STOCHASTIC SCREENING: WHAT TO DO WHEN YOUR RIP DOESN'T SUPPORT IT AND COMPARISON WITH CONVENTIONAL SCREENING ON AN OFFSET PRESS

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Abstract:

Amplitude modulated (AM), or halftone, screens place varying sized dots in exact locations to simulate a continuous tone image. In contrast, frequency modulated (FM), or stochastic screens, place identical sized dots in a random pattern to simulate a continuous tone image. This paper compares AM and FM screens on the same press sheets from the same set of plates on an Offset printing press. The AM screens were produced using standard RIP settings on an AGFA ProSet 9550 Imagesetter, while the FM screens were produced using the "diffusion dither" option in Photoshop prior to sending to the RIP. In order to achieve a meaningful comparison of images printed by the different screening methods, we developed a set of cutback curves for the black ink to obtain "zero" apparent Tone Value Increase (dot gain) on press for each screening method. These curves were then applied to all four colors in the 4-color press run. Colorimetric measurements showed good agreement between the two screening methods. Dot fidelity analysis showed that viable dots were obtained with either screening method, but that significant Tone Value Increase (TVI) occurred from film to plate and from plate to press with either screening method. The independent cutbacks to zero apparent TVI were required since the actual TVI was different for the two screening methods.

Introduction:

AM and FM screening take two totally different approaches to generating dithering patterns for reproducing a continuous tone image (Fischer 1989, Schlapfer 1994, Tritton 1996, Chung 1997 and Scheuter 1985). AM screening is another name for the conventional method of generating digital halftones. It breaks up an image into dots of varying sizes and precisely centered on a rectangular grid to simulate the original (usually photographic) image. In order to produce a four color image using AM screening, varying screen angles are generally applied to cyan, magenta, yellow, and black (CMYK) to avoid printing identical grids on top of one another and producing objectionable moiré patterns (Yuasa 1994). Furthermore, there is always a physical and mathematical relationship between number of gray levels, the resolution of the imaging device and the screen ruling, such that there is always a tradeoff between resolution and number of reproducible grayvalues (Scheuter 1985).

FM screening, on the other hand, keeps the dots the same size and varies the frequency, or number, of dots and the location of those dots to simulate the original image (Scheuter 1985 and Stanton 1994). In FM screening, screen angles are not necessary when printing a four-color process job. The elimination of screen angles results in the eradication of the patterns (i.e. moiré) in the printed image, which are associated with printing multiple screens of nearly the same frequency. A pure FM process would be deterministic and would suffer from periodic moiré patterns (Stanton 1994), but a randomization can be used to break up the periodicity (Carli 1993)). This latter process is called stochastic screening (Molla 1988). The terms "error diffusion" or "diffusion dither" are also often used to describe this process.

This paper shows the on-press production of both AM and FM screened images, simultaneously, from the same plates and on the same press sheets. In addition, we show that FM, or stochastically screened images, can be produced on any device, regardless of whether the RIP (Raster Image Processing) of the device supports such screening, by using imaging editing tools, such as Adobe Photoshop. In addition to visual comparisons, we present colorimetric and dot fidelity analysis of the different screened images. A summary of the equipment used for this research is given in the Appendix.

Experimental Procedures:

Initial configuration

In order to reproduce both AM and FM screened images from the same color separations in a manner that allows a meaningful comparison of brightness and chromaticity, it is necessary to control them to the same tone value increase (TVI, formerly known as dot gain) on press. Controlling the TVI of one printing process to match a standard or another printing process is well known. For offset printing, standards (Adams 2000) such as SWOP (2001a) (Specifications for Web Offset Publication), GRACoL (2002) (General Requirements for Applications in Commercial Offset Lithography), PROP (Adams 2000) (Prepress Recommendations for Offset Packaging) and SNAP (2000) (Specifications for Non-Heatset Advertising Printing) specify ink dot gain target values along with screen rulings, screen angles and target densities. Many of these have been incorporated into the ISO 12647 (1996) standard . For flexographic printing, "cutback curves" (Samworth 1998) are usually applied in prepress to compensate for the fact that the flexographic process exhibits larger TVI than offset for a given dot area on film. Generally, the target is to simulate about a 20% TVI at a nominal 50% dot area, which is consistent with the offset standards discussed above.

