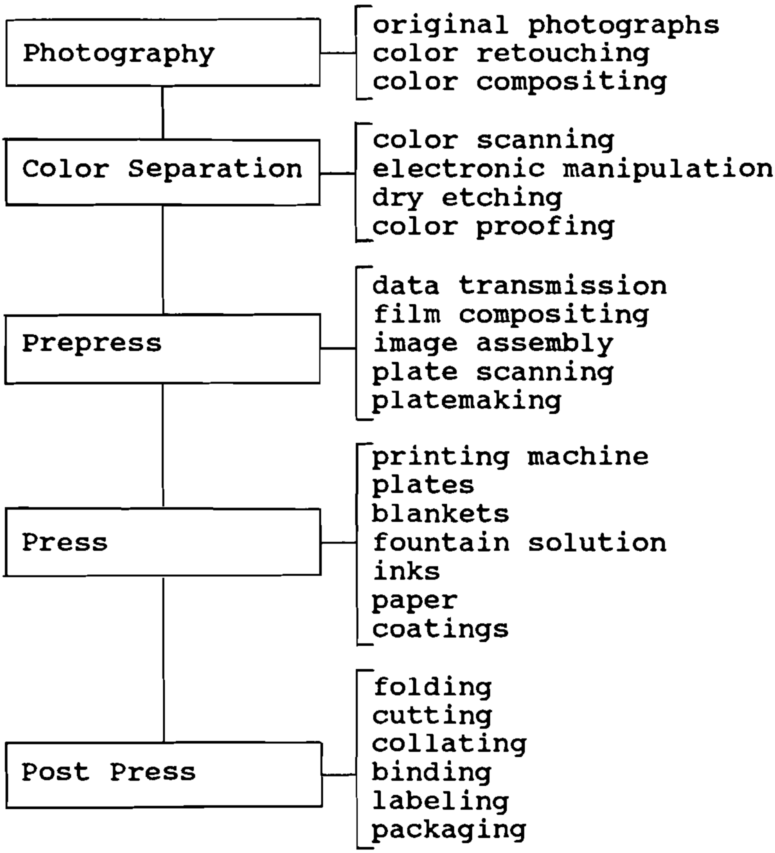
Alternately, high quality color reproduction can be defined as the most pleasing facsimile of the original art, which is usually a color photograph. Quality in this sense is subjectively determined and controlled through a process of visual approvals. The need for subjective judgment is rooted in two areas. First, even the highest quality sheetfed lithographic printing is severely limited in information content when compared with a color photograph. Second, all observers see color differently and, more importantly, have differing color preferences.

The limitations of lithographic printing compared with color photographs include restrictions of tone, color, detail and fit. The tonal range of a well exposed transparency can exceed 3.5 density units, while printed reproductions rarely exceed 2.0. The dyes used in photographic films are more colorimetrically pure than the pigments used in printing inks. Thus, a greater range of colors can be created in a photograph than on the printed sheet. The detail depicted in a color photograph is based on a random grain dye structure varying in fineness with the photographic speed of the film. The printing process imposes four overlapping dot structures across this detail. The detail rendition is greatly reduced, and moire' patterns are introduced into the image. The color photograph is invariably in perfect register since the image was formed on the substrate that carries it (except in the rare instance of dye transfer prints). During color separation the information from the photograph is physically separated onto four pieces of film to be ultimately recombined on the sheet of paper as it moves through four stations of the printing press. Inevitably, some deviations from perfect register are experienced.

The limitations of the color reproduction process compared with the photographic original prevent the exact matching of photographs on the printed sheet. Compromises must be made, and certain losses are inevitable. With today's electronic scanners there is tremendous flexibility in terms of the assignment of tones and colors. Unfortunately, there are no absolute rules that establish which compromises lead to the best reproduction. The most accurate reproduction, for example, is not necessarily the most pleasing reproduction. It depends on the subject matter of the original photograph and upon the taste of the observer. Memory colors play an important role in subjective evaluations. It is more important to reproduce a scene as an observer thinks it should look than as it actually looked. For example, many color reproductions will gain in subjective rating if the blue sky is reproduced at a higher saturation than is contained in the photograph.

