Stochastic Screening for Flexography and Its Application to Expanded Gamut Printing

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Abstract

Although it offers many benefits, stochastic screening is known to present difficulties when applied to the flexographic printing process. However, with a high industry interest in expanded gamut printing, it is necessary to explore the potential success of stochastic screening in flexography and its application to the expanded gamut printing process. The study was conducted to determine the performance of stochastic screening in flexography and its effectiveness when applied to expanded gamut printing.

To do this, a systematic approach was used. First, a single-color target comparing three different stochastic patterns was printed and analyzed. From that, a specific screening was chosen and implemented into a 7-color characterization that generated an ICC profile with an extended gamut. The profile was then applied to an expanded gamut application where continuous tone images of classical paintings were reproduced.

The findings show that due to advancements in flexographic technology, stochastic screening performed well with great print contrast values averaging around 51% and a small minimum dot size of 38 microns. When applied to seven color printing, it proved to prevent moiré issues and produced a very large gamut with a gamut volume of 1,007,582. As expected, Tonal Value Increase was a slight issue that could be researched in further study. Overall, the results were exciting and present a hopeful view for the future of stochastic screening in flexography.

Introduction

Historically, there has been a high interest in stochastic screening throughout the industry. The enhanced image quality and absence of moiré make this screening method desirable to all types of printers. However, due to its limitations, stochastic screening has proven to be difficult to successfully implement into the flexographic printing process. Expanded gamut printing is another area of the printing that is of high interest, particularly among the package printing industry. It offers the benefit of simulating nearly all spot colors with only seven inks as well the ability to expand the restricted color gamut of CMYK continuous tone images closer to their original color space. However, due to the screen angle constraints of conventional halftone screening, it is nearly impossible to fully prevent undesirable moiré patterns when printing with seven colors. With recent advancements in flexographic technology, there is a need to explore the potential success of full implementation of stochastic screening into the seven color expanded gamut printing process.

Stochastic screening is a method of creating halftone separations of an image using randomly distributed halftone dots. Where as conventional screening simulates densities by varying the sizes of the dots that are arranged in a grid, stochastic screening uses dots of the same size placed at varying distances from each other to simulate densities (Packaging Technology, 1994).

Because of this, stochastic screening offers several advantages over conventional screening. First, it completely eliminates the possibility of apparent moiré patterns. Unlike conventional screening where the axes of screens have to be separated by at least 30° to achieve an acceptable minimum pattern, there are no screen angles involved in overlapping halftone screens with stochastic screening. Therefore, the randomly placed dots do not form patterns. This also allows for the opportunity to print more than four colors on top of each other without moiré. This is especially valuable to the expanded gamut printing process. Also, because there are no angles involved, slight misregistration errors on press tend to be more forgiving with stochastic screens. An error as small as .01° can cause color shift issues when using conventional screening, but with stochastic screening no color deviations are caused by misregistration. Stochastic screening is also known to enhance image quality because of its ability to increase ink densities, which directly improves tonal range and contrast. Lastly, the small dots used in stochastic screens function to improve the overall sharpness and detail of images (Eldred, 2008).

Although it has its obvious advantages, there are a couple major issues with stochastic screening; apparent graininess and tone value increase. Stochastic dots tend to produce a grainy texture in flat tones making it more suitable for application to images with texture and patterns. Because more dots are used to simulate densities, the dot gain associated with each printed dot will contribute to a larger overall tonal value increase. In flexography, dot gain is already known to be an apparent problem, so the two working together causes an excessive amount of dot gain that is difficult to control (Eldred, 2008).

