COLOR REPRODUCTION CHARACTERISTICS OF STOCHASTICALLY SCREENED IMAGES

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Abstract

The experimental results described in this paper are from two different tests conducted by GATF to compare the reproduction characteristics of stochastic screens with those of conventional halftone dots. A film duplication test was performed to compare the effects of exposure level on dot gain, and a press test was designed to measure several reproduction characteristics of stochastic and conventional screens under normal press operating conditions. The press test was run with both conventional and waterless lithography. The validity of the findings is limited to the specific printing systems and materials used.

Background: Digital Screening

During the early 1970s, the lithographic printing process first began to incorporate electronic dot generation via high-end electronic color scanners as an alternative to traditional photomechanical screening techniques. The early pioneers[1] in this new technology used a newly discovered light source, the laser, as a recording device to convert pictorial information from continuous-tone originals directly into halftone color separations, bypassing traditional photomechanical contact screening.

By the late 1970s, Scitex introduced the first color electronic prepress system (CEPS) that could be linked to existing high-end scanners and perform analog-to-digital conversion of picture data. The ability to scan, digitize, store, and process image data led to the use of CEPSs to electronically dot-etch, photocompose, clone, paginate, and assemble images for graphic reproduction.[2]

During the 1980s, many advances in computer hardware and software allowed for even greater flexibility in electronic image manipulation, such as retouching, color correction, and gray component replacement. As raster image processors (RIPs) improved, so did computer storage capacity and data processing efficiency.

Advances in digital screening were paralleling the developments in electronic image manipulation. Because CEPSs remained linked to high-end scanners, which image halftone dots evenly in a fixed grid, digital screening tended to use predetermined

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screen rulings where the size (amplitude) of the dot was changed (modulated) to correspond to the gray levels being reproduced.

Amplitude-modulated (AM) digital screening produces each halftone dot from (usually) four scanned pixels, which are themselves divided into a matrix of recording spots. (Confusingly, these tiny spots are often referred to as dots, as in "dots per inch" or dpi, which is a measure of resolution.) Pixel values are transformed into an array of binary numbers that control the on/off imaging of these spots.

Using a typical matrix of 6×6 binary spots produces a halftone dot consisting of 144 spots (4×6×6). The selected dot matrix, as well as the number of scanned pixels and the recording spot size, depends on the imagesetter used, but 6×6, 8×8, and 12×12 matrixes are common.

This approach is referred to as deterministic or as an order dither because it assigns recording spots to a bitmap in a "coherent area."[3] That is, each halftone dot fills in from the center outward, spot by spot, with each spot adjacent to another one.

In general, the coherent areas are programmed to produce symmetrical dot shapes such as square, round, or elliptical, but they can also be arranged to produce nonsymmetrical dot shapes. A spot arrangement in the form of a bitmap can be defined for each tone value and stored in memory. The same pattern is used every time for that tone value.

Although digital AM screening has proven to be an excellent method for producing halftones, it does have limitations. There is a physical and mathematical relationship between the number of gray levels, the resolution, and the screen ruling such that there is always a tradeoff between resolution and the number of reproducible gray values.[4]

Also, the algorithms for conventional screen angles of 15° and 75° can never be exactly calculated and require long computational times because of their irrational tangents.

The late 1980s were dominated with desktop publishing and desktop color separation. Although the new desktop systems could be linked to traditional high-end scanners, a new breed of image capture and imagesetting devices that used charge-coupled devices and solid-state lasers emerged to enhance the productivity of the desktop systems. The major constraint on these new devices was the need for higher-resolution AM screening methods.

However, other screening methods using frequency-modulation (FM) techniques began to emerge. In its simplest form, FM screening consists of fixed-size spots whose center-to-center spacing is modulated according to the density of the original. In practice, the placement of these spots within a picture element varies randomly for a given tone value.

Early precedent for random screening is seen in the collotype process of the 1880s.[5] More recently, random grain printing, developed during the 1950s and '60s by Enco and Howson-Algraphy, used random variations in plate graining and coating thickness to reproduce continuous-tone images. This process, however, proved to be difficult to control and not compatible with production needs. As late as 1973, manufacturers were introducing new photomechanical methods to produce random-screened images such as Polychrome's random-micro-lenticular (RML) screen.

However, it was not until 1989 that Fischer[6] pointed out the practicability of using digital FM screening to produce high-fidelity images at low resolutions that were visually equivalent to the traditional AM-screened images. A purely frequency-modulated screening process would be deterministic and would suffer from periodic artifacts (e.g., moiré patterns). When randomization is used to break up periodicity, it is called *stochastic screening.*[7]

Stochastically screened spots are randomly spaced and clustered within the matrixes and do not form coherent areas like AM digitally screened spots. This is the major difference between FM and AM digital screening. However, as the halftone dot sizes increase towards 100% coverage, the clustered random pattern of the FM screen begins to fill in and approaches the coherent formation of AM screening. In contrast to the predictability of the spot patterns in AM screening, the only predetermined factors with FM screening are the spot size, the area of coverage within a matrix, and the total spot perimeter.

Figure 1 shows a comparison of a 50% tone produced by 150-lpi AM halftone dots using Agfa Balanced Screening™ (ABS) with a 2,400-dpi FM stochastic screens using Agfa CristalRaster™ version 1.2. (This version has two levels of screening: 2,400 and 3,600 dpi, which are calibrated to 150 and 300 lpi respectively.)

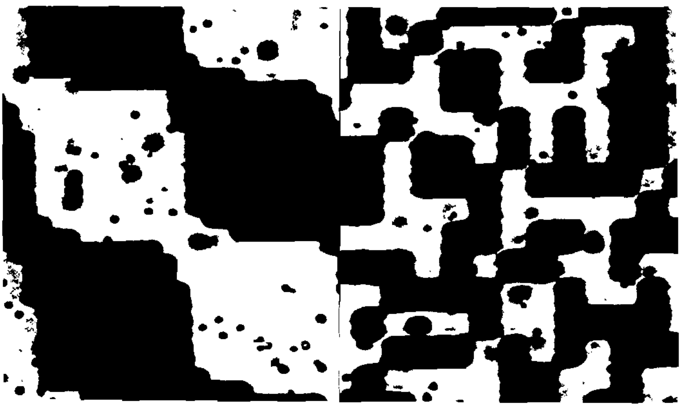

Figure 1. Photomicrographs at 170× of 50% conventional and stochastic dots.

The reported advantages of stochastic over conventional screening are as follows:[8]

- The perception of higher-resolution reproductions at lower actual scanning and recording resolutions due to the fine dot structure
- No tradeoffs between attainable gray levels and resolution
- No burdensome computational problem of screen angles with irrational tangents
- Less unsharp masking
- Quicker makereadies
- Greater run stability and latitude on press when subjected to variations in ink density and misregister

The disadvantages of stochastic compared to conventional screening are:

- The need for hard dot structures from imagesetters
- The need for prepress proofing systems to resolve the FM dot structures and optically simulate FM dot gain on press
- The need for critical control in film contacting and platemaking procedures
- The need to minimize and control dot gain during press operations

Recent experiments at GATF by Stutzmann and Lind have shown that stochastic screens (2,400-dpi Agfa CristalRaster,™ version 1.2) have more total dot perimeter for any given gray level than 150-lpi conventional AM screens produced with ABS. On average, there are 14.5 times as many spots present at any given gray level and 3.4 times the total dot perimeter with the stochastic screen.