Here, we find it most convenient to cutback both AM and FM screened outputs to target "zero" apparent TVI on press. This required us to characterize or "fingerprint" the printing press consistently for both screening methods. To achieve this, tonal values of images were adjusted using the "curves" feature in Adobe Photoshop, much like the procedure discussed by Fleming (2004). The resulting adjusted color separations were output to an AGFA ProSet 9550 imagesetter using images placed in Adobe PageMaker. This generated film, from which plates for a Heidelberg KORD offset printing press could be exposed.

The RIP supplied with the ProSet 9550 does not support direct generation of FM screened images. To work around this problem, the "diffusion dither" option in Photoshop was used to generate FM screened separations, prior to sending them to the AGFA RIP. Imation Viking GMX negative working subtractive plates for the KORD (21.625" x 24.625") were exposed using a NuArc 631 Exposure System. TVI was determined by comparing the specified dot area to the actual printed dot area. The printed area was measured with an X-Rite 328 densitometer and dot areas were estimated from the Murray Davies (Murray 1936) equation. The "curves" feature of Photoshop was then used to systematically cutback samples that were printed using black ink only. These curves were then applied to all four process colors, assuming that the TVI would be independent of ink color. The procedures we followed are detailed below.

Figure 1 TVI calibration image. The digital file for this image was provided by DICE America.

1. Test image setup

Our methods of generating cutback curves for output devices to correct to zeroTVI are discussed elsewhere (Fleming 2004). This involves printing a calibration test image from a digital file, which contains known percentages of the CMYK process colors.This image was obtained from DICE America as an EPS (Encapsulated Postscript) file (Figure 1). Since the AGFA RIP didn't generate FM screens, we couldn't output separations to the imagesetter in the usual fashion. Instead, we had to use the "diffusion dither" option in Photoshop. Since this feature only operates on grayscale images, by converting them to bitmap, we had to generate separations as grayscale files. This was accomplished by saving the image in DCS format (Quark 1993) . DCS (Desktop Color Separations) is a variation of the EPS format, developed by Quark, whereby the CMYK color separations are output in separate files as EPS grayscale images.

For calibration purposes, we worked with the black separation. The FM screened black separation was generated by opening the black DCS separation in Photoshop and converting it to bitmap employing the "diffusion dither" option.The initial AM screen was output to the imagesetter at 141.42 lpi @ 45° generated using 1200 dpi and the FM screen was output at 1200 dpi by choosing 1200 dpi in the Photoshop Diffusion Dither dialog box.

2. Dot area measurement on press sheet

The film negative from the imagesetter was developed and a plate was exposed.The plate was mounted on the Heidelberg KORD press and several hundred good press sheets were printed using Sun Chemical black ink.The press sheet samples were collected and measured to determine dot area.The dot area was determined using an X-rite 328 densitometer, which has built-in electronics for applying the Murray-Davies Equation (Murray 1936) .These dot area measurements were used to develop cutback curves, which were later applied to the test images for the final color press run.

TVI correction for AM and FM screens

The above-described procedure was repeated for five iterations.Then we obtained a set of press sheets adjusted to no apparent TVI, within the precision of the process. It took three press runs to achieve satisfactory results for the AM screened test pattern and an additional two press runs to obtain satisfactory FM screened image results.The final correction curves used with Photoshop are depicted in Figure 2.The primary purpose of this adjustment to noTVI, for both screening methods, is to obtain two printed images that have the same nominal color values, but differ only in screening method.