In the past, the combination of the poor dot gain performance with flexography and stochastic screening has prevented stochastic screening from being implemented into many flexographic systems. However, in response to this issue a new screening method was introduced to the industry know as hybrid screening. Hybrid screening involves using stochastic patterns in the highlights of an image (usually 10% and below) and conventional screening for the additional mid-tones and shadows. This allows for controllable dot gain while still printing highlights that truly fade to zero. (Gooran, 2005)

However, when it comes to expanded gamut printing, the application of hybrid screening still presents the problem of moiré. When printing with seven colors, it is possible through the use of an ICC profile to place complementary colors on the same screen angle and ensure that they will never appear when their complementary color is printed. This resolves the moiré issue for green and orange, however, violet (or blue) cannot be placed on the same angle as yellow. Usually when creating four-color halftone separations, cyan, magenta and black are placed the required 30° apart leaving no room for the fourth color yellow in 90°. Since yellow is the least noticeable color, a compromise is made and it is placed 15° apart from cyan or magenta. Placing violet on that angle, however, is a problem since it is a very noticeable color and will influence unacceptable moiré patterns. Instead, placing it on the same angle as black is suggested so that it will only moiré with black. No matter what, using conventional or hybrid screening for 7-color process printing will yield undesired moiré patterns. For this reason, there is need for the implementation of stochastic screening in the expanded gamut printing process.

With the introduction of HD Flexo from Esko-Artwork, there is a renewed optimism for stochastic screening for flexography. One of the major factors that has contributed to the poor performance of stochastic screening in flexography is inability to hold a small minimum dot size. The high resolution of HD Flexo technology provides better spot definition allowing for smaller spot sizes. Smaller dot sizes help reduce the graininess issue that arises when using stochastic screening, as well as produce sharper images (PackagePRINTING, 2009).

The objective of this study was to explore the implementation of a stochastic screening in flexography and its application to expanded gamut printing.

Hypothesis Statement

Because of developments in flexographic technology, the application of stochastic screening in flexography will yield acceptable results and will be an effective solution for completely preventing moiré in expanded gamut printing.

Methods and Materials

All three press runs were conducted on an Omet Varyflex 7-Color Press at The Sonoco Institute of Packaging Design and Graphics using an 8pt C1S paperboard from MeadWestvaco, CMYKOGV UV inks from Environmental Inks, and Dupont Cyrel DFM Fast Plates. The plates were imaged using a CDI Spark 4835 with

Inline UV by Esko-Artwork and developed using a Dupont Cyrel Fast 1000TD. The plates were mounted with a Lohmann DuploFLEX 5.2 (Medium Soft) mounting tape. Harper 1000cpi/1.7 BCM anilox rolls were used.

Stochastic Benchmark

In order to determine the best stochastic screening method for the specified printing conditions, a single-color test run was performed. The purpose of this test was to compare three different stochastic screening methods at different line rulings.

A fingerprint file (see Appendix B) was set up using Adobe Illustrator. Monet, Monet for Flexo, and Organic screens were chosen and each arranged in to tint scale columns at different selected LPIs (85, 100, 120, 150, 175, 200). Using Esko Automation Engine, the layout was driven through a workflow.

After printing the single-color (black) fingerprint, the dot areas of each screening method were measured using an xRite 300-series Spetcrodensitometer which calculates dot area using the Murray-Davies formula. The results are shown in Appendix A.

7-Color Characterization

After determining the optimal stochastic screening method, a 7-color press characterization was performed to generate an ICC profile for the Omet Varyflex under the specified print conditions. In order to gather enough information about the different combinations of seven colors, 8 different IT8.7/4 targets had to be printed and measured. These included two sets of each combination of CMYK, OrangeMYK, CGreenMYK, and CMBlueK. In order to ensure that complementary colors will never appear on top of each other in a color build, OGV were substituted for CMY respectively one time to create the corresponding IT8.7/4 targets. Utilizing these IT8.7/4 characterization targets, a layout was set up using Adobe Illustrator. (see Appendix C) Two copies of each target were placed into the layout along with a gradation strip of each color. However, this did not require placing 16 separate targets on one sheet. In order to limit the sheet size, the OGV color stations were only turned on when their complementary color station was turned off. This yielded four different sheets of the different color sets.

Once the layout was finalized, Monet stochastic screening at 150 lpi (38 microns) was applied, and it was sent through a proofing workflow and printed on the Epson Stylus 7900. Under the same conditions as the single-color test, the characterization was then printed paying close attention to maintain an even impression across the sheet and to follow industry standard ink densities.

