An Analysis of Sheetfed Lithographic Print Attributes

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Abstract
This paper summarizes the findings of a study of sheetfed lithographic printing attributes conducted by the Graphic Arts Technical Foundation (GATF). The study was undertaken to obtain a print profile for high quality sheetfed lithography. This profile is needed to establish attainable print specifications for this industry segment. Thirty-five GATF member companies printed a test form using different press/ink/paper combinations, and submitted 107different samples. Ink dryback, density aim points, dot gain, ink trapping, print contrast, gray balance, and color variation were all studied. Ink dryback was found to vary with different printing systems, but overall a small density loss can be expected as the sheets dry, especially in black. The industry was found to be running at density aim points lower than those set in the General Requirements for Applications in Offset Lithography (GRACoL) guidelines for all ink colors. The relationship of dot gain and screen ruling for black ink showed an increase in dot gain with finer screen rulings. Average midtone dot gains for 150-lpi printing were 20% for cyan, 20% for magenta, 20% for yellow; and 22% for black. Ink trapping on coated paper averaged 72 for blue, 89 for green, and 76 for red. The print contrast values were higher for coarser screen rulings. They were examined in relation to the solid ink densities, 50% dot gains, and 50%/75% dot gain ratios. Gray balance was found to be lower in cyan content than the gray values listed in the Specifications for Web Offset Publications (SWOP). The selected tertiary colors showed clear perceptual differences with different printing conditions. Differences of about 12 ΔE units from the target CIELAB coordinates can be expected when a screen build is sent to a random commercial offset lithographer.

Introduction
This study was designed to provide information useful for setting realistic print specifications for commercial offset lithography. Such specifications are needed because printing is increasingly treated as a commodity rather than a skilled craft. The growing use of distributed production schemes means that the same job can be printed on two different presses with the expectation that the results will match. In addition, color management software is increasingly being used to

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control color consistency throughout the digital imaging workflow. These software programs would greatly benefit from realistic default attribute settings for high-quality commercial offset lithography.

GATF, whose mission includes providing technical services to the lithographic printing community, was well positioned to solicit participation from quality-conscious U.S. lithographic printers. GATF also has technical consultants in the field who can assist in testing and verifying potential specifications.

The print attributes of heatset web offset lithography (used for magazine printing) was measured by the Print Properties Committee of the Graphic Communications Association. The results were used by the SWOP Committee in setting the print specifications for press proofing and the guidelines for production printing. Following the lead of SWOP, the Specifications for Non-heatset Advertising Printing (SNAP) Committee studied the attributes of non-heatset web offset lithography (used for newspaper printing) to develop attainable specifications for that industry segment.

There are no broadly accepted U.S. specifications for general commercial lithography. There are several reasons why it has been difficult to establish such specifications. The great diversity of products that can be grouped under "commercial offset lithography" has dissuaded some researchers. The commercial offset industry acts according to a competitive rather than a cooperative paradigm. In a competitive paradigm, each printing system is operated at its optimum quality point to obtain the best printing for the customer. Alternatively, in a cooperative paradigm, such as magazine printing, each printing system is run to common achievable aim points so that printing from different presses can match. There is less need in a competitive environment for a common set of print specifications because each company strives for the highest quality output. Also, sheetfed printers are often guarded about their print parameters in order to protect their competitive advantages.

The GRACoL Committee has now published the third revision of a communications handbook for the commercial offset market. The handbook provides a broad spectrum of recommendations regarding the production of printed pieces. It contains a Printing Guidelines Chart giving aim points and tolerances for a variety of print attributes. Some printers, including several GATF members, have not been able to successfully print within the GRACoL guidelines. This has prompted the current study to measure the print attributes of quality-conscious lithographers as a basis for establishing achievable aim points.

This study investigates some attributes that are not commonly specified in industry guidelines. These include ink dryback and the KCMY maximum coverage components. Both densitometric and colorimetric measurements were used in this analysis. The recommended aim points are all densitometric values because the densitometer is still the primary tool for process control at the printing press. A more complete report of this study is available from GATF in the Research & Technology Report entitled *GATF Sheetfed Print Attributes Study*.