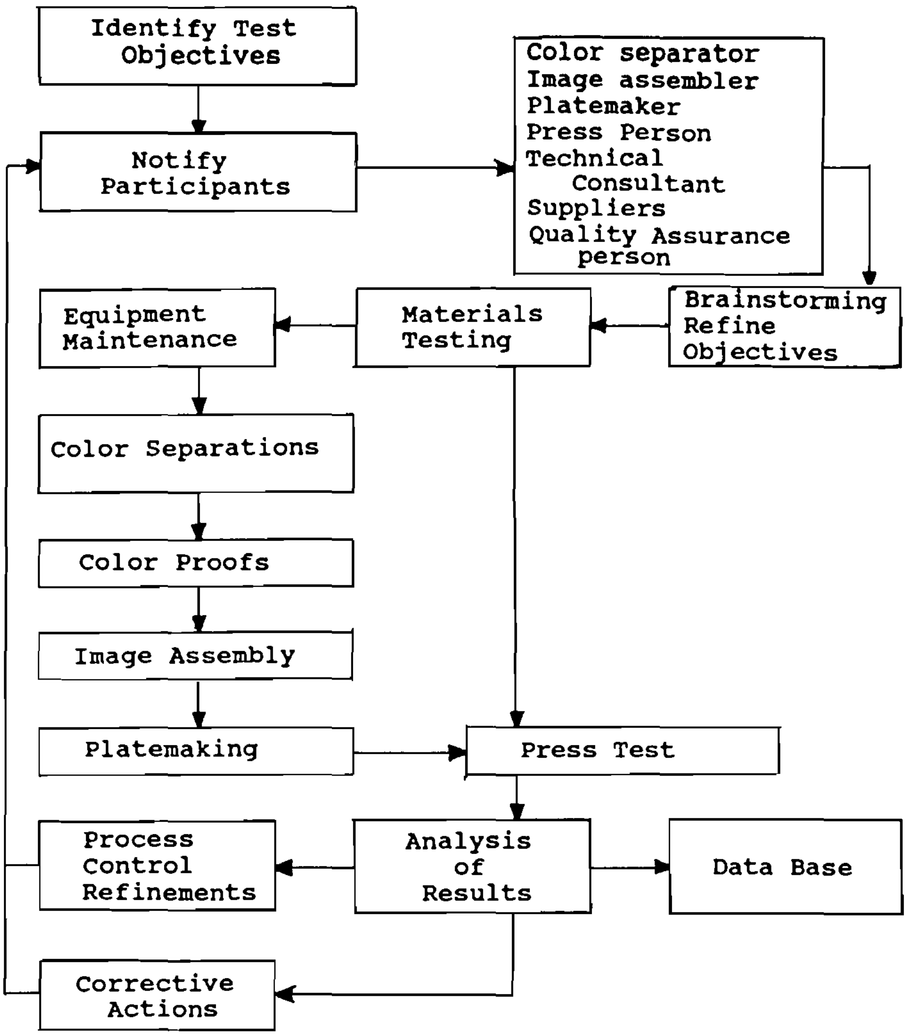
The subjective nature of best color reproduction is accommodated through a series of visual color approvals. This process typically occurs at three stages: the color photograph, the color proof, and the pressrun. The subjective preferences of the customer are expressed through the approval process. The color proof is a vital communications link in the color reproduction process.

Objective measurements are used in conjunction with the subjective color approval to provide consistency and predictability within the printing system. The structure of this quality control process depends on a systems approach to color reproduction. The printing system (represented in Figure 1) is treated as an interrelated series of operations rather than a collection of unrelated processes. Points of image transfer are identified, characterized and monitored. For efficient and consistent high quality results, a predictable link must exist between the color separation films and ink-on-paper.