1. Obtaining data

After each press run five samples were selected at random and the dot area was measured as described above. The measured dot area value was subtracted from the target dot area to determine the amount ofTVI on press.This information was used to determine the cutback curves shown in Figure 2.

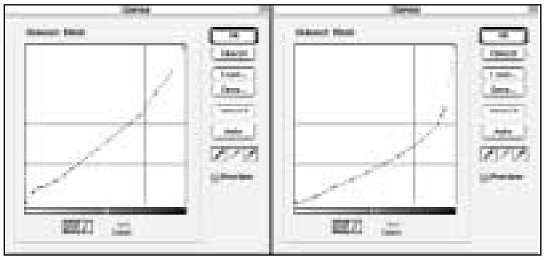


Figure 2 Cutback curves used to adjust to zero apparent TVI on press.The left was used for AM screening, while the right was used for FM Screening.

2.Applying Corrections

The correction curve for the AM screened case was applied to the original gray scale image file and the result was saved into a new file. For the FM screened case the correction curve was applied to the original grayscale image file, the file was converted to bitmap with the diffusion dither option and the result was saved as a new file.

Major obstacles in producing AM and FM screened images

During this study, two distinct problems occurred that had to be overcome prior to printing a full four-color image. The problems were 1) no dots were present in the highlight area of the FM screened plate at 1200 dpi, and 2) the dot area of the 1200 dpi image was very difficult to control on press, because only dots that merged together to form "clustered dots" on the plate actually printed. In order to address these problems the following actions were taken.

1. Split plate exposure

The tonal ranges of the AM and FM screened images were very different.The FM screened image had a very small tonal range due to the fact that the small 1200 dpi dots could not be resolved at the 30 unit exposure setting that had been optimized for conventional AM screened images.The highlight dots were present on the negative but they were not resolved on the plate. In order to recalculate the optimal exposure setting for the FM image, a series of step exposures were performed. From these exposures, a new exposure setting of 110 units was chosen for the FM screened images. We continued to use the recommended 30-unit exposure setting for the AM screened images.

2. Using 600 dpi versus 1200 dpi

The dot area of the 1200 dpi test image was almost impossible to control on press.This is due to the extremely small dot size involved. 1200 dpi corresponds to nominally a 21 µ square dot. The actual dot size on film was determined by densitometric measurements to be less than 3 µ.This resulted from recorder TVI (dot gain) on the imagesetter, which reduced the effective size of clear area on the negative. A size of 3µ is less than the plate resolution, which is in the 4-6µ range. To compensate for this, the image was reduced from 1200dpi to 600 dpi when the diffusion dithered bitmap file was created. By reducing the number of dots present, we were able to control the TVI more precisely. At 600 dpi, the actual effective square dot size was determined to be 24µ, which is resolvable on the plate, even though the nominal square dot size for 600 dpi is 42µ. As we shall see, the final dot size on press is significantly larger. The stochastic cutback curve shown in Figure 2 was based on 600 dpi dither pattern.

After these two actions were taken, we were able to print a process color job to compare the two screening methods.

Process color image manipulation

The image chosen for this project was taken from a Corel Photo CD. This image is shown in Figure 3. Since this image was obtained as a digital file, no color corrections were applied other than those necessary to control the press output. However, since it was a digital file, there was no original to compare with other than the monitor image. Thus, the only comparison that could be made was the AM screened version with the FM screened version.

1. Image Editing operations

The image was opened in Photoshop 4.0 in RGB mode and converted to CMYK. The RGB to CMYK conversion was performed with a monitor setting, having $\gamma = 1.8$, a white point of 5000°K and Trinitron phosphors and assuming SWOP (2001a) inks with no dot gain. In current ICC color management terminology (Fleming 2002 and Sharma 2003), this process corresponds to converting to CMYK with a generic Trinitron monitor profile as the RGB working space and the Photoshop 4 default CMYK working space profile (using Photoshop 6 or 7, for example). The assumption of no dot gain is because we have calibrated to zero apparent TVI. The image was then saved as 5 files (a low-resolution composite preview and 4 separations) in DCS format. The separations were opened in grayscale mode. The AM correction curve was applied to each separation and saved under a new name. The separation files were reopened, the FM correction curve was applied, the image was converted to bit map with a 600 dpi diffusion dither and was saved under a new file name. This produced the color separations as four gray scale files for each screening method.