Population

The population of interest to this study were high-quality sheetfed lithographic printers. The designation of the group as "high-quality" recognizes the wide variety of products printed by sheetfed lithography. The high-quality sheetfed printers are meant to include printers of annual reports, advertising brochures, direct mail pieces, and other full-color products. These products are most frequently printed on gloss coated papers.

This population is a subset of a larger population of sheetfed commercial offset lithographers, which includes book printers, packaging printers, and others. Each different industry segment requires a different set of specifications. The GRACoL guidelines have eight sets of aim points based on paper type and printing process to accommodate different industry segments. This study focused primarily on sheetfed lithographic printing on gloss coated papers.

Characteristics of the Sample

GATF invited member companies with more than 40 employees to participate in this study. Thirty-five companies submitted a total of 107 different printed samples for this study. Additional samples did not fit the criteria of the study and were not included in this paper. The majority of the samples were on gloss coated papers, with a few on matte coated and uncoated papers.

The participants of this study, because they are GATF members, tend to be technically oriented. Furthermore, the fact that these companies voluntarily participated in this study indicates that they are quality conscious.

Six of the participants, about 15% of the responding companies, used computer-to-plate (CTP) systems. The rest of the participants output negative films and made photomechanical printing plates. No printers reported using positive-acting plates for this study. Most of the printers who used four- or six-color presses used the KCMY print sequence (one used CKMY). None of the samples were printed with stochastic screens, and none used waterless lithography.

Procedure

Participants were provided with a digital test form on a CD-ROM. They were asked to place the Encapsulated PostScript (EPS) file in their page assembly program, and to output the file at their preferred screen ruling according to their established workflow. They were asked to linearize their imaging devices and not to apply any compensation curves to the test form.

The press was run to two different density conditions: the in-house density aim points, and the aim points from the GRACoL Printing Guidelines Chart. The participants were not supplied with a proof of the test form to serve as a press guide; instead, they were asked to run only to densities. After target densities were achieved across the press, five samples were labeled and sent to GATF for analysis.

Participants were asked to measure their own ink dryback. They were cautioned to use the same densitometer for the wet and dry measurements. They were also told to make the wet density reading immediately after pulling the sample, and the dry readings after the sheet was dry.

At GATF, all the samples were measured with a Tobias Status-T scanning densitometer. All the solid patches across the color control bar were measured, and the averages for each color were recorded as the densities for that sheet. Those the samples that were found to be within the GRACoL tolerance limits for density were treated as a subgroup. The samples that were labeled as "in-house aim points" were also treated as a subgroup.

Spectral measurements were made at GATF from all the samples with an X-Rite spectrophotometer using D-50 illuminant. These readings were made to obtain perceptually based measurements of color differences.

The analysis of data was performed and the results were shared with the participants.

Limitations of the Study

Any study of operating printing systems must contend with a myriad of uncontrolled variables. In this study, some of the pertinent data was self-reported. The pressruns were not observed. There was no independent confirmation of film recording or platemaking. In addition, no two printing systems are the same; they vary in equipment, printing materials, and environmental conditions.

The participants used several different brands and weights of paper, which were categorized under the broad headings of "gloss coated", "matte coated", or "uncoated." Differences in the printing characteristics of the individual stocks were not investigated. Substrates such as board, which does not fit in any of the categories, were not included in the study.

The participants made dryback measurements with their own densitometers. The variability in density readings due to spectral response differences between the instruments had minimal effect on the dryback data since only density differences were of interest (rather than absolute density measurements.) Another source of variation was from the inconsistent time lapses between the time of printing and the measurement of the wet ink densities. Ideally, the wet readings would be carefully timed since the ink gloss changes rapidly in the first few minutes after printing.

Except where noted, the densitometric and colorimetric measurements made by GATF were single readings. They were not averages of multiple readings from the same patches. Questionable readings were double-checked and either confirmed or corrected.

There was no opportunity to inspect the films or printing plates used by the participants, and therefore, non-linear filmsetters and overexposed printing plates were not identified.

The Test Form

A digital four-color test form, Figure 1, was designed for this study. The form includes test targets and color photographic images to make up a 19x25-in. press form with balanced ink take-off.