The Test Form

A digital test form (Figure 2) that filled one-half of a 19×25-in. press form was developed at GATF to compare the print characteristics of stochastic with conventional screens. The same test form was used for the film duplicating test and the press test. Half of the form was stochastically screened and the other was conventionally screened. Since both halves contained the same elements, direct comparison between the two methods is achieved.

The stochastic images were produced with 2,400-dpi Agfa CristalRaster screens (versions 1.2 and 2.1). The conventional halftones were Agfa Balanced Screens (ABS). The test form was assembled on a Macintosh computer using Illustrator 5.1, Photoshop 2.5.1, and QuarkXpress 3.2. The forms were processed through a Cobra raster image processor (RIP) and output on an Agfa SelectSet 5000 imagesetter. Dot area readings were made from each set of films with an X-Rite 361 transmission densitometer to confirm the accuracy of imagesetter linearization. Image assembly was performed at GATF.

The test form contained the following elements:

- A color control bar running across the trailing edge of the sheet to provide means for press control
- A linearization tone scale consisting of dots in all four process colors from 1-20%, then in 5% increments through 80% and then 1% increments from 80-100%. These targets were measured on the films to confirm the linearization settings of the imagesetter.

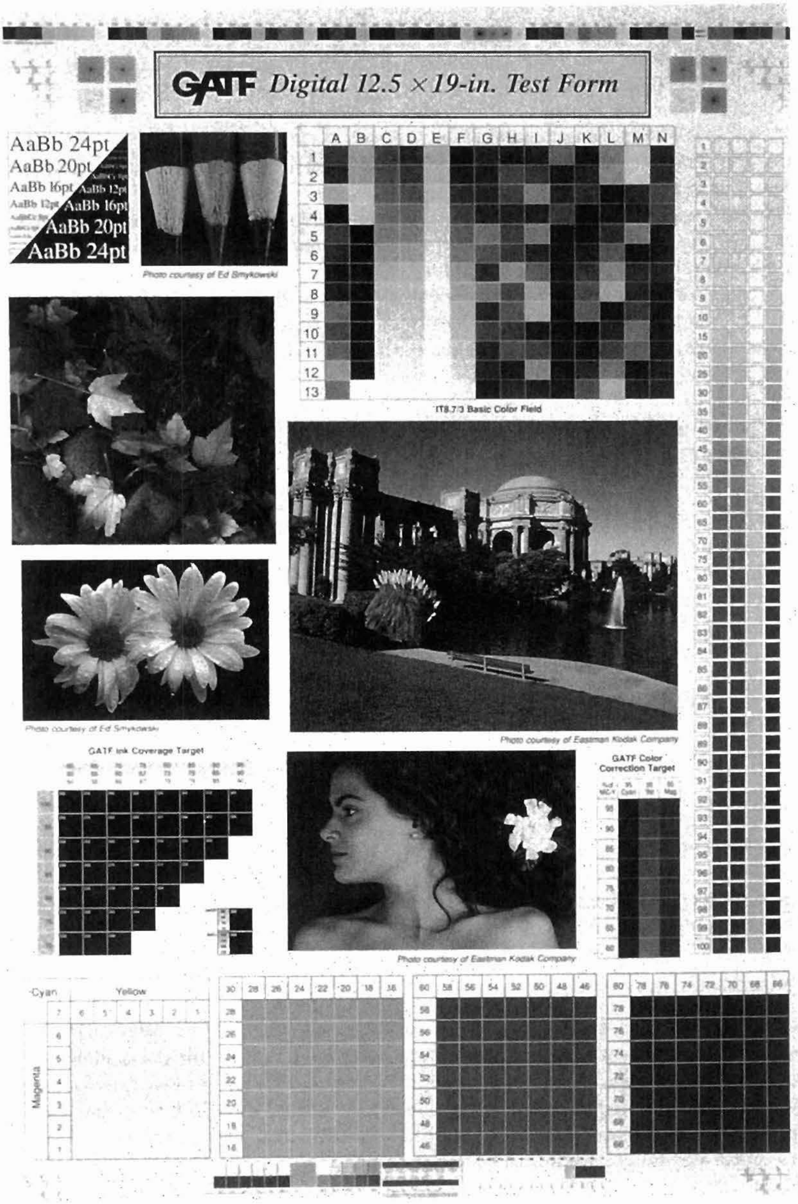

Figure 2. The test form design used in the film duplicating and press tests.

- Transfer grids for controlling color register
- Star targets to detect directional effects during printing
- A type resolution target in both positive and reversed-out modes
- An IT8.7/3 basic color field. This color field is described in the standard ANSI IT8.7/3-1993, *Graphic technology--Input data for characterization of 4-color process printing*. This target contains halftone scales for the four process colors and a variety of two-, three-, and four-color overprints.
- A gray balance chart to measure the three-color dot area requirements for creating neutral gray tones at four different levels of darkness
- An ink coverage target containing a variety of black squares with different amounts of four-color dot area coverage to determine the amount of dot area needed to create a maximum black within a given printing system
- A color correction target consisting of three scales of blue, green, and red, which is used to find the best ratio of two process inks to make accurate overprint colors.
- Five photographic images to judge the rendition of detail, the effects of moiré patterns, the sharpness of reproduced images, and the rendition saturated colors, pastel colors, and difficult tertiary colors like fleshtones
- Windows for UGRA Plate Control Wedges to monitor the exposure during platemaking

The Film Duplicating Test

The film duplicating test was performed after the press test, and a more advanced version of CristalRaster screening (version 2.1) was available. Therefore, the test form was output with the newer version. In addition, an ABS elliptical-dot screen ruling of 175 lpi was used for the conventional side of the test form because it was thought to be more closely analogous to 2,400 dpi CristalRaster.

DuPont CRR-4 duplicating film was used with DuPont CUFD rapid-access chemistry in a DuPont 37-C rapid-access processor. An integrated point light source and a Douthitt Option-X vacuum frame were used.

The stochastically and conventionally screened halves of the test form were assembled on the same flat. The tone values of halftone step scales were measured on the films. No other part of the test form was evaluated in the film duplicating test.

The exposure was adjusted to achieve a near dot-for-dot reproduction of the conventional screen (18 units). Then a series of four overexposures were made in a logarithmic progression (one-half stop intervals). The tone values on the resulting films were measured. The plotted data is presented in Figure 3.

Several observations are derived from examining these curves. As overexposure increased, the stochastic screen showed far greater dot gain than the conventional screen. For example, when the films were overexposed by a factor of four, the gain in he 50% dot was 30% for the stochastic screen and 12% for the 175-line screen. The reduced exposure latitude for stochastic films indicates that careful exposure control is needed for film duplication with stochastic images.