Figure 3. Image chosen to compare AM and FM screening on press.

2. Page Layout operations

The AM and FM images were placed into Adobe PageMaker, one separation at a time, and sent to the imagesetter. For each color the links were updated from a master composite image link so the AM and FM images would remain in register relative to one another and the separations would remain in register relative to the same set of registration marks. The AM screened images were imaged at the optimized digital halftones of 126.5 lpi @ 18.43° for cyan, 126.5 lpi @ 71.57° for magenta, 133 lpi @ 0° for yellow and 141.42 lpi @ 45° for black.

Results and Discussion

Initial configuration press run assessment

Figure 4 shows the TVI that occurred during the initial press run. The FM image (1200 dpi) incurred a significant amount of both positive and negative TVI. Negative TVI (TVL for Tone Value Loss) resulted from extreme recorder TVI in highlights upon producing negatives on the imagesetter. This recorder TVI in highlights reduced the size of the clear areas to about 14 % of the intended dimension (2% of the intended area). TVI occurred in midtones and shadows due to significant net TVI from film to plate to press.

Dot area correction of AM and FM images press run assessment

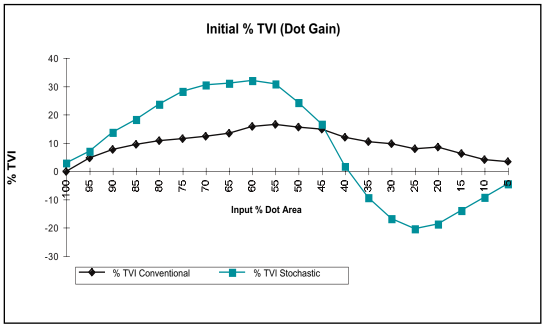


Figure 4. Initial TVI curves for AM (conventional) and FM (stochastic) screening

Figure 5 shows the apparent TVI that was measured after the final cutback curves were applied to the test image. The Stochastic dot pattern was generated at 600 dpi as discussed above. Note that the change in scales masks the almost full order of magnitude reduction from actual TVI to apparent TVI. These were judged acceptable, within the precision of the process, for making the desired comparisons. The correction curves that produced the results shown in Figure 5 were applied to each of the process color images of the car.

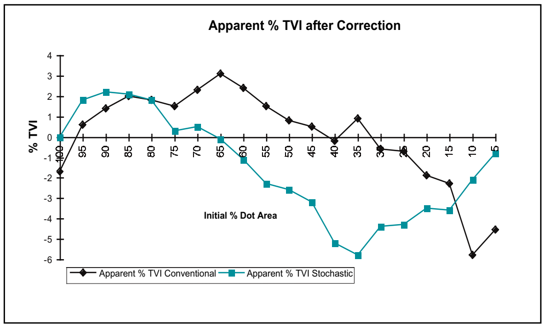


Figure 5 Final apparent TVI curves for AM (conventional) and FM (stochastic) screening.

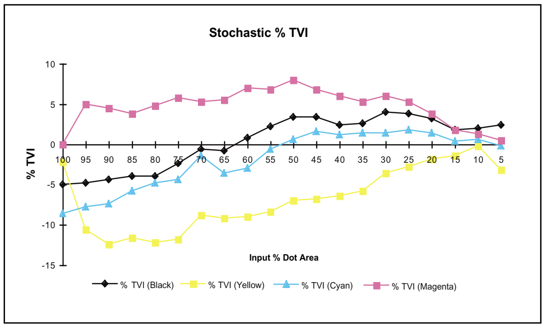


Figure 6 Apparent TVI for the different colors for FM screened test image.