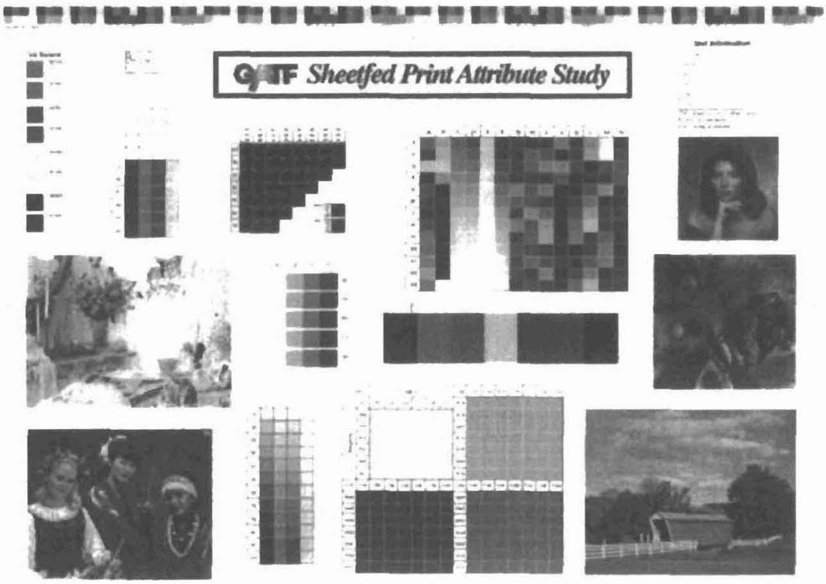


Figure 1. Test form.

The test form was supplied to the participants as an EPS file. It contains an embedded native PostScript information block that records data collected from the RIP including:

- Name of the imaging device
- PostScript version
- Horizontal/vertical resolution
- Screen ruling/dot shape/screen angle

A two-tiered color bar spans the trailing edge of the form to measure during the press run. The top row of the color bar is a repeating series of solid KCMY ink patches. The bottom row contains tints, overprints, and star targets. The color bar is designed to measure the print attributes of density, dot gain (25%, 50%, 75%), ink trapping, print contrast, and gray balance. In addition, the star targets provide some diagnostic capability to detect directional disturbances in dot formation.

Besides the star targets, the only diagnostic targets on the test form are the ink mottle patches. The single-color mottle patches are used to assess the uniformity of ink lay, while the two-color patches show the uniformity of ink transfer.

A special target was provided to help the participants with the measurement of ink dryback. This target is vertically aligned so that the two density measurements needed to calculate dryback are from the same ink key zone. In general, the targets on the test form were aligned to minimize variation due to adjacent ink key differences.

The remainder of the targets on the test form are process characterization targets. These include: the dot size comparator, tone scales, ink coverage target, gray balance chart, and the IT8 Basic Data Set. These were the targets principally used in this analysis.

The photographs on the test form are GATF test images, which emphasize different color reproduction challenges. One exception is the image of the three musicians, which is an ISO Standard Color Image Data (SCID) image.

Ink Dryback

Ink dryback is the term for the decrease in optical density between the time a sheet of paper is first printed and after the ink has dried. The term *dryup* is used to describe the opposite phenomenon when the optical density increases after the ink has dried. The change in gloss as the ink film dries is generally postulated as the cause for the density changes.

The dryback phenomenon makes it difficult to match previously printed pieces using density numbers as the guide. The ink color and the paper surface are both important influences on the amount of dryback to expect. With a given press/ink/paper combination, the dryback can be predicted based on prior testing. The average dryback values for commercial offset lithography from this study can be used for predicting density changes on non-tested printing systems. Table 1 contains summary statistics from the dryback data.

A total of 81 samples were used to ascertain the dryback information: 70 gloss coated samples, 6 matte-coated, and 5 uncoated. The values presented for matte and uncoated papers are based on fewer samples, and, therefore, display much wider confidence intervals.