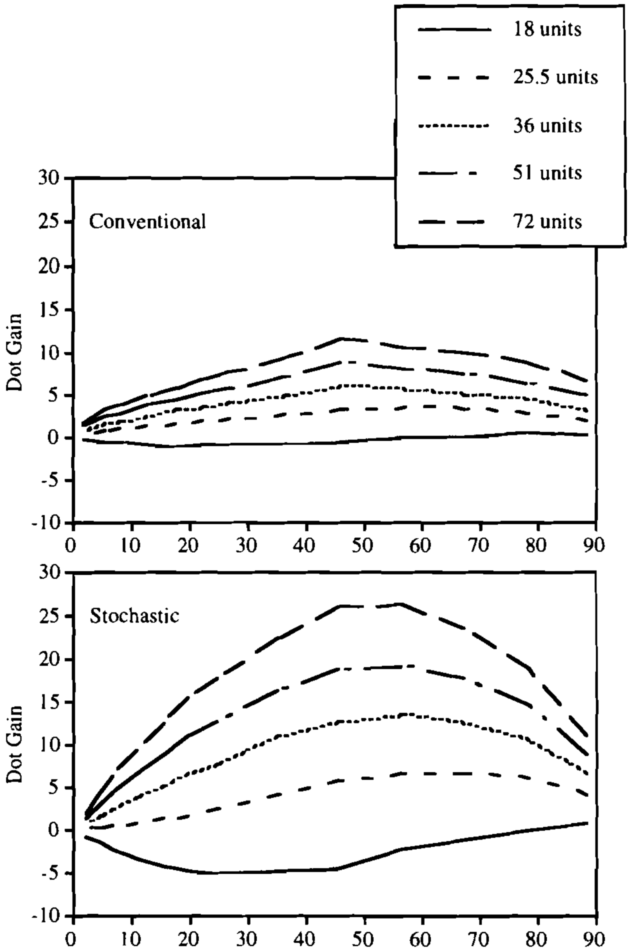

Figure 3. Film dot gain curves.

The 18-unit exposure provided approximate dot-for-dot reproduction of the conventional halftone screen (a nearly horizontal line centering on zero dot gain). However, the stochastic screen did not yield an acceptable dot-for-dot duplication at this exposure level. A second series of film duplicates was made from the stochastic image in an effort to achieve near dot-for-dot results (Figure 4).

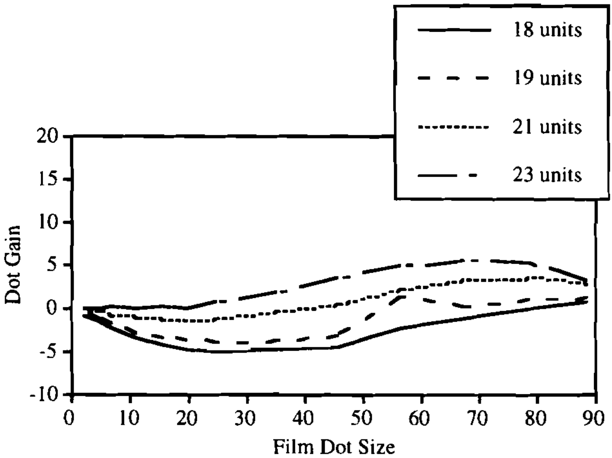

Figure 4. Stochastic dot-for-dot effort.

Figure 4 reveals that near dot-for-dot film duplication for the stochastic image was not attainable under the experimental conditions. Note that the 60% data point on the 19-unit line appears to represent a slight measurement error. When the dot gain for the highlights is near zero, the shadows have about 5% gain. Similarly, when the gain in the shadows was near zero, the highlights were underexposed. This finding indicates that with stochastic screens, tonal changes during film duplication should be accounted for when the reproduction system is calibrated. Stochastic images should not be duplicated unless this calibration has been performed. In contrast, conventional screens can be duplicated with careful control of exposure with minimal effects on tone reproduction.

A similar exposure study for platemaking would be useful, but it is difficult to accurately read tone values on aluminum plates. The findings from this film duplication test indicate that careful control of platemaking with stochastic screens is a reasonable precaution.

Press Tests

The press tests were performed by Komori America at its Rolling Meadows facility. The tests compared 2400-dpi CristalRaster 1.2 with elliptical-dot 150-line ABS screens. The press was a 28-in. six-color Komori Lithrone equipped with Tri-Service zone temperature controlled inking. The paper was Consolidated 100# Reflections II. The inks were DPI convertible inks; the same inks were used for both the waterless and the conventional lithographic pressruns. The blankets were Dayco Patriots 3000's. The plates were made by Multiple Image in Elmhearst, Ill. Toray negative plates were used for the waterless printing, and Fuji negative plates were used for printing with water. The UGRA Plate Control Wedge was used to monitor plate exposure.

Both stochastic and conventional films of the same test form (Figure 2) were run side by side on the same press form. Agfa automatic compensation for dot gain was not used with the stochastic half of the test form, although the pictures (not the targets) were individually adjusted in Photoshop to match the dot gain of the conventional films. The imagesetter was linearized for each of the two dot structures. Figure 5 shows photomicrographs of the two printed dot structures at 94× magnification. The assembled test form was printed twice; once by conventional lithography with fountain solution and once by waterless lithography.

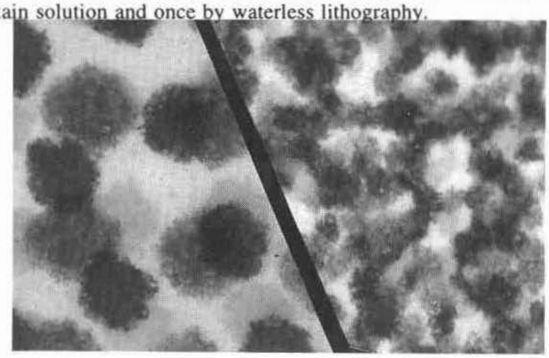

Figure 5. Photomicrographs of dot structures.

The following abbreviations are used throughout the rest of this paper to refer to the four printing conditions included in the press tests:
W-Sto = with water; stochastic screens
W-Con = with water; conventional screens
NW-Sto = no water; stochastic screens
NW-Con = no water; conventional screens

Approximately 100 samples were randomly taken from each pressrun after the press was determined to be at equilibrium. Each of these samples was measured across the color control bar with an X-Scan reflection densitometer. The printed sheets showed good consistency through the run. For statistical analysis, each ink key was treated as a separate population so that differences in ink key settings would not inflate the variability data. A sample of the test run statistics for a series of ink keys over the center of the form is shown in Table 1.

An examination of these data shows that the densities were slightly higher on the conventional side of the sheet than on the stochastic side. Also, the standard deviation for the black ink on the stochastic side printing with water is noticeably higher than the other standard deviations. This probably indicates that an ink adjustment was made during the period of the run when the samples were taken.

		K	C	M	Y
W-Sto	Avg. dens.	1.62	1.14	1.36	0.97
	Std. dev.	0.052	0.027	0.031	0.016
W-Con	Avg. dens.	1.78	1.23	1.42	1.02
	Std. dev.	0.023	0.015	0.010	0.007
NW-Sto	Avg. dens.	1.65	1.16	1.36	0.97
	Std. dev.	0.017	0.013	0.013	0.007
NW-Con	Avg. dens.	1.81	1.15	1.43	0.97
	Std. dev.	0.029	0.013	0.014	0.007

Table 1. Pressrun statistics.

Single samples were selected for further analysis from both the waterless prints and from the prints with water. These samples were picked by examining the density trend lines for all colors and choosing a sample that was close to the mean for every color. Status 'T' density readings were made from these samples with an X-Rite 418 color reflection densitometer, and colorimetric readings were made with an X-Rite 938 SpectroDensitometer. Where possible, color measurements were made in accordance with the procedures in ANSI CGATS.4-1993 *Graphic technology—Graphic arts reflection densitometry measurements—Terminology, equations, image elements and procedures* and ANSI CGATS.5-1993 *Graphic technology—Spectral measurement and colorimetric computation for graphic arts images*.