Four color press run assessment

Four plates were exposed through the separation negatives. They were printed in the order YMCK, using Sun Chemical SWOP standard process inks. Table 1 shows the target densities and the average solid ink density of 5 samples of each ink and screen type. Note that the measured densities were significantly lower than the target densities. This has nothing to do with the screening method, since a printed solid uses no screen. The low densities are a function of the press performance, depending on ink rollers, water rollers and ink/water balance. The apparent variation of ink density between screening methods represents density variations across the press sheet, not intrinsic behavior of the screening method.

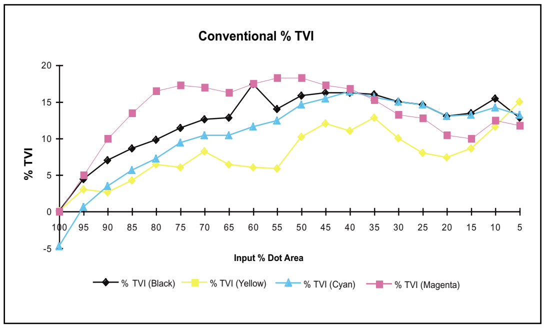


Figure 7 Apparent TVI for the different colors for AM screened test image.

Screen Type		Cyan	Magenta	Yellow	Black
Conventional	Target	1.20-1.35	1.30-1.45	.95-1.10	1.55-1.75
	Average	.95	1.18	.83	1.53
Stochastic	Target	1.20-1.35	1.30-1.45	.95-1.10	1.55-1.75
	Average	.84	1.28	.78	1.33

Table 1. Target densities and the average solid ink densities of 5 samples at each screen type

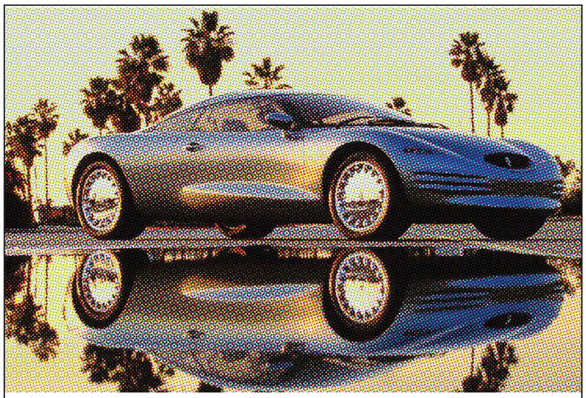
TVI of FM screened images

After the press was optimally inked with each ink color and the corresponding separations printed with that ink, we mounted the final calibration plate on the press and printed the test pattern to assess the TVI for each process ink. The results for each ink color for the FM screened strips are shown in Figure 6. These data show a significant amount of apparent TVL in cyan, yellow, and black, but a significant apparent TVI in magenta. The magenta showed TVI at essentially all tints, with a peak of about 7% in midtones. On the other hand, the yellow showed apparent TVL at essentially all tints with a maximum loss of 12% in shadows. The cyan and black show TVI for highlights and midtones and TVL for shadows. The TVL can be attributed in part to the low solid ink densities (the Murray Davies calculation was normalized to the highest observed density for a given color) from Table 1 and a possible ink distribution problem.

TVI of AM screened images

The corresponding apparent TVI results for the AM screened test image are shown in Figure 7. These data show that there was a significant amount of apparent TVI in all four colors at all tints, with the exception of the 100% cyan. The 100% cyan had TVL due to possible ink/water balance problems and low ink densities observed on some of the selected sample sheets. The dot areas for all of the samples in Figures 6 and 7 were normalized to the highest sampled density of the given color, regardless of the screening method. This explains how both methods showed TVL at 100% ink for cyan. At least one sample had exactly zero TVI, while some others had TVL from the choice of normalization. This will always be true, but normally it is not so noticeable as in this case where the stochastic side of the plate showed significantly lower cyan density (c.f. Table 1).