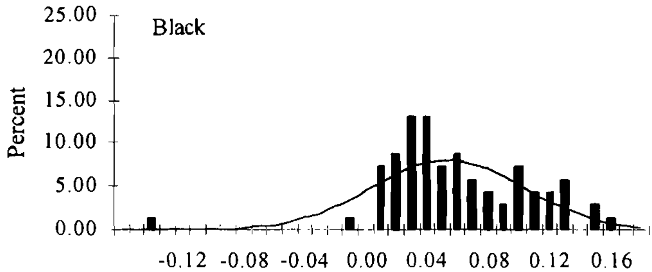
The confidence intervals around the means show the range of possible mean values at 90% confidence. There were enough samples on gloss-coated paper to calculate skewness (symmetry) and kurtosis (central tendency).

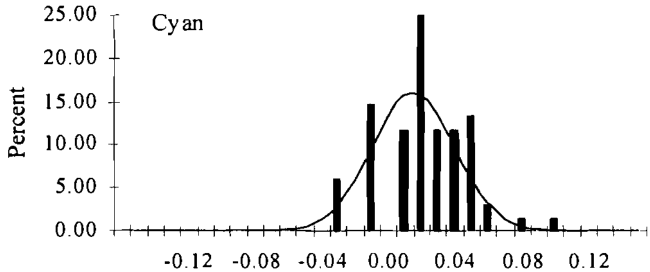
Paper	Stat.	Black	Cyan	Magenta	Yellow
Gloss	**Dryback**	0.06 ± 0.010	0.02 ± 0.004	0.02 ± 0.004	0.02 ± 0.006
	Std.dev.	0.05	0.02	0.02	0.03
	Skew	-0.67	0.14	0.28	0.66
	Kurtosis	2.95	0.14	0.34	0.54
Matte	**Dryback**	0.12 ± 0.045	0.04 ± 0.025	0.03 ± 0.025	0.02 ± 0.025
	Std.dev.	0.06	0.03	0.03	0.03
Uncoated	**Dryback**	0.11 ± 0.095	0.08 ± 0.038	0.05 ± 0.048	0.06 ± 0.029
	Std.dev.	0.10	0.04	0.05	0.03

Table 1. Density dryback results.

The largest dryback values occur on uncoated paper, supporting the theory that change in gloss is the primary mechanism for ink dryback. The drybacks from matte coated papers are between the gloss coated and the uncoated values. The dryback values for black ink were higher and more widely distributed than the values from the other three printing inks. This finding was consistent for all paper surfaces.

Figure 2 shows histograms from the dryback data for gloss coated papers.





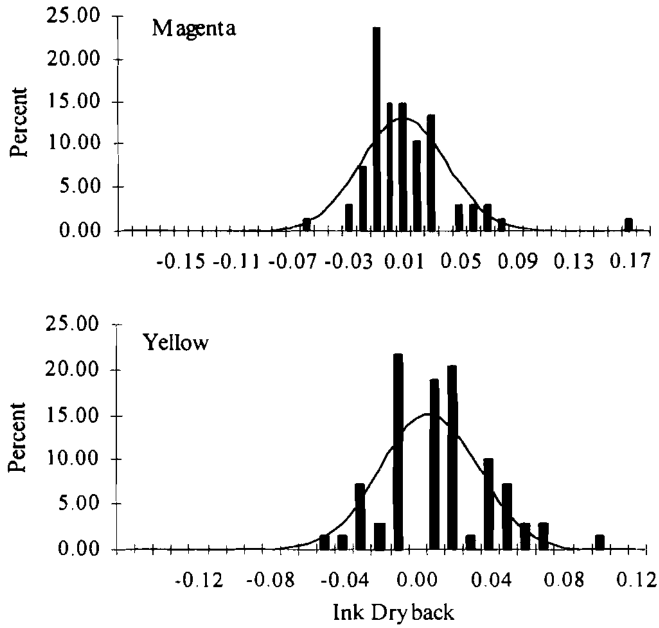


Figure 2. Dryback density histograms for coated papers.

The distributions are nearly normal for the cyan, magenta, and yellow inks. Only black ink has a kurtosis value of greater than 1.0, indicating a more widely dispersed population than the normal distribution. The skewness values for all colors are close to zero, indicating that the dryback distributions are nearly symmetrical.