COLOR REPRODUCTION SYSTEM
Figure 1

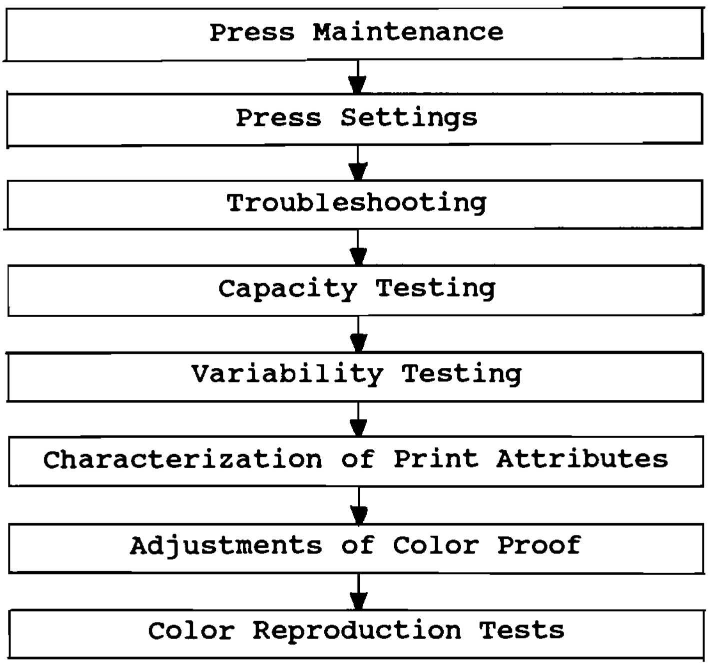
Establishing a predictable printing system requires a careful process of testing and optimization. The predictability of the system is founded on preventive maintenance, consistent sources of materials, and frequent monitoring of production conditions. The sequence for optimizing the quality output of a printing system begins from the press and works backwards to the color separation department. Initially, a planning phase is undertaken. Objectives are delineated, responsibilities are set, and channels of communications and feedback are established. It is important to involve the craftspersons in the planning as well as the execution phase of a quality improvement program. A flowchart is a useful tool for coordinating the various activities that comprise a thorough testing program. A sample flowchart is shown in Figure 2.



FLOWCHART
Figure 2

A flowchart constructed at a high level of specificity provides a road map for the testing process. The critical path identifies the elements that will cause delays if they are not completed within the time frame of the chart.

The press testing cycle itself contains a logical order of events as shown in Figure 3.



PRESS TESTING CYCLE
Figure 3

The press manufacturer's specifications are followed when performing press maintenance and adjusting the settings on the press. Regularly scheduled preventive maintenance is essential for consistent high quality results, since the color reproduction system is predicated on unchanging (predictable) characteristics.

The troubleshooting stage consists of a series of preliminary press tests followed by the running of the GATF Sheetfed Test Form. The preliminary press tests may include the following: break-away dry solids, full-coverage dry solids, full-coverage wet solids, a mechanical ghosting test, and a press register test. In combination, these tests will detect imperfections in the surfaces or settings of press cylinders, patterns of uneven ink delivery, patterns of uneven dampening, the extent of mechanical ghosting, and problems of image fit between the cylinders of the press.

The GATF Sheetfed Test Form furthers these diagnostic efforts. The test form contains an extensive array of quality control targets that fall into three broad categories: diagnostic, process control, and standardization. The process control and diagnostic targets are used first to establish representative printing conditions on the form and then to analyze the quality of the printed image.

Before a meaningful press study can be made, it is necessary to gain assurance that the printing plates are properly made. Register accuracy, halation, uniformity of exposure, and exposure level are all concerns that must be addressed. The GATF Sheetfed Color Printing Test Kit provides a Register Test Grid and an Ugra Plate Control Wedge (both with User's Guides) to assist the printer in testing and monitoring the platemaking operation. The images of the Ugra scales on the test plates are examined prior to makeready. The plates should conform to the exposure level recommended by the manufacturer.