A simulation of the printed press sheet is shown in Figure 8. The top image is printed using nominal 66 lpi halftone @ 600 dpi (63.25 lpi @ 18.43° for cyan, 63.25 lpi @ 71.57° for magenta, 66.67 lpi @ 0° for yellow and 70.71 lpi @ 45° for black, exactly half the frequency of the press run. The bottom image is printed with a stochastic screen generated by the diffusion dither option in Photoshop. Both images have been cutback to zero apparent TVI for comparison purposes.



Conventional

Stochastic

Figure 8 Simulation of press print using a conventional halftone screen on the top and a stochastic screen on the bottom.

Colorimetric Measurements of Selected Areas

In order to quantitatively compare the colors in the printed output, we measured selected regions of the printed images. Since there was no hard copy original, there is no way to know how the printed output should look. However, given that the color separations used the Photoshop 4 default CMYK space, we can use the Photoshop 4 Default CMYK working space profile to estimate the expected printed colors. These values can be read using Photoshop, by selecting a region of the image and invoking the histogram display.

The regions of the car were chosen for sampling; one on the right front wheel highlight between the top two spokes, one in the sky immediately above the right front palm tree and one on the right front fender above the bumper. The CIELab values for these regions of the printed image were measured, for three press sheets chosen from the top middle and bottom of the delivery end of the press, with a Gretag SPM60 Spectrophotometer, using a D65 reference. Correspondingly, regions of the image file were selected in Photoshop and the average Lab values were determined from the histogram tool. Comparisons of the results are given in Table 2. The standard deviations for the file reflect variation throughout the selected region of the image. The standard deviations for the press sheets are variations over the three sheets. Neither of these standard deviations represents variations due to matching the exact area sampled with the spectrophotometer with that sampled in the displayed image. The ΔE values are calculated from the usual distance formula (CIE 1971):

$$\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{.5} \tag{1}$$

When comparing these values, we should recall that the file values were intended for nominal "SWOP" inks on "SWOP" coated paper. The previously recommended paper from Deferiet Paper Company is no longer available (SWOP 2001b). The paper used for our research was a "standard" coated paper that was donated to the Department of Paper and Printing and Western Michigan University. With this in mind, the agreement between the printed and expected values is remarkably good for the wheel and sky area. The agreement for the fender is not as good, with the conventional being significantly better for this case. Note, however, that the stochastic is significantly better for the wheel and sky areas.

Recall that, if the same average ink coverage had been obtained throughout the image for the two methods, then they would be colorimetrically indistinguishable from one another. In this case, neither would necessarily match the expected ones in the file. The variation between the two methods really results from the differences between Figure 6 and Figure 7, for the actual TVI. If no apparent TVI had been obtained, then the printed samples would look the "same color". Even if the colors look the same, the printed images won't look the same. They may differ, for example, in sharpness and uniformity. This is related to dot fidelity, which is discussed below.

Some of the variations between the printed and file colors can be explained if we compare the colorimetric values for the solid process colors and the three-color overprint. These are given in Table 3. There is no effect of screening on these values, because solids are unscreened. We note that all of the values are far from the nominal values. Not only are the measured values far from the nominal values, but also the primary colors are greatly reduced in saturation. This has the effect of reducing the effective printing gamut. The high L value for black and three-color black also reduces the printing gamut. Thus, the agreement of the color of the chosen areas is better than could have been expected, and possibly fortuitous.