The printed targets were then taken and measured using an xRite Isis eyeOne Spectrophotometer. After measuring multiple copies of each target, MeasureTool was used to average the sets of measurements and using ProfileMaker 5.0, ICC profiles were created for each of the four-color combinations. These four ICC files were then compiled in Esko's Color Engine to form one 7-color ICC profile.

Expanded Gamut Application

The information gathered from the previous tests was then implemented in an expanded gamut application. Several continuous tone images of famous paintings were selected to be reproduced with stochastic screening and the expanded gamut process. These samples can be found in the *2013 Clemson University TAGA Journal.*

The images were converted into seven colors using an Esko-Artwork technology called Equinox. Equinox is a module within Esko's Color Engine that allows for standardization of printing presses for five, six, or seven colors of choice. Using the Equinox plug-in within Adobe Photoshop, the chroma of each painting was pushed to achieve a preferred reproduction for the new 7-color profile.

The images were then placed into a layout in Adobe Illustrator. In order to analyze the effects of the 7-color process, CMYK images were placed beside the same CMYKOGV images. Monet screening was then applied at 150 lpi (38 microns) and the file was driven through the workflow.

The job was then printed on the Omet Varyflex under the same conditions as the previous runs.

Results and Discussions

Stochastic Benchmark

The results of the single-color stochastic test provided information for examining the screening performance of *Monet* and *Monet For Flexo* stochastic screen patterns. According to Esko-Artwork, the difference between the two patterns deals with the consistency of dot size. *Monet Screens* use first order stochastic screening, which means the exact same dot size is used throughout the tonal range. *Monet for Flexo* Screens, however, use second order stochastic screening meaning slightly bigger dots are used in the shadows than in the highlights in effort to prevent the holes between dots from filling in in the shadow areas. (Esko-Graphics, 2004) Although included on the layout, results for *Organic Stochastic* were not analyzed or included in this report due to obvious visual flaws in the patterns.

The first aspect of concern when looking at the screen performance was dot gain. As shown in **Figure 1.1 and 1.2**, there was an apparent of amount of gain throughout the different LPIs and patterns. There was an average mid-tone gain of 28% ranging

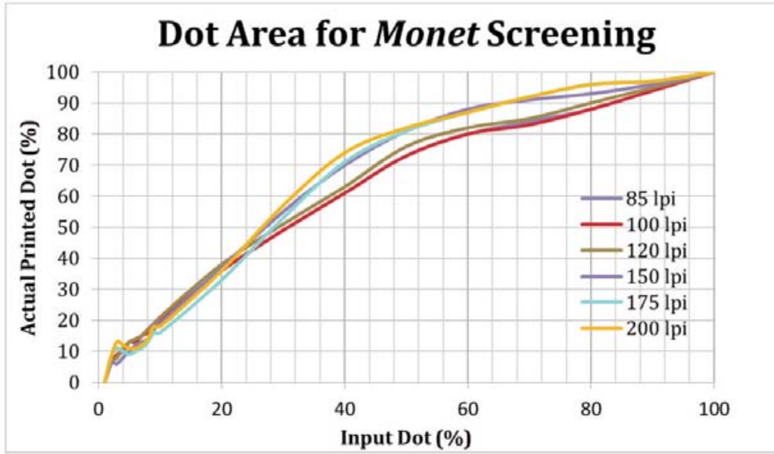

Figure 1.1: *Dot gain curves in percent (%) for Monet Stochastic Screening*

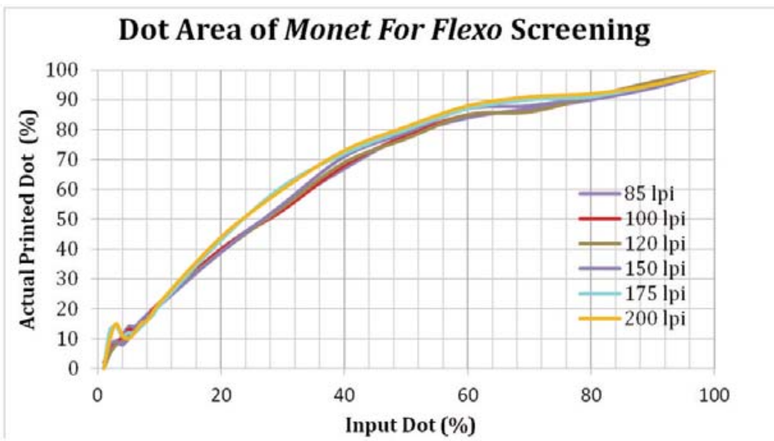

Figure 1.2: *Dot gain curves in percent (%) for Monet for Flexo Stochastic Screening*