After the plates have been inspected and mounted on the press, the makeready process proceeds. The colors are brought into register with the aid of the Transfer Grids on the test form. The ink keys are adjusted to achieve production inking levels. These levels can be refined through the capacity testing and variability testing stages that follow; however, initial settings are needed for the diagnostic testing. In the absence of existing shop standards, the use of the SWOP ink references available from the International Prepress

Association is recommended. The high densities on the SWOP High/Low patches should serve as the target densities for this testing. The Solid Color Control Bar across the trailing edge of the test form is used to adjust the ink settings. The water feed is set to achieve a just-above-scumming condition.

When balanced inking is achieved across the test form, the diagnostic targets are analyzed to discover problems in the printing. These targets include: Ladder Targets, Star Targets, QC Strips, Mottle Patches and Vernier Targets. The Ladder Targets are located on each side of the press form to print around the cylinders. These targets are extremely sensitive to problems of dot transfer, ink/water balance and paper transport. Loose blankets, fan-out, paper slipping in the grippers, gear streaks, slur, doubling, and excessive dampening are some of the conditions that can be found with the Ladder Targets.

The Star Targets, located at several strategic positions on the Sheetfed Test Form, are used to diagnose excessive ink spreading (dot gain), slur, and doubling. The relative sharpness of different colors can be ascertained by comparing the printed Star Target images. The presence of slur or doubling can be distinguished from dot gain. The direction of movement or dot displacement can be deciphered from the printed target.

The QC Strip is used to evaluate ink/water balance. There are several sets of QC Strips on the test form. The orientation of the target is such that excess water will cause wash marks to appear on the horizontal element of the target. Insufficient water will result in fill-in between the straight-line elements of the target.

The Mottle Patches are visually evaluated to detect the presence of ink mottle. Ink mottle is a condition of uneven ink coverage that can appear in either single ink films or overprints. Ink mottle in the blue (cyan plus magenta) overprint patch is most common.

The Vernier Targets are used to obtain an accurate measure of print length differences between the various units of the press. With the Vernier Targets, dimensional changes occurring in the paper as it moves through the press are measured both across the sheet and in the direction of travel. Paper stretch and paper fan-out can both be measured.

If adverse printing conditions are detected with the diagnostic targets, corrective measures should be taken before proceeding with the optimization and characterization of the process. Once it is determined that good printing conditions exist, a systematic approach to optimization of the process can begin.

There are two tests recommended at this point: a test to find the highest inking level appropriate for the printing system, and a test of process variability to set the allowable tolerances for the system.

One approach to optimization testing is to systematically change the ink density of each color through a range that encompasses the potential operating densities for the inks. The ink and water are brought into balance and samples are taken at regular intervals from too little ink to too much ink. The print contrast value is calculated from each sample. A graph is constructed for each color by plotting the print contrast (y-axis) against the ink density (x-axis).

Typically, the print contrast will increase with increasing ink feed until a point is reached where too much ink is being applied. Further increases in ink density will then result in lower print contrast values. The apex of the curve denotes the highest print contrast that the printing system can achieve for a given color. This point should be the upper tolerance limit for production press operation. To determine the aimpoints and lower tolerance limit, a variability study is necessary.

The variability study will show the amount of variation that occurs during the printing process in the absence of human intervention. Ideally, the duration of the pressrun used to measure variability will approximate the normal production run of the printing plant. To perform a variability study, the density is set 0.07 units below the density that was associated with highest print contrast. Otherwise, the normal production density aimpoint, or the high density ink reference from SWOP, can be used for this study. During the press operation the ink and water should be brought into balance; the press should be allowed to run without intervention from the operators. At least 100 random samples are collected from the printed sheets. These samples are kept in order from beginning to end of the run. They are then subjected to statistical analysis. Densities are measured, and the mean and standard deviation are calculated for these measurements. The mean value should be very close to the density aimpoint used for the run. The standard deviation is a measure of the variability of density readings. The process control limits for density should be based on the natural variability that is inherent in the process. Many manufacturing processes allow plus-or-minus three standard deviations as the tolerance limits. This range encompasses over 99% of the population. Thus, there will be less than 1% chance that a sample selected for measurement will be out-of-tolerance due to the natural variation of the system. This implies that the operator can adjust the process with confidence when a sample is found to fall above or below the tolerance limits.