	L	L Std. Dev.	a	a Std. Dev.	b	b Std. Dev.	∆E from File
Wheel							
File	96.7	.4	-.6	.6	5.6	.8	
Stochastic	91.6	.3	-1.5	.1	5.8	.38	1.1
Conventional	87.2	.8	-2.4	1.0	4.3	.2	5.4
Sky							
File	94.7	.2	-3.8	.5	14.8	.8	
Stochastic	91.0	.3	-3.2	.5	10.6	.6	4.7
Conventional	85.4	.2	-3.9	.8	1.4	11.1	7.1
Fender							
File	38.1	2.0	5.9	3.2	-29.4	4.6	
Stochastic	54.3	1.7	5.1	1.2	-17.4	1.0	20.2
Conventional	39.7	4.7	4.2	6.5	-20.7	2.0	9.1

Table 2. Comparison of colorimetric values between press sheets and those in the digital file.

	L	L Std. Dev.	a	a Std. Dev.	b	b Std. Dev.	∆E from File
Cyan							
Profile	62		-31		-48		
Printed	52.9	2.8	-16.8	1.7	-40.6	.6	18.4
Magenta							
Profile	48		83		-3		
Printed	51.3	3.7	58.8	1.7	3.6	4.5	25.3
Yellow							
Profile	94		-14		100		
Printed	90.2	.1	-.9	.4	72.2	2.7	28.5
Black							
Profile	0		0		0		
Printed	38.1	2.4	1.0	.2	1.97	.8	38.2
3 color Black							
Profile	18		9		-5		
Printed	29.0	1.9	14.5	2.3	-1.9	3.5	12.0
Paper							
Profile	100		0		0		
Measured	94.3	.41	-.6	.2	3.7	.5	6.8

Table 3. Comparison of colorimetric values between press sheets and those in Photoshop 4 CMYK profile.

Dot Fidelity Analysis

Printed dot fidelity is known to be an important component of image quality (Fleming 2003 and Sarafano 1999) . For a given device resolution, controlled uniformly sized and shaped dots produce sharp and uniform images, regardless of the screening method. Dot fidelity analysis was performed for the different colored inks, the two screening methods and the printing plate used to print the calibration pattern, using the methods of Fleming et. al. (2003). Image analysis was aided by ImageXpert 9.1.4 from ImageXpert and Image Pro Plus 4.5 from Media Cybernetics. The data were taken from the nominal 5% "Black" tone step on the calibration image. Recall that all colors were printed from the same calibration plate (see TVI of Images discussions above.) The Results are summarized in Table 4.

The measured dot areas are similar for all colors and both screening methods. This is consistent with the dots at the 5% tint being the smallest dot that can be held on the press. The average dot area on the plate of about 1200µ^2, corresponds to a circular dot diameter of about 40µ, a square-dot side of_ 35µ. This is smaller than the nominal square dot area of about 1800µ^2 and nominal square dot side of about 42µ. This results from the larger than expected exposed area on the negative, which translates to a TVL (dot loss) on the corresponding positive.

Color	Dot Area (μ^2)	Area Standard Deviation (μ^2)	Roundness	Roundness standard deviation
Conventional				
Cyan	3810	730	0.88	0.05
Magenta	5480	870	0.83	0.08
Yellow	4260	690	0.84	0.08
Black	3790	620	0.84	0.09
Average	4335	1080	0.85	0.08
Plate	1154	176	0.93	0.10
Stochastic				
Cyan	3340	430	0.88	0.06
Magenta	4320	860	0.85	0.07
Yellow	4250	580	0.86	0.05
Black	2680	450	0.86	0.10
Average	3750	1134	0.86	0.07
Plate	1298	279	0.82	0.16

Table 4. Dot fidelity data for the four colored inks and the printing plate.

The estimated clear dot area of the film was about 600 µ, corresponding to a square dot dimension of 24 µ, for the stochastic dot. The corresponding clear dot area for the conventional film was estimated to be about 1000 µ and a circular dot diameter of 36 µ.The latter number was obtained by multiplying the nominal cell area of 32258 µ, for a 141.14 lpi halftone times 3.14% coverage calculated from the Murray-Davies equation.Thus, the dot on the film is about a third of the nominal area and the dot on the plate is about two thirds of the nominal area for the stochastic case. However, the final printed dot was about twice the nominal area and three times the area on the plate. In all, the area grew six times the area on the film.The average dot area of about 4000 μ^2, translates to a square dot 63 µ on a side, or a circular dot 71µ in diameter. Likewise, the printed dot for the conventional case grew to four times the area on the film.