from 23% to 32%, which is high compared to and industry standard of around 15% or 20%. Highlights proved subject to an average gain of 6.5% ranging from 5% to 9%. These results indicate that stochastic screening held up to its reputation of high dot gain. However, the overall results aren't terrible and should be potentially controllable with a simple compensation curve.

Print contrast compares the density of the solid to the density of the 70% tone, basically indicating the print quality in the three-quarter tones. Overall print contrast results were great with an average measurement of 51%. (**See Table 1**) Typically, a higher percentage, such as 51%, is desirable because it indicates the ability to have the highest possible solid ink density while still being able to hold open the tones.

Print Contrast						
Pattern Type	**85 lpi**	**100 lpi**	**120 lpi**	**150 lpi**	**175 lpi**	**200 lpi**
Monet for Flexo	55%	55%	54%	52%	49%	48%
Monet	57%	57%	55%	47%	44%	44%

Table 1: *Print Contrast measurements comparing SID to 70% tint.*

Dot performance is another major aspect of the success of stochastic performance. The ability to hold a small stable minimum dot size is critical for quality tone reproduction. The results shown in **Table 2** show the differences in printed dot sizes of the *Monet* and *Monet for Flexo* patterns at the different LPIs. The table also contains the theoretical dot size of the *Monet* screen calculated using a formula, provided by Esko-Artwork, that relates the dot size in microns to the equivalent LPI ruling. Inherently, as the LPI is increased, dot size becomes smaller and frequency increases.

When visually analyzing the results of the printed stochastic target, it was evident that some of the dots screened at higher LPIs were dropping out. For *Monet*, the highest ruling before apparent holes in the pattern were visible was 150 LPI or 38 microns. For *Monet for Flexo*, it was 120 LPI or 48 microns. This presented the minimum dot size that could be held on press using the available technology.

Printed Dot Size in microns (µ)						
Dot Type	85 lpi	100 lpi	120 lpi	150 lpi	175 lpi	200 lpi
Monet (Theoretical)	66.82	56.80	47.33	37.87	32.46	28.40
Monet (Actual)	95.25	94.23	72.90	52.07	52.58	51.82
Monet For Flexo	64.01	64.52	62.74	50.29	44.96	46.99

Table 2: *Printed dot size measured in microns.*

After evaluating the overall performance of the printed stochastic screen patterns, the conclusion was made that *Monet* at 150 LPI (38 microns) performed the best. It had a great print contrast value of 47%, which indicates its ability to hold detail in the shadows. When looking at the dot gain curve, it possessed a smooth curve. That means it should have consistent tonal transitions throughout the tonal range. Also, out of the tested screens, it held the smallest minimum dot size of 38 microns. This is important because a smaller minimum dot will enhance image quality and lessen the graininess effect associated with stochastic screening. Lastly, Monet at 150 LPI was also chosen because it didn't contain any visually obvious patterns at any of the printed screen tints. In some of the other screens, snaking patterns were visible to the eye at certain tints.