The backing material used behind the samples during color measurement deviated from the specifications of these standards, which calls for a spectrally non selective, diffuse-reflecting material with an ISO reflection density greater than 1.50. The color and density measurements from the backing material used in this test are shown in Table 2. The backing material used was slightly too light and too blue to meet the standard, but it was the best available choice.

	Densities				CIE values		
	K	C	M	Y	L*	a*	b*
Backing	1.22	1.24	1.20	1.13	29.64	-0.39	-5.15
Substrate	0.06	0.06	0.06	0.04	94.73	0.86	-4.59

Table 2. Density and color measurements from the backing material and the unprinted substrate.

The ink densities were measured across the selected sample sheets. The ink profiles are shown in Figure 6. Ink zones 1–8 represent the stochastic half of the sheet, and zones 9–16 are on the conventional half. In most cases, the inks are well balanced across the two press forms. Black ink density, however, is higher on the conventional half of the test form on both runs. Also, cyan is not very uniform across the form from the waterless run.

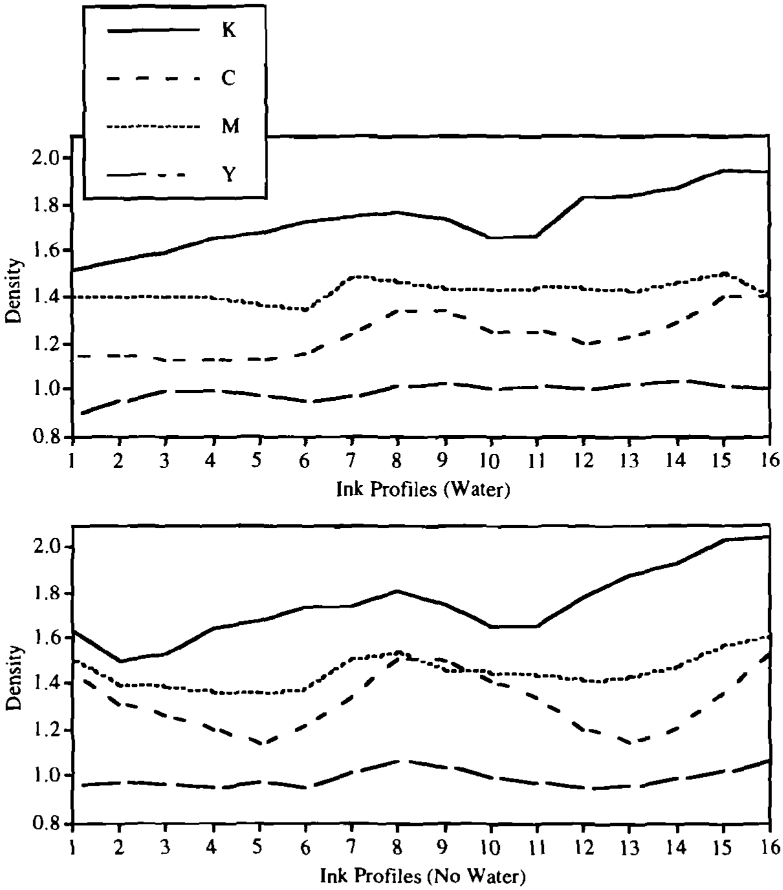

Figure 6. Ink profiles across the press sheet. Zones 1-8 cover the stochastic half of the test form and 9-16 cover the conventionally screened half.

Picture Detail Evaluation

Two commonly cited advantages for using stochastic screens are the absence of moiré patterns and improved rendition of picture detail. A careful examination of the four-color reproductions of this test form in both the waterless and regular lithographic pressruns supported these two claims.

Although there were no harsh moiré patterns in any of the 150-line reproductions, slight patterns were detectable in some areas. These patterns were virtually eliminated in the stochastic renditions.

However, in an area of sky, where there was a soft vignette from light blue to deep blue, the 150-line reproduction was smoother and more realistic than the stochastic image, which was decidedly more grainy.

Tiny portions of picture detail were better rendered with the stochastic screens. Figure 7 shows two photomicrographs from a small architectural detail at xx magnification. This higher detail rendition provides an overall appearance of greater image sharpness for the stochastic screens.

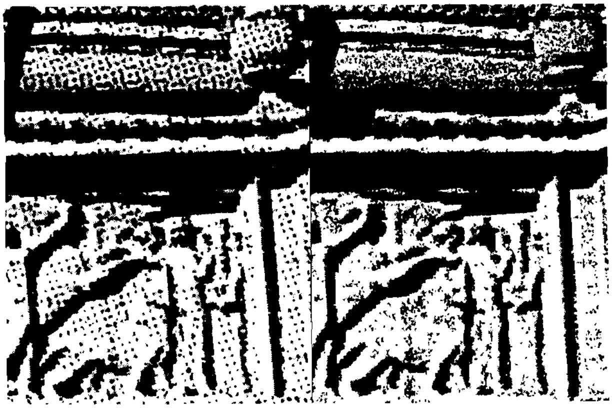

Figure 7. Photomicrograph of image detail at 11× magnification.

The limitations of this study prevented a meaningful comparison of the overall print quality and color rendition of the two screening technologies. To perform such a study, it would be necessary to establish optimum printing conditions for each type of screen within the same reproduction system. The printing conditions in this study were representative of common commercial settings, but they were not truly optimized for either screening technology.

Dot Gain

A large difference in dot gain was found between the two types of screens and between the two types of lithography. Dot gains were measured from the tone scales incorporated in the IT8 basic color field. The dot gains were calculated from the measured film dot values rather than from the nominal values. Therefore, the small variations between the indicated and actual dot areas on the films did not influence the results. Graphs of the dot gains are shown in Figure 8.