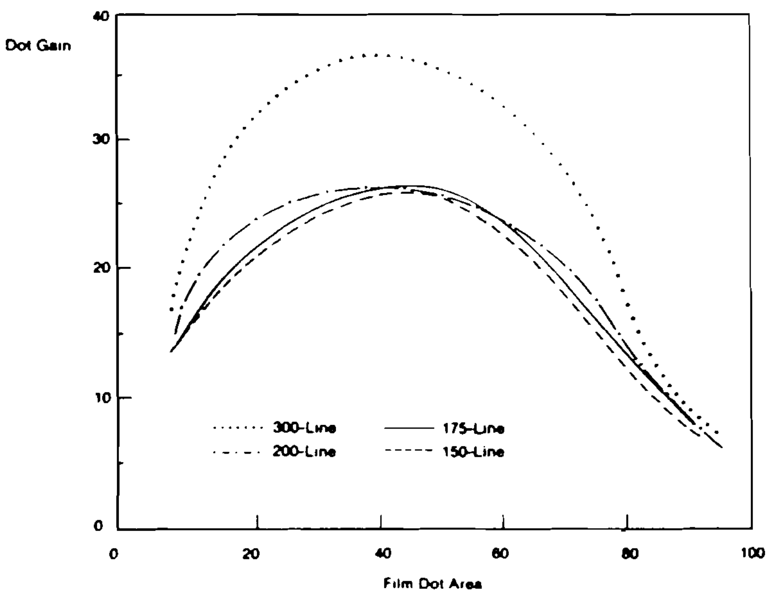
The confidence intervals are based on the assumption that the density variations during the pressrun are representative of a normal population. It is a good idea to test the goodness-of-fit between the experimental data and the unit normal distribution. The experimental data will first be normalized to the Z-scale. The two indices of skewness and kurtosis are of interest in assessing the goodness-of-fit. The index of skewness describes the symmetry of the experimental data; a zero value means the population is symmetrical. If the actual skewness value is strongly positive or negative the printer should seek out the cause of this bias. The kurtosis index describes whether the experimental data is more or less tightly clustered than points on the normal distribution. A zero kurtosis value is normal. Positive values indicate more densely packed data, while negative values represent data that is more widely distributed than the normal curve. In this instance, large negative values are a cause for concern to the printer.

Two graphs that can help in investigating the data are frequency polygons and attribute-versus-time graphs. The frequency polygon can be constructed from the normalized data and superimposed over the unit normal distribution. Differences of skewness and kurtosis can be seen from the two curves. The graph depicting the density values (y-axis) versus the sample number (x-axis) shows the performance of the density over time. This graph will reveal trends that occur during printing. For example, if density steadily declined during the pressrun, it would be apparent from this graph.

Various print attributes other than ink density can be evaluated from these samples. These include dot gain, print contrast, and ink trapping. The attribute-versus-time graphs are of particular interest when examining the performance of these print attributes.

The density aimpoints for production printing are set at three standard deviations below the densities associated with highest print contrast. The tolerance limits are plus-or-minus three standard deviations. This will result in different tolerances for the different ink colors, but the tolerances are based on the natural variation of the printing system. The ink trapping values should be measured at the new operating density levels. If the ink trapping values have fallen significantly from the previously experienced ink trapping, some adjustments may be necessary to the density aim-points to compromise between high print contrast and successful ink transfer in forming overprint colors.