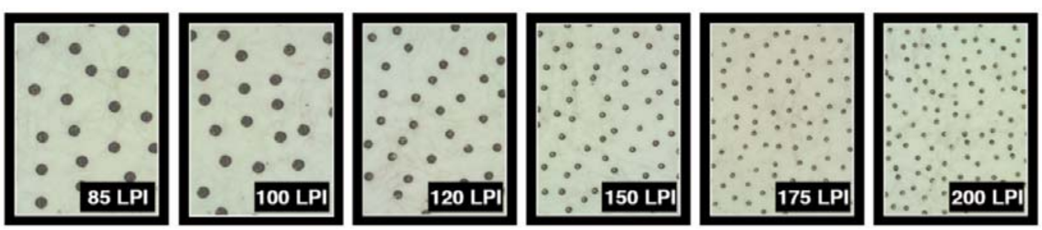

Figure 2.1: *Monet dots on printed target at 5% tint.*

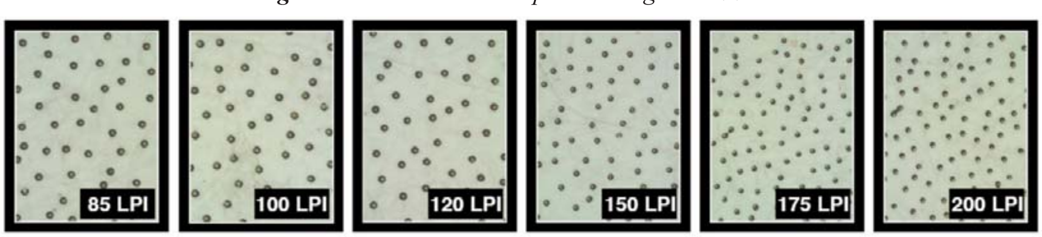

Figure 2.2: *Monet For Flexo dots on printed target at 5% tint.*

Expanded Gamut Application

The results from the 7-color characterization and product run show an overall successful application of stochastic screening to the expanded gamut printing process. First of all, as predicted, it completely prevented the presence of moiré in 7-color printing. This was proven because when visually analyzing the results from the characterization run and the reproduced paintings, there were no apparent patterns visible.

Also, the common dilemma of graininess in image reproduction when using stochastic screening proved to be minimized, most likely due to the ability to hold a small dot size (38 microns) using HD Flexo technology. Although classical paintings that contained a lot of texture and detail were chosen to illustrate the advantages of stochastic screening, the lack of graininess in the reproduced images was still impressive.

Concerning gamut expansion, the results showed that the color gamut, when using the 7-color process, was successfully extended. **Figure 3** compares the gamuts of the 4-color profile and the 7-color profile generated during the characterization. As shown, the 7-color gamut is dramatically larger (more chroma) than the 4-color gamut. **Table 3** gives the gamut volumes for each profile as well as the GRACoL standard 4-color flexographic profile. These gamut views and volume calculations were derived using Esko Color Engine Pilot. The gamut of the 7-color profile generated in this study is over twice the size of the 4-color standard. It is also worth noting that the gamut of the 4-color profile generated in this study is larger than the 4-color GRACoL standard. According to a previous study, stochastic screening yields a larger gamut than conventional screening. This is mainly due to the fact that there is more optical dot gain in halftone screening. Optical dot gain has a graying effect on filtered light, directly limiting the chroma of a gamut (Pritchard, 2009). This is exciting because it adds another benefit to implementing stochastic screening in expanded gamut printing, by suggesting that using stochastic screening will generate a more chromatic gamut than would conventional screening.

Gamut Volume	
Profile	Volume
4/C GRACoL	467871
4/C Stochastic	584168
7/C Stochastic	1007582

Table 3: *Gamut volumes compared.*

* *There was a small issue with the printed product that is worth noting. When comparing the proof of the art reproductions to the printed art reproductions, it appears that the dot gain was not properly compensated for as the images printed considerably darker on press. The conditions of all the runs were all matched, so it is assumed that something went wrong with the compensation on the computer. However, it is not clear where the error was.*

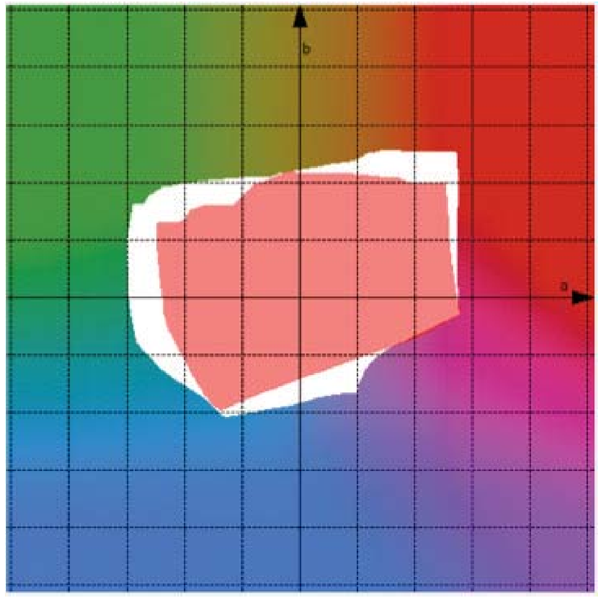

Figure 3: *4-Color Stochastic Profile (Red) vs. 4-Color Stochastic Profile (White)*