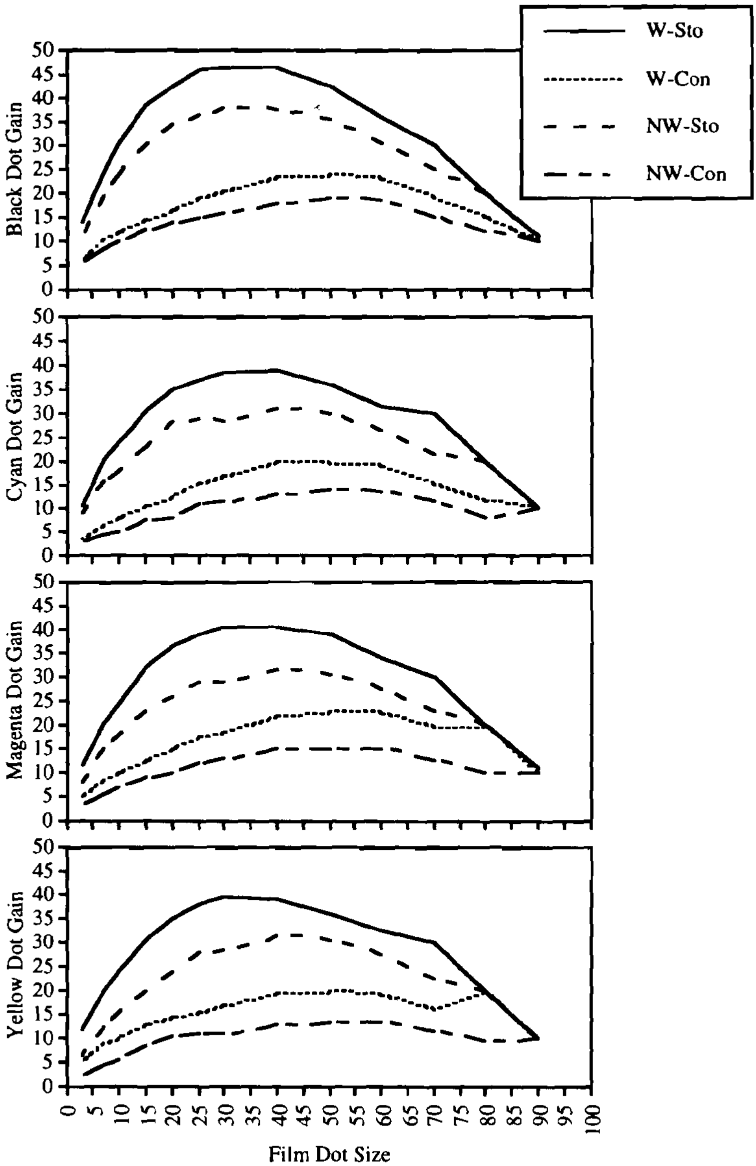

Figure 8. Dot gain curves for the four printing conditions of the press test.

Several observations were made from these dot gain curves. There is an anomaly in the shadow areas of the dot gain curves where several of the curves tend to converge and descend along a 45° straight line. This is due to the fact that the densitometer reads these shadow tones as solids.

The stochastic screen exhibited far greater levels of dot gain than the conventional halftone for every ink color. It is also important to note that the stochastic dot gain curves have a less symmetrical shape (i.e., considerably more quartertone dot gain) than the conventional dot gain curves. This indicates that it is not sufficient simply to increase the overall dot gain allowances when making stochastic films; rather, the proportion of dot gain through the scale must be adjusted as well. It is important to realize that the human observer is very sensitive to differences in quartertone rendition.

The dot gain curves also show that the waterless printing exhibited consistently lower dot gain than printing with water. For conventional screens, this lower dot gain tended to be proportional throughout the tone scale. Therefore, conventional separations that were going to be printed by waterless lithography could be successfully made by lowering the overall dot gain allowance without changing the dot gain proportions.

Figure 9 presents a series of graphs showing the difference in dot gain between waterless printing and printing with water. The plots for the stochastic and conventional halves of the test form are shown on the same graph.

Again, the shadow portions of the graphs showing the dot gain difference between waterless and regular lithography are influenced by the fact that there is a 100% limit for dot size, and dark tones are sometimes interpreted as solids by the densitometer. However, the graphs show an interesting and consistent pattern. There is about the same change in dot gain at the midtones for both stochastic and conventional screens, but in lighter values, there is considerably greater dot gain difference with the stochastic screens than there is with conventional screens. This phenomenon causes the dot gain curves of the stochastic screens to be more symmetrical with waterless printing than they are when printing with water. This, in turn, indicates that the dot gain curve shape (as opposed to the magnitude of dot gain) does not require as much adjustment for waterless printing as for normal lithography with stochastic screens.

Print Contrast

The index of print contrast was calculated from solid and 75% patches. The new standard, ANSI CGATS.4-1993, specifies that an 80% tone area would be appropriate for the printing stock used in this test, but 75% was chosen so that the results could be evaluated in terms of the prevalent data currently available.

Print contrast is closely correlated with dot gain within a given printing system. It is used to determine optimum inking densities, and it is a popular process control parameter. Table 3 shows the print contrast values for this test.

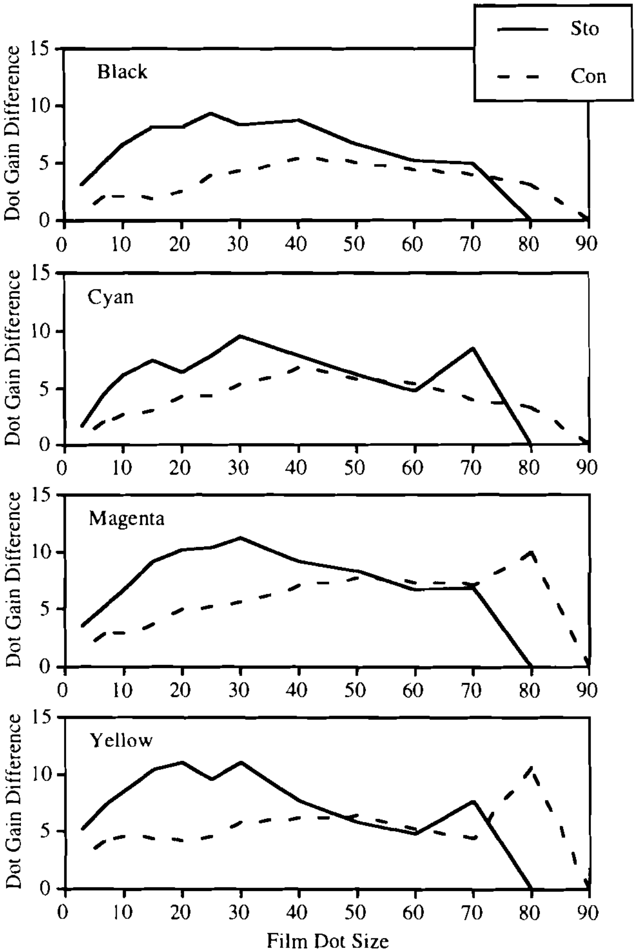

Figure 9. The difference in dot gain between the waterless and regular pressruns, plotted for each color and each screening method.

	K	C	M	Y
W-Sto	10.2	12.4	8.1	7.7
NW-Sto	23.7	23.5	22.6	15.9
Diff.	13.5	11.1	14.5	8.2
W-Con	43.5	36.6	37.6	29.3
NW-Con	48.8	43.2	44.8	35.7
Diff.	5.3	6.6	7.2	6.4

Table 3. Print contrast values.

The print contrasts for conventional screens with water, ranging from 29.3 to 43.5, are typical values for sheetfed printing on coated stock. For the waterless run, these values increased by an average of 6.4. This increase is consistent with the lower dot gain levels experienced with waterless printing. More tones in the shadow end of a reproduction can be distinguished with waterless printing.

The print contrast values for stochastic printing with water, ranging from 7.7 to 12.4, are extremely low. This is due to the higher dot gain levels of stochastic screens. It indicates that the important shadow information in a reproduction should not be confined to the region between 75% and 100% film dot area. These findings suggest that the print contrast index as it is now used may not be appropriate for stochastically screened images. Instead, a tone value less than 75% should be chosen to provide a more sensitive index of shadow detail.

When waterless lithography was used, the stochastic print contrast values increased by an average of 11.8. This is further evidence that waterless printing profoundly improves the dot gain characteristics of stochastic screens.

Ink Trapping

Blue, green, and red ink trapping were measured for solid inks and for tone values at 20%, 40%, and 70% (Figure 10). The solid trapping is not influenced by the halftone structure, but it was conjectured that the trapping at lower tone levels might be influenced by the dot structure.

Although the trapping values showed differences between the four different printing conditions, there was not a discernible pattern. In general, trapping was lower for higher amounts of coverage with all printing conditions tested.