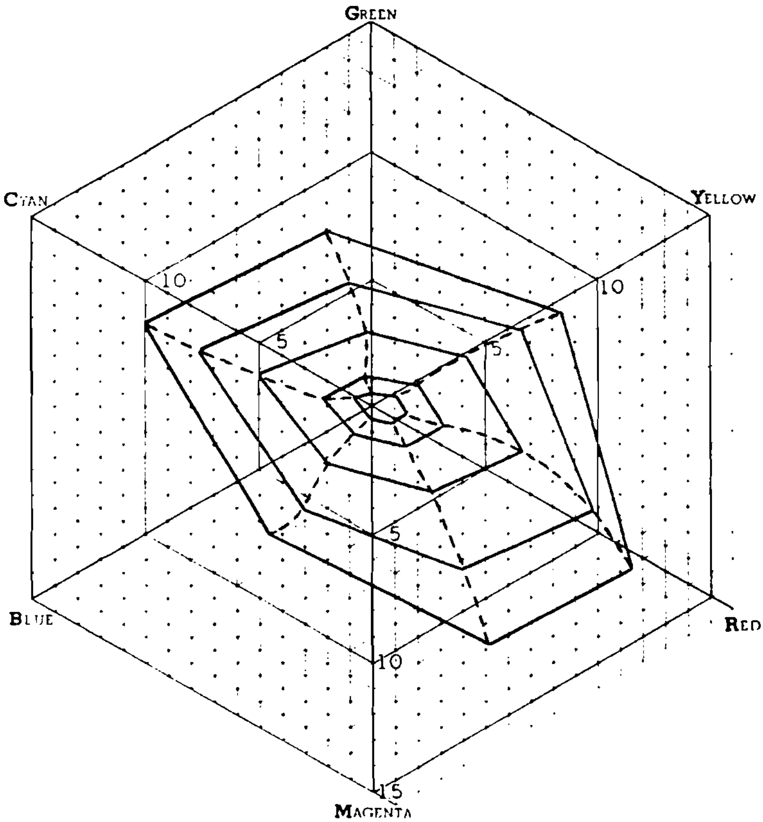
With the troubleshooting and the process optimization completed, the next phase is the characterization of the printing system. It is important that characterization follow troubleshooting and optimization since the printing characteristics will then be indicative of good press operating conditions. The GATF Sheetfed Test Form contains several targets that measure printing characteristics: Tone Scales, a Dot-Size Comparator, Overprint Scales, an Ink Coverage Target, a Gray Balance Chart and some elements of the Ugra Plate Control Wedge. The Tone Scales are used to measure the dot gain of the printing system for each ink color at eleven points throughout the range of reproducible dots. These measurements are used to construct dot gain curves. From the dot gain curve, the apparent printed dot size of any film dot can be predicted. The Dot-Size Comparator target allows the measurement of dot sizes for three different screen rulings (175-, 200-, and 300-lines). The dot gain characteristics of these fine screen rulings can be compared to the dot gain found from the 150-line Tone Scales. (Figure 4)



DOT GAIN CURVES
Figure 4

Generally, the dot gain will increase with increasing screen rulings. In the experimental data plotted in Figure 4, the curves change shape as well as increase in magnitude. The 200- and 300- line curves are skewed towards the lower dot sizes, indicating a pronounced increase in quartertone dot gain.

The Overprint Scales show the hues achieved when equal dot sizes of two, three, and four of the primary ink colors are printed together. The two- color overprints (red, blue, and green) are used with the cyan, magenta, and yellow Tone Scales to construct GATF Color Hexagons at selected original dot sizes, as shown in Figure 5.