The mean dryback density values from Table 1 (black 0.06, cyan 0.02, magenta 0.02,and yellow 0.02) can be used as default values for commercial offset lithography. However, it is best to measure the dryback of each printing system to obtain the most precise control in hitting specific dry densities.

Density Aim Points

The average values of the in-house density aim points are shown in Table 2. The gloss coated subgroup consisted of 44 samples submitted from 35 companies.

Paper	Color	Densities	Std. dev.
Gloss	Cyan	1.33 ± 0.03	0.10
	Magenta	1.39 ± 0.03	0.10
	Yellow	0.98 ± 0.03	0.10
	Black	1.62 ± 0.03	0.12
Matte	Cyan	1.24 ± 0.09	0.09
	Magenta	1 30 ± 0.09	0.09
	Yellow	0.97 ± 0.05	0.06
	Black	1.46 ± 0.11	0.11
Uncoated	Cyan	0.91 ± 0.14	0.09
	Magenta	1.01 ± 0.11	0.07
	Yellow	0.81 ± 0.03	0.02
	Black	1.04 ± 0.06	0.03

Table 2. In-house density aim points.

The standard deviations indicate that there was a wide range of in-house density aim points among the companies in the study. The wider confidence intervals for matte coated and uncoated papers are due to the small sample sizes for these substrates. In general, the matte coated and uncoated density aim points are lower that the gloss coated aim points, but they have similar balance between the process colors.

The average density values from the in-house specifications were lower than the GRACoL guidelines for all colors. The average values from Table 2 can be used as default density aim points for sheetfed lithography since these densities are achievable by the largest section of the population.

Screen Ruling

Participants were asked to print the test form at their most commonly used screen ruling. Table 3 shows the number of companies that used various screen rulings.

Screen	Number of companies	
	Imagesetters	Platesetters
133-lpi	2	1
150-lpi	13	2
175-lpi	8	2
200-lpi	6	1

Table 3. Screen rulings used by participants.

There was a fairly even division between 150 lpi and finer screen rulings (175 lpi plus 200 lpi) indicating that one cannot assume a particular screen ruling for all of commercial offset lithography. Dot gain and print contrast both vary with screen ruling, so, it is necessary to specify screen ruling when establishing guidelines for process control. The best single screen ruling to choose for an industry-wide specification would be 150 lpi since some printers may struggle with finer screens. It would be reasonable to use 150-lpi specifications for 175- or 200-lpi work if the aim points for dot gain were raised by appropriate amounts.

Dot Gain and Screen Ruling

The relationship between dot gain and screen ruling was examined for black ink only. It was assumed that the other inks would exhibit characteristics similar to black. The test form contains a dot-size comparator that has four tone values at five different screen rulings from 85 to 200 lpi. This target is a native PostScript file that bypasses the screen ruling setting in the RIP and allows the imagesetter or platesetter to image more than one screen ruling from the same file.

Several participants opened the test form EPS file as an application document, and then resaved it as another EPS file before imaging it. This process rendered the dot-size comparator nonfunctional since it was imaged in a single screen ruling rather than at various screen rulings. All of the companies using platesetters resaved the EPS file, and, therefore, no data was available for CTP systems on the relationship of dot gain and screen ruling. The samples that were used in this portion of the analysis are only the ones where the target performed as designed. There were 29 samples on gloss-coated paper; 7 samples on matte coated paper; and 6 samples on uncoated paper.

A sample graph of dot gain versus screen ruling is shown in Figure 3 for 50% dot gain on gloss coated paper. Average slopes and correlation coefficients were calculated for each subgroup and tone level.