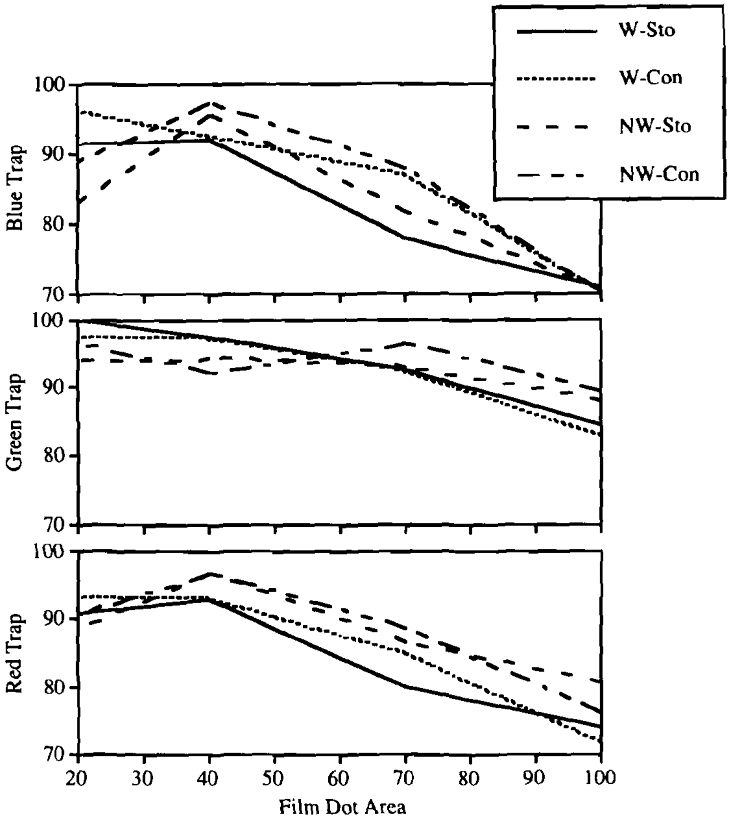

Figure 10. Ink trapping.

Gray Balance

Gray balance was measured at four different levels of darkness for each printing condition. Colorimetric measurements were used to select the most neutral three-color patches (i.e., those patches closest to the origin of the CIE L*a*b* color space.) Table 4 shows a data table consisting of the CIE L*a*b* coordinates, the black densities, and the dot sizes of the selected neutral patches.

	L*	a*	b*	K Dens.	C	M	Y
W-Sto	82.70	-0.86	-4.19	0.21	7	5	5
W-Con	87.69	0.40	-3.46	0.15	7	5	5
NW-Sto	84.47	-0.71	-4.81	0.19	7	4	5
NW-Con	89.20	-0.81	-3.71	0.13	7	3	5
W-Sto	57.67	0.68	-0.62	0.59	30	22	24
W-Con	70.00	-0.12	-0.40	0.39	30	24	28
NW-Sto	62.65	-0.21	-0.08	0.51	30	24	28
NW-Con	73.19	-0.32	-0.97	0.35	30	22	28
W-Sto	40.64	0.07	-0.46	0.94	60	48	54
W-Con	48.26	-0.58	0.79	0.77	60	52	56
NW-Sto	44.60	-0.39	0.22	0.85	60	50	54
NW-Con	54.15	-0.42	0.60	0.66	60	48	54
W-Sto	30.36	0.02	-8.05	1.21	80	66	72
W-Con	33.96	0.95	-5.47	1.11	80	76	78
NW-Sto	30.97	-0.21	-3.21	1.19	80	76	78
NW-Con	36.57	2.08	-1.08	1.03	80	74	78

Table 4. Gray balance data table.

The gray balance data table shows that some printing conditions and darkness levels contained patches that were closer to the CIE L*a*b* origin than others. The most consistent difference between the gray balance from different printing conditions was that the stochastic patches were darker, due to their higher dot gain, than the conventional screens. This difference is seen in the black density measurements made from the selected patches. The relationships between cyan, magenta, and yellow dot sizes did not seem to change in a systematic way with the different printing conditions. These relationships are seen in the gray balance curves shown in Figure 11.

The gray balance curves show similar relationships of dot values between cyan, magenta, and yellow for all the printing conditions. This finding is not surprising, since the inks were the same in all four cases. It does not appear that dot structure or the presence of water had a major influence on gray balance.

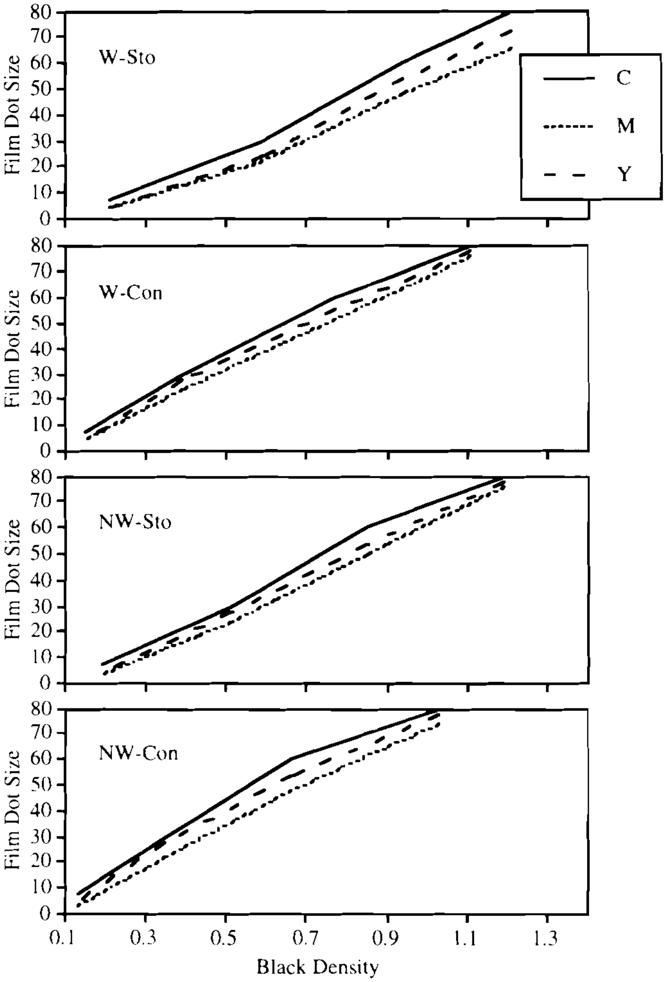

Figure 11. Gray balance curves.

Ink Coverage Target

The reflection densities were measured from a selection of patches from the ink coverage target. The total ink coverages of the measured patches ranged from 245% to 385%. A graphic representation of the black densities of these patches is shown in Figure 12.

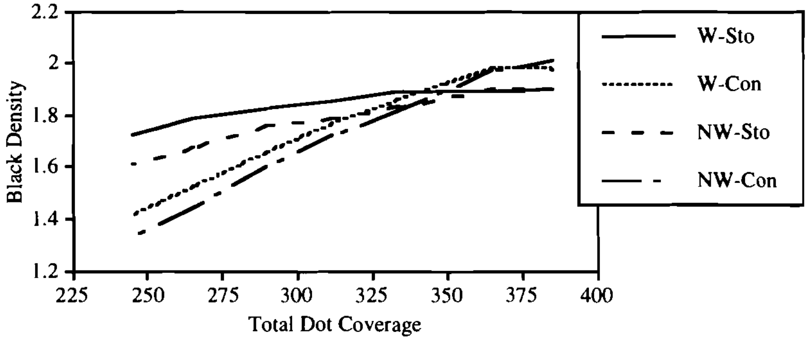

Figure 12. Reflection densities from ink coverage target.