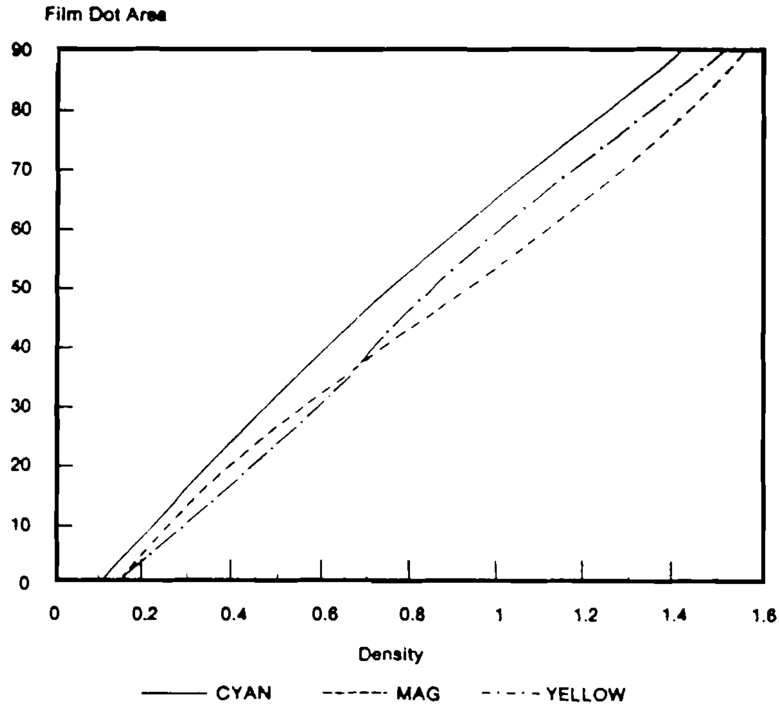
10%, 25%, 50%, 75% and 100%
COLOR HEXAGONS
Figure 5

Multiple hexagons are a convenient means for examining several print attributes simultaneously. The distance of any point from the center is an indication of the saturation of that color. The distances of points from the radial hue lines of cyan, magenta, yellow, green, blue, and red are indicative of the hue errors of the colors. This is used to evaluate the success of color correction for ink hue deficiencies. Print contrast is visually displayed as the distance between the 75% hexagon and the solid color hexagon. The 25% and 50% dot gains are similarly shown by the sizes of the corresponding hexagons. The arc segments connecting the 25%, 50%, 75% and 100% blue, green and red points show the increasing effects of ink trapping with increasing ink coverage.

Multiple hexagons can be plotted by a computer interfaced with a reflection densitometer, greatly reducing the time required to construct them. For process control, hexagons are plotted from a press OK sheet. When subsequent samples are taken, hexagons are made. The OK sheet and the sample hexagons are superimposed on a light table. A quick visual examination will detect any changes in ink density, hue, trapping, or dot gain.

The Ink Coverage Target is used to measure the densities that are produced from various combinations of cyan, magenta, yellow, and black ink coverage. Thus, the effects on shadow density of reducing the maximum ink coverage from 400% to a lower value, for example 340%, can be documented. When Gray Component Replacement (GCR) is used it is important to specify the optimum total dot area coverage so that the tonal range of the printing system is not reduced due to insufficient ink coverage in the shadows. If necessary, an undercolor addition (UCA) program will be used in combination with GCR to restore the needed coverage in the shadows.

The Gray Balance Chart is used to determine the three-color gray requirements at eight points throughout the tone scale. The printed target is visually compared against a gray scale to find the cyan, magenta, and yellow film dot sizes needed to produce neutral gray on the printed sheet. The selected patches are measured with a reflection densitometer. This data is used to construct gray balance curves, as shown in Figure 6.



GRAY BALANCE CURVES
Figure 6

The three-color gray requirements for any density can be interpolated from the gray balance curves. Reproducing a neutral gray scale with cyan, magenta, and yellow is of particular interest because it indicates that the hue deficiencies of the process inks have been successfully corrected.

The Ugra Plate Control Wedge contains a series of highlight and shadow elements that are examined to find the largest and smallest film dots that will successfully reproduce with a given printing system. These dot values form the end points for the halftone films made for that system. The dot values in the highlights are of particular interest because the difference between unprinted substrate and minimum printing dot is used to distinguish between specular and diffuse highlights in the scene.