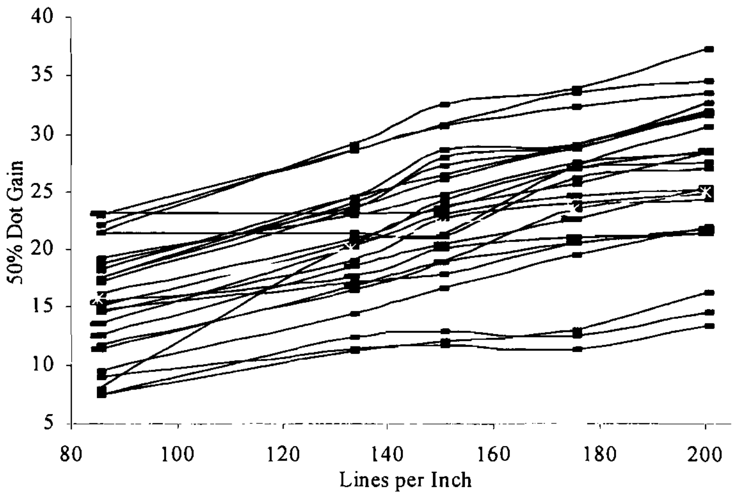


Figure 3. Dot gain vs. screen ruling.

The correlation coefficients showed consistent relationships between dot gain and screen ruling. A straight-line model was sufficient to characterize the relationship since very little additional accuracy was gained by testing higher-order models. Table 4 contains the average dot gain differences between different screen rulings.

Tone	Paper	Dot gain differences			
		85-133	133-150	150-175	175-200
10%	Gloss	2.9	1.5	1.5	1.5
	Matte	1.8	0.0	1.1	-0.1
	Uncoated	3.1	0.1	0.9	-0.7
25%	Gloss	4.3	1.8	2.3	2.0
	Matte	2.8	1.1	1.2	1.3
	Uncoated	4.7	1.7	0.9	1.2
50%	Gloss	5.0	2.1	2.2	1.9
	Matte	4.5	1.3	2.1	2.0
	Uncoated	5.2	2.0	1.8	1.6
75%	Gloss	3.0	1.2	1.5	1.0
	Matte	3.1	1.8	1.2	1.4
	Uncoated	3.5	1.8	0.9	1.1

Table 4. Average dot gain differences at different screen rulings.

The uncoated papers in this study did not exhibit significantly higher increases in dot gain with finer screen rulings than the coated papers. This is puzzling in light of the increased amounts of optical gain that uncoated papers exhibit and the increased amount of dot perimeter with finer screen rulings. The low number of samples in the uncoated category could account for this discrepancy.

On average, compared to gloss coated samples at 150 lpi, black dot gain will be 2.2% higher if 175-lpi screens are used, and 4.1% higher if 200-lpi screens are used.

Dot Gain

Since dot gain is partially dependent on screen ruling, the data was divided by screen ruling as well as paper type prior to calculating average dot gain values. The dot gains for several different tone values were measured from the tone scales on the test form. The tone scales were aligned vertically on the sheet so that all the tone patches would fall within the same ink key zone. Consistency of dot gain across the press form was not measured. Figure 4 shows the average dot gain curves with 90% confidence intervals for 150-, 175-, and 200-lpi screen rulings for the imagesetter samples on gloss coated papers.