In Figure 12, printing with water resulted in higher densities for heavy amounts of coverage, but this finding is complicated by the differences in inking density during the two pressruns (see Figure 6).

In the ink coverage graphs of stochastic and conventional screens in Figure 12, the conventional plots have steeper slopes. Although the densities that result from a high amount of coverage are similar for stochastic and conventional screens, this relationship changes for lower amounts of ink coverage. For conventional screens, the densities resulting from dot area coverages below 365% decrease rapidly, indicating that a total dot area coverage of about 360% is required to achieve a suitably dark shadow with either printing process. However, with stochastic screens the density falloff is far more gradual. About 330% dot area coverage is sufficient to provide acceptable shadow density with either printing process. This finding is consistent with the higher amount of dot gain exhibited by stochastic screens.

Color-Correction Target

The color correction target is used to judge the best two-color combinations for creating saturated secondary colors of the correct hue. The best combinations vary with different printing systems.

Colorimetric measurements were made from the color-correction target for the blue, green, and red overprint combinations. The data table for blue (Table 5) shows the cyan and magenta dot combinations, the CIE L*a*b* coordinates, the chroma, and the hue angle for each of the four printing conditions. The blue data was chosen to represent the set because the findings for all three secondary colors were similar, with the blue falling between the red and the green in magnitude.

The delta E values in the first column of Table 5 represent the total color difference between the top and bottom patches of the color correction target. It is evident that the stochastic screens do not create as broad a range of colors (i.e., lower delta Es)

	C	M	L*	a*	b*	C*	h°
W-Sto	95	95	28.0	24.5	-49.4	55.1	296.4
	95	90	28.4	24.3	-49.2	54.9	296.3
	95	85	28.4	24.3	-49.0	54.7	296.4
delta E	95	80	28.5	23.3	-49.4	54.6	295.3
8.23	95	75	28.8	23.1	-49.0	54.2	295.2
	95	70	29.7	21.5	-49.2	53.7	293.7
	95	65	30.6	19.6	-49.0	52.7	291.8
	95	60	31.9	17.2	-49.0	52.0	289.3
W-Con	95	95	26.8	21.2	-50.8	55.0	292.6
	95	90	27.9	19.0	-50.5	53.9	290.7
	95	85	29.2	16.2	-50.0	52.5	287.9
delta E	95	80	31.2	11.6	-49.9	51.2	283.1
24.75	95	75	32.9	8.2	-49.4	50.0	279.4
	95	70	34.7	4.6	-49.5	49.7	275.3
	95	65	36.3	1.7	-49.1	49.1	271.9
	95	60	37.9	-0.9	-48.8	48.8	269.0
NW-Sto	95	95	26.2	22.5	-50.0	54.8	294.2
	95	90	27.0	21.4	-50.3	54.6	293.0
	95	85	27.4	20.0	-50.3	54.2	291.7
delta E	95	80	28.3	17.8	-50.6	53.6	289.4
15.26	95	75	29.5	16.0	-50.1	52.6	287.7
	95	70	30.3	14.1	-50.5	52.5	285.6
	95	65	31.9	11.5	-50.4	51.7	282.8
	95	60	33.4	9.1	-50.2	51.0	277.7
NW-Con	95	95	26.4	23.2	-48.0	53.3	295.7
	95	90	27.9	20.4	-47.7	51.9	293.1
	95	85	29.7	16.0	-47.3	49.9	288.7
delta E	95	80	31.7	11.5	-47.2	48.6	283.7
27.86	95	75	33.7	7.7	-46.7	47.3	279.4
	95	70	35.4	4.0	-46.9	47.1	274.8
	95	65	37.2	1.4	-46.5	46.6	271.7
	95	60	39.1	-1.6	-46.3	46.3	268.1

Table 5. Data measurements from the blue portion of the color-correction target.

from the same film dot range as do the conventional screens. This finding, consistent with other findings in this study, is attributable to the higher dot gain of stochastic screens.

In the case of blue, a hue angle of 270° represents an accurate blue hue in the CIE L*a*b* color space (i.e., the blue axis). It is interesting to note that 270° was not contained in the range of hue angles from the stochastic screens for either type of printing, while it was encompassed in the range of hues resulting from conventional screens. It would be necessary to extend the range of tone values in the color-correction target to obtain a hue angle of 270° with stochastic screens. It should be noted that common practice is to select the desired blue overprint visually, not through colorimetric analysis.

Selected Color Patches

Eight tertiary colors from the IT8 basic color field were chosen for colorimetric analysis. The colors were selected to provide a broad sampling of the CIE L*a*b* color space. Figure 13 shows the L*a*b* locations of the colors for the conventionally screened images printed with water. The CIE L*a*b* plots of a single color patch (H-6) are shown in Figure 14 for all four printing conditions.

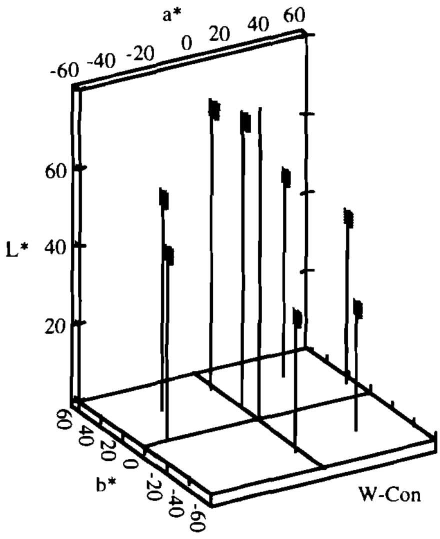

Figure 13. CIE L*a*b* locations of the selected colors.

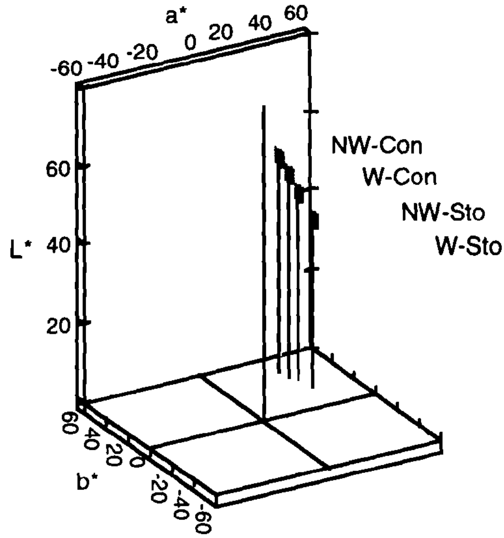

Figure 14. CIE L*a*b* locations of patch H-6 (20%C, 70%M, and 100%Y) for the four printing conditions.

The plots in Figure 14, which were typical for the selected patches, show that the colors resulting from the stochastic screens were darker than those from conventional screens. This finding is linked to the higher dot gain exhibited by stochastic images. The difference was less pronounced for printing without water than for regular lithography. Saturation and hue changes between the four printing conditions were also observed. Further examination of these differences is aided by Table 6, which shows the IT8 designation of the chosen blocks, the cyan, magenta, and yellow components, the CIE L*a*b* coordinates, the CIE chroma values, and the hue angles for the four printing conditions.