Conclusion

Overall, the hypothesis was accepted and supported by the results found. With the implementation of HD Flexo technology, Monet stochastic screening produced satisfactory print quality results and was effectively applied to the expanded gamut printing process to completely prevent the existence of moiré.

The exceptional print contrast results illustrated stochastic screenings ability to enhance image quality by improving overall tonal range and contrast. The small minimum dot size held helped to combat the graininess issue correlated with stochastic screening, and also demonstrated stochastic screenings benefit of reproducing sharp images. Its application to the expanded gamut process was effective and produced a very large gamut. Tonal Value Increase did prove to be an issue when combining stochastic screening with the flexographic printing process. Although, the results were not terrible and offer the potential to be easily compensated for, it is an area of the process that could be improved. One opportunity for further study would be to use hybrid screening for CMYKOG and to implement stochastic for the seventh color, Violet. It is possible the single stochastic screen would be sufficient to avoid the moiré and perhaps reduce the TVI issues.

The use of stochastic screening in flexography is an area of the printing industry that is becoming more and more promising with the improvement of technology. The results found in this study address some of the issues associated with this topic and add optimism to its future success in the industry.

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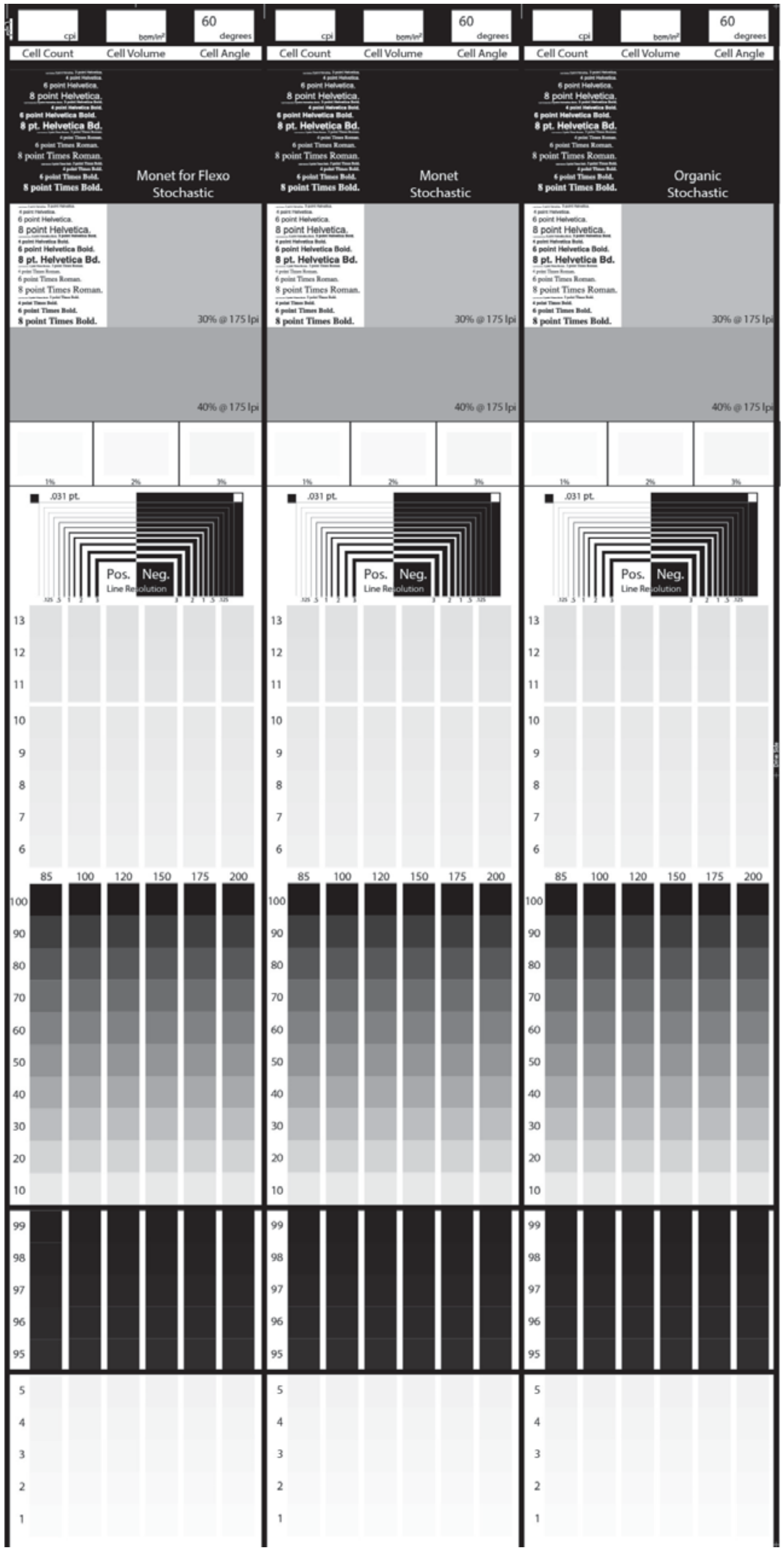
APPENDIX A: Dot Area measurements for Monet and Monet for Flexo Stochastic Screening