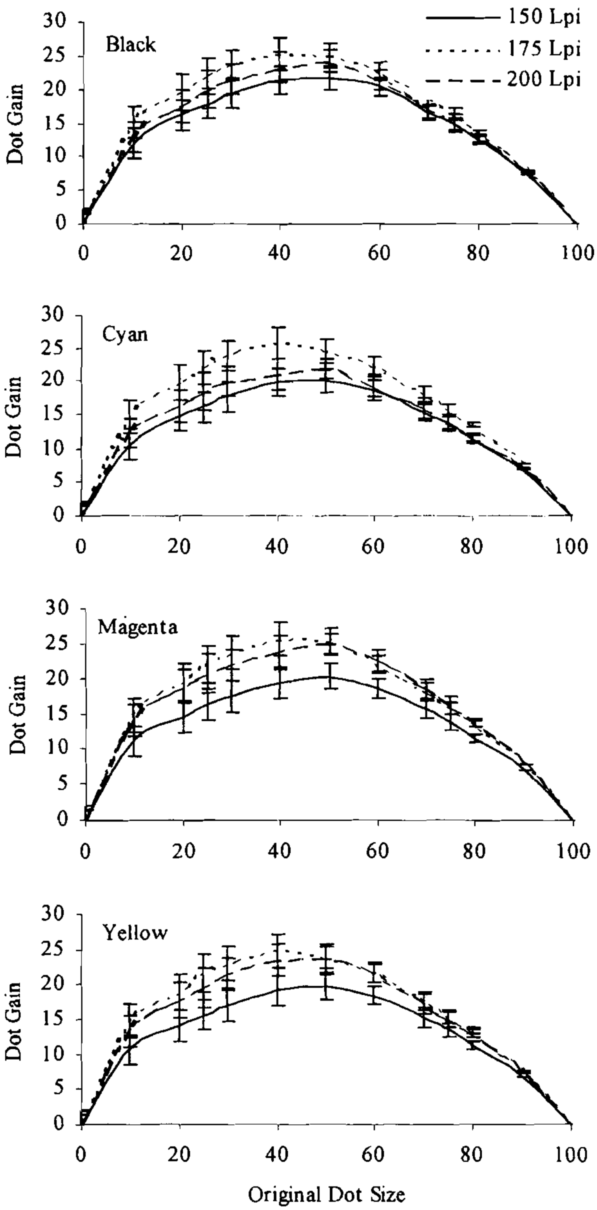


Figure 4. Dot gain curves for 150-, 175-, and 200-lpi samples on gloss coated paper.

The 200-lpi samples from this study had lower dot gains than the 175-lpi samples. This violates the rule that finer screen rulings experience higher levels of dot gain. Perhaps the companies in our sample who ran 200-line screens were more quality conscious overall than the printers using 175-line screens. The 200-lpi data are based on 12 combinations of printing conditions from 6 companies, while the 175-lpi data was taken from 13 conditions from 8 companies.

The dot gains of the four colors show slight skewing towards the lighter tone values. This increases at finer screen rulings. Table 5 contains the average 50% dot gains from the gloss-coated samples running to in-house density aim points. Only imagesetter sheets were included. The platesetter workflow has lower dot gain than the imagesetter workflow since the platesetter workflow has one less image transfer step.

Screen	Cyan	Magenta	Yellow	Black
150-lpi	20 ± 3	20 ± 3	20 ± 3	22 ± 2
175-lpi	25 ± 3	26 ± 3	24 ± 3	25 ± 4
200-lpi	22 ± 2	25 ± 2	25 ± 3	25 ± 3

Table 5. 50% dot gains on gloss coated paper.

The values in Table 5 show that the average gains to expect with a 150-line screen on coated paper are about 20% for all the process colors, and 22% for black. The dot gain averages at 175 lpi are appreciably higher than the GRACoL guidelines, and the samples represented by Table 5 were printed at lower than GRACoL densities. With the inks and papers used by the participants, the GRACoL guidelines for density and dot gain are not simultaneously achievable for many companies.

The relationship between the 50% dot gain and the age of the printing press was analyzed. A moderate positive correlation (about 0.50) was found for all four colors. Therefore, there is a slight tendency to get higher dot gain from an older press, but there are many other more significant factors in the printing system.

Print Contrast

Print contrast is an increasingly popular process control parameter because it is a value that one wishes to maximize, and because it is influenced by both density and dot gain. Within a given printing system, the correlation between print contrast and dot gain is very strong. The average print contrasts measured from the tone scales are shown in Table 6 for the gloss coated samples.

Color	150-lpi		175-lpi		200-lpi	
	Prt. con.	Std. dev	Prt. con.	Std. dev	Prt. con.	Std. dev
Black	39	6.3	36	5.2	38	6.0
Cyan	37	6.4	33	4.5	37	3.8
Magenta	37	6.8	32	5.4	33	2.7
Yellow	28	5.6	24	3 2	25	4.6

Table 6. Print contrasts from gloss coated imagesetter samples.

The print contrast numbers tend to go down as the screen frequency increases because of the higher dot gains associated with finer screens. Contrary to expectations, the 200-lpi group has higher print contrast than the 175-lpi group. Again, we postulate that the printers running 200-line screens were a more quality conscious group overall.

The ratios between 50% and 75% dot gains (shown in Table 7) were found to be fairly consistent. If the 50% dot gain is known at a given density level, then the print contrast can be predicted with reasonable accuracy.