The differences in the darkness of the reproduced colors is seen as the differences in L* values for the various printing conditions (lower values indicate darker colors). Increases in saturation are indicated by higher C* values, and changes in hue are seen as different h° values. Note that the selected patches did not all show the same differences. For example, there was very small darkness differences between the four reproductions of patch H-1, while there were very large ones between the I-8 patches.

	C	M	Y		L*	a*	b*	C*	h°
H-6	20	70	100	W-Sto	42.0	39.0	22.6	45.1	30.1
				W-Con	50.6	35.2	38.3	52.1	47.4
				NW-Sto	46.9	36.9	32.6	49.2	41.4
				NW-Con	54.5	32.7	43.0	54.0	52.7
H-7	20	20	70	W-Sto	59.6	1.0	37.5	37.5	88.5
				W-Con	71.6	-1.7	39.8	39.8	92.4
				NW-Sto	66.3	-1.2	41.3	41.3	91.7
				NW-Con	74.8	-1.4	38.4	38.4	92.1
H-8	70	20	100	W-Sto	47.3	-30.4	19.9	36.3	146.8
				W-Con	54.2	-32.9	31.6	45.6	136.2
				NW-Sto	50.6	-32.0	27.1	41.9	139.8
				NW-Con	57.6	-28.7	37.8	47.5	127.2
H-12	100	70	20	W-Sto	31.1	8.6	-32.2	33.3	284.9
				W-Con	34.5	-3.1	-38.6	38.8	265.5
				NW-Sto	32.2	5.0	-33.9	34.3	278.4
				NW-Con	36.2	-1.9	-36.9	36.9	267.0
I-8	20	20	40	W-Sto	60.5	2.1	18.1	18.2	83.2
				W-Con	73.2	0.4	15.2	15.2	88.5
				NW-Sto	66.9	0.9	19.0	19.0	87.4
				NW-Con	76.0	1.0	13.9	14.0	85.8
H-1	70	100	20	W-Sto	30.5	22.9	-28.5	36.6	308.8
				W-Con	31.1	33.5	-30.8	45.6	317.4
				NW-Sto	31.1	27.5	-28.9	39.9	313.6
				NW-Con	32.2	39.6	-28.2	48.6	324.6
H-10	100	20	70	W-Sto	45.1	-37.0	7.6	37.7	168.4
				W-Con	48.0	-48.6	0.1	48.6	179.9
				NW-Sto	46.5	-41.6	7.6	42.3	169.7
				NW-Con	50.1	-44.6	0.8	44.6	178.9
H-4	20	100	70	W-Sto	39.8	44.5	16.3	47.4	20.1
				W-Con	42.3	56.1	16.6	58.5	16.5
				NW-Sto	41.8	50.3	19.8	54.0	21.5
				NW-Con	43.8	58.7	16.8	61.1	15.9

Table 6 Colorimetric values of selected patches.

Values for delta E, an overall color difference index, were calculated from the data in Table 6 for the color differences between types of screening and types of printing. These values appear in Table 7.

No.	W-Sto W-Con	NW-Sto NW-Con	W-Sto NW-Sto	W-Con NW-Con
H-6	18.3	13.5	11.3	6.6
H-7	12.6	9.0	8.1	3.5
H-8	13.8	13.3	8.2	8.2
H-12	13.7	8.5	4.2	2.6
I-8	13.0	10.4	7.1	3.1
H-1	10.9	12.2	4.6	6.7
H-10	14.2	8.3	4.8	4.6
H-4	11.8	9.1	7.1	3.0

Table 7. Delta E values of selected color patches.

An examination of the delta Es in Table 7 reveals higher color difference values for the two screening techniques when water is used than when waterless lithography is used (the second and third columns of Table 7). Furthermore, the color differences between waterless and regular lithography are generally higher when stochastic screens are used than when conventional screens are used (last two columns of Table 7). Again, the differences were not uniform for the selected colors, and, in some instances, the patterns were reversed. For example, patch H-1 showed a higher color difference with conventional screens than with stochastic screens under the two types of lithography. This anomaly may be explained by the local inking conditions on the two halves of the press form during the two pressruns (see Figure 6). However, the overall pattern of color changes is that larger color differences were found between the two types of screens when they were printed with water than when waterless lithography was used.

Conclusions

When evaluating the results of these tests, it is important to remember that they represent specific testing conditions. The screening system, materials, imaging system, and printing system that were used are important factors. The results cannot safely be generalized to other printing conditions.

The film duplication exposure test showed that the stochastic screen had far more dot gain due to overexposure than a 175-line conventional screen. It is apparent that more careful exposure is needed for the stochastic films.

The film duplication test also showed that no acceptable dot-for-dot duplicate was made from the stochastic images. Therefore, the dot size changes due to film duplication must be accounted for in the calibration of the reproduction system for stochastic screens. With conventional screens, film duplication was very close to dot-for-dot, and therefore it is not necessary to calibrate separately for this operation.

On the printed test forms, both screening techniques yielded excellent renditions of the images. The stochastic screens provided slightly more image detail than the conventional ones. The stochastic screens were completely free of moiré, but graininess was evident in vignetted areas.

The press test confirmed that stochastic screens have more dot gain than conventional screens. It was also found that the dot gain curves for stochastic screens were shaped differently (less symmetrical) than dot gain curves for conventional screens. Therefore, when stochastic screens are used, the magnitude *and* the distribution of dot gain must be adjusted.

When waterless printing was used, the dot gains were lower for both types of screens. This reduction was particularly great for the stochastic images, and it tended to counteract the quartertone shift that was evident when printing with water. It appears that waterless printing is a particularly effective process to use with stochastic screening.

Due to the higher dot gain of stochastic images, print contrast values were found to be very low. It is probable that a more sensitive print contrast index for stochastic screens would be based on a film dot value lower than 75%.

No distinct pattern attributable to screen type was found in ink trapping at several tone levels. Waterless printing yielded slightly higher green and red traps for the solid inks.

The ratio of process inks needed to achieve gray balance was not substantially different for the two screening techniques. The gray patches for stochastic screens were darker for a given amount of coverage due to the higher dot gains.

For the printing system in this study, the total dot coverage required to produce an acceptable shadow density is lower for stochastic screens (330%) than for conventional halftones (360%).

Similarly, the two color overprint ratios used to produce blue, green, and red hues are different for stochastic screens. An examination of selected tertiary colors found that large color differences resulted from the reproduction of three-color patches with the two screening techniques and with the two methods of printing, This finding indicates that different dot area values are needed to make matching colors with each of the printing conditions. It is not clear that printing with water could achieve CIE Chroma (saturation) values as high as those achieved by waterless printing.

In summary, stochastic screens require different treatment than conventional ones. The prepress reproduction of images needs to be done with great care. The reproduction characteristics of stochastically screened images are different by nearly every measure, not only in magnitude, but also proportionally (as indicated by different curve shapes).

Many of these differences presumably are corrected for in the compensation program that can be applied before outputting stochastic images to film. These programs are designed to make stochastic images reproduce in a similar way to conventional screens. The ideal compensation program would take into account the type of printing, since waterless and conventional lithography produced different changes with stochastic screens.

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