The color reproduction characteristics obtained from the Sheetfed Test Form are representative of a printing system that can be verified as being in control and free of major defects. Since the color proof will serve as a visual link between the color separations and the pressrun, it is advantageous to adjust or choose a proofing system that provides a good match with the press. The GCA/GATF Proof Comparator II is used for this purpose. This target is available as a stand-alone product. The color separators makes proofs from the individual target films that are compared against the printed image of the Proof Comparator on the Sheetfed Test Form. Adjustments are made to the proofing system until a best match is obtained. The color proofs made under these conditions are predictive of the best printing that the press can produce.

The Sheetfed Color Printing Test Kit includes a 4 x 5 inch Kodak Ektachrome Q-60A transparency to optimize scanner settings for Ektachrome film. The target contains 198 color patches and two gray scales to adjust the gray balance, the selective color settings, and tone reproduction of a scanner. Scans are made of the Ektachrome target. Color proofs are made from the separation films and compared with the Ektachrome original. The Sheetfed Test Form provides a convenient means to extend this process to the printing press. The four windows of the Sheetfed Test Form can be used to compare four sets of separations at different tone and color settings.

Three 5 x 7-in. color transparencies, as well as separations made from them, are included in the Sheetfed Color Printing Test Kit. If the testing objectives are limited to the press, the supplied GATF separations are used. However, if the color scanner is included in the testing strategy, the transparencies are used (along with the Kodak Q-60A target) to evaluate tone and color reproduction. The color transparencies were designed to present a variety of challenges to the color separator. One transparency contains a predominance of light tones. Another is dominated by dark tones. The third transparency is a group portrait.

Color tests can be devised to evaluate tone reproduction, color correction, detail enhancement, screen ruling, dot shape, or gray component replacement. For example, a single transparency can be separated with four different tone curves, and the four printed images can be compared. Transparencies other than the supplied ones can also be incorporated in the testing.

At this point the press has been tested. The optimum printing levels have been determined. The color proofing system and color scanner have been adjusted to the printing characteristics of the press. The next step is to establish production control procedures based upon this testing. The Sheetfed Color Printing Test Kit includes a GATF Six-Color Control Bar that matches the control bar imaged across the leading edge of the Sheetfed Test Form. This facilitates the conversion of process control aimpoints from a well printed test form to a production run. Even the appearances of the visually evaluated Star Targets and Dot Gain Scale-IIs are translated to the production environment. When a well-printed test form is obtained at optimum inking conditions the Six-Color Control Bar can be cut off and mounted on the press console to be compared directly with samples taken during production.

The procedure for process control still must accommodate subjective evalutions. But, if the proofing system has been adjusted to match good printing conditions, minimal distortions from optimum inking are required at press side to obtain an OK sheet. The makeready procedure is as follows:

1. The printing units are brought into register with each other.

2. The ink levels are adjusted to the previously determined optimum values.

3. The water feed is set to achieve a just-above-scumming condition.

4. A sample is taken and compared against the color proof.

5. The ink and water settings are adjusted to provide the best achievable match with the color proof.

6. The print attributes of density, dot gain, ink trapping, print contrast, and hue error/grayness are measured on the OK sheet.

Subsequent samples taken during the production run are measured and compared with the conditions found on the OK sheet. The press operator must examine the samples carefully to detect defects that are not measured by the print attributes. These include variations of register, ink mottle, paper picking, hickeys, scumming, water catch-up, and others.

In summary, the GATF Sheetfed Color Printing Test Kit offers the printers a new tool for diagnosing, optimizing, and measuring the attributes of a lithographic printing system. The printing press can be diagnosed for fidelity of ink and dot transfer. The optimum inking levels can be determined for a given press system. The color reproduction characteristics can be measured. The color proofing system and color scanner can be adjusted to good printing conditions. Finally, production control can be facilitated.

Literature Cited

Stanton, A.P., GATF Sheetfed Color Printing Test Kit User's Guide. Pittsburgh: GATF, 1988.