The increased apparent exposed area on imaging the negative, which leads to a TVL (i.e. dot loss) in the clear area, which then increased 4-6 times in area on press, points out one of the weaknesses of film based workflow.This is the underlying reason why highlights become so difficult to control when using film. This is one of the advantages of Computer to Plate (Adams 1999) (CTP) systems, where the film step is eliminated. For CTP, there may be positive TVI on the plate and there will be positive TVI from plate to press. However, this should be more controllable by directly imaging the smallest printable dot on the plate.

Recently, it was proposed that FM screening exhibits primarily optical TVI, with little or no mechanical contribution (Creo 2002). As seen here, there is significant mechanical TVI from plate to press with either screening method. For the tone step analyzed here, the measured TVI values from plate to press are virtually identical for the two screening methods. It is difficult to imagine any offset process with a rubber blanket that doesn't exhibit mechanical TVI, even with waterless plates.

Summary and Conclusion:

The primary goal of the research reported here was to compare AM and FM screening on the same plate on the same press. In order to obtain a valid comparison, we chose to linearize the tonal response to obtain zero or low tone value increase. Assuming TVI is independent of ink color, we chose to linearize for a single color (black) printing of both AM and FM screened images and use the results for all printed colors.The results show that by using the "curves" feature of Photoshop, the amount of TVI can be reduced by an order of magnitude. SWOP (11) specifies 15-25% TVI at the 50% tone step on press, depending on color. However, all of the values are significantly below this range after linearizing. Without this adjustment, the AM screened values in Figure 4 are consistent with this range, while the FM screened values in Figure 4 are significantly higher in midtones and shadows and TVL (dot loss) is significant in highlights.

The linearized tone values were used to produce a process color printed piece.The results shown in Figures 6 and 7 indicate that the correction curve that was developed for black ink is not as accurate for all process inks on the chosen coated stock as for the original black ink. In order to achieve smaller apparent TVI, for all colors, one should develop cutback curves for each ink type and substrate combination.This is a topic for future investigations. Indeed the results summarized in Figures 6 and 7 can be used to generate such curves, at least for the given inks and substrates.

Spot checks of color values in the printed image showed good agreement between the screening methods and with values predicted by the computer file, even though the individual solid colors were significantly different from those stored in the Photoshop 4 CMYK working space profile.

Dot fidelity studies using image analysis indicated well-formed, reasonably uniform dots for both processes. Both processes showed significant TVI for film to plate to press.

Acknowledgment

We wish to that the following individuals and companies for their advice and support in this project: John Serafano of LSI, and Eric Huntington of North American Color, Joe Falasco of Welch Packaging and Sun Chemical Corporation who donated the ink for this work. Our interactions with them and their support provided us with an excellent environment to experiment and learn. We thank ImageXpert for donating a workstation and software that was used for the dot fidelity analysis.

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Appendix A.

Equipment and materials used.

Prepress:

Computer:	Mac 7600/132
Monitor:	17" Multiscan 1705
Screen:	AM-133 lpi FM-600 dpi
Software:	PageMaker 6.5, Photoshop 4.0
Imagesetter:	AGFA ProSet 9550
Film:	#1 Network, #336 HP Infrared Film

Press:

Press:	Heidelberg KORD
Paper:	Simpson, 80lb. Silverado Matte
Plate:	Imation Viking
Ink:	Process Inks-Sun Chemical Naturalith II Initial Black- Sun Chemical Ebony OSSF Dense Black
Ink-down Sequence	YMCK
Printing Speed:	2,500 impressions per hour