Dot Area for *Monet for Flexo* Screening (%)						
Input Dot	**85 lpi**	**100 lpi**	**120 lpi**	**150 lpi**	**175 lpi**	**200 lpi**
1	2	0	0	0	0	0
2	6	6	5	8	13	10
3	8	9	8	9	14	15
4	11	10	9	8	11	11
5	14	13	11	10	12	10
10	22	22	22	21	21	22
20	40	40	39	39	43	44
30	54	53	54	55	61	60
40	67	68	69	71	72	73
50	78	78	77	79	80	81
60	84	85	85	87	87	88
70	87	86	86	88	90	91
80	90	91	91	91	91	92
90	94	96	96	94	95	95
100	100	100	100	100	100	100

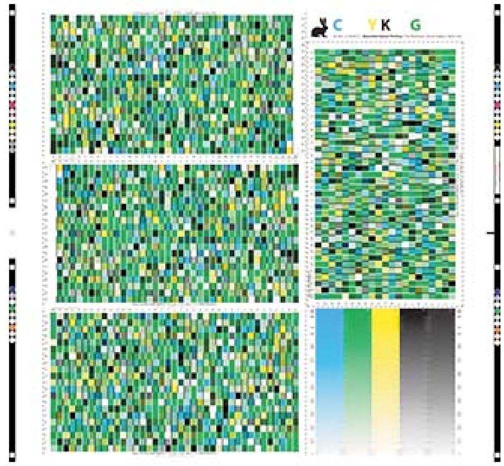
Dot Area in Percent for *Monet* Screening (%)						
Input Dot	**85 lpi**	**100 lpi**	**120 lpi**	**150 lpi**	**175 lpi**	**200 lpi**
1	0	0	0	**0**	0	0
2	6	6	6	**6**	8	8
3	8	9	8	**6**	11	13
4	11	10	11	**8**	10	12
5	13	13	13	**10**	9	11
10	21	20	21	**19**	16	18
20	36	36	38	**37**	33	36
30	49	49	51	**55**	53	57
40	61	61	63	**70**	71	74
50	73	73	76	**81**	81	82
60	80	80	82	**88**	87	87
70	84	83	85	**91**	92	92
80	88	88	90	**93**	96	96
90	94	94	95	**96**	97	97
100	100	100	100	**100**	100	100

APPENDIX B: Single-color Stochastic Benchmark Layout



APPENDIX C: 7-Color Characterization Layouts

(CMYK)



(CGYK)

(CMVK)

(OGYK)