Color	150-lpi		175-lpi	
	Ratio	Std. dev.	Ratio	Std. dev.
Cyan	1.43	0.25	1.56	0.15
Magenta	1.45	0.24	1.60	0.19
Yellow	1.44	0.15	1.55	0.15
Black	1.47	0.17	1.53	0.24

Table 7. Ratios of 50% to 75% dot gains.

If the GRACoL guidelines were met for density and dot gain, then the expected print contrasts based on the 175-lpi 50/75 dot gain ratios from this study would be as follows: black 47, cyan 44, magenta 46, and yellow 37. These values are higher than the GRACoL tolerances for all colors.

Ink Trapping

The four companies that used two-color presses were not included in the ink trapping evaluation. Remarkably, all of the remaining companies applied the process colors in C-M-Y sequence. The ink trapping was measured using the Preucil trapping equation. The results are displayed in Table 8.

Paper	Overprint	Trap	Std. Dev.
Gloss	Blue-CM	72	8.1
	Green-CY	89	6.5
	Red-MY	76	9.5
Matte	Blue-CM	63	12.4
	Green-CY	88	5.3
	Red-MY	75	6.9
Uncoated	Blue-CM	66	3.9
	Green-CY	87	2.6
	Red-MY	59	7.3

Table 8. Ink trapping values.

The trapping values for uncoated paper are lower than the traps for the two types of coated paper (except for green, which is nearly equal). The blue trap on matte coated paper showed a very large range from 47 to 78. The cause for this large variation in blue traps is unknown.

The relationship between the trapping values and the density level of the second-down inks was investigated. Scatter diagrams were plotted (as shown for green in Figure 5), and correlation coefficients were used to calculate r-squared values as follows: blue 0.65, green 0.73, and red 0.59.

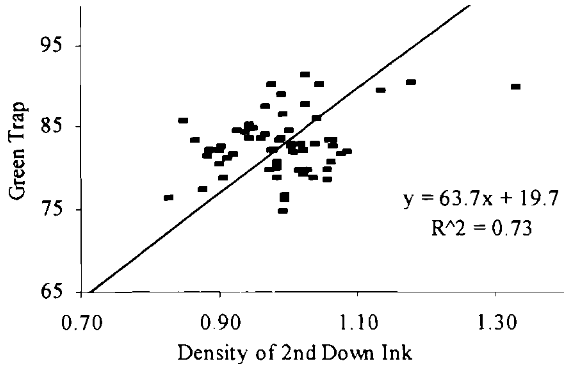


Figure 5. Green trap verses density of the second down (yellow) ink.

Although the r-squared values indicate that trap depends somewhat on density of the second-down ink, an examination of the scatter plot shows poor fit between the experimental data and a straight-line model. Other factors affecting trap, such as ink tack or ink strength, might show stronger correlations with trap values than do printed ink densities.

Total Area Coverage

The test form contained an ink coverage target (see Figure 6) to evaluate the black density levels that result from different amounts of total dot area coverage. It is desirable to keep the total dot area coverage as low as possible while still maintaining a high black density in the extreme shadows.

The target has set amounts of three-color coverage (in approximate gray balance) that vary by column. Each row has a different amount of black coverage. The total dot area coverage amounts are shown in reversed-out white lettering for each patch in the target. When the target is printed, the black density in each patch is measured. This data can be used to determine the practical limit for the total dot area coverage for a printing system. All the ink coverage patches were measured; Figure 7 shows a 3-D graph of the average measurements from 150-lpi imagesetter samples.

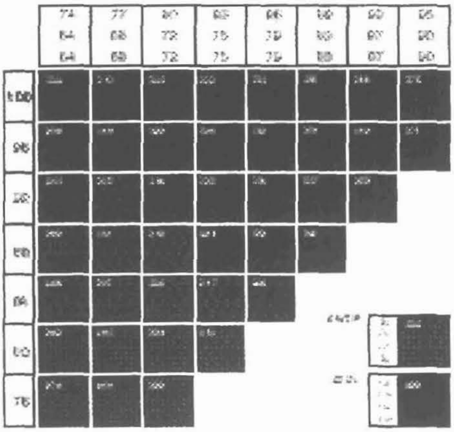


Figure 6. Ink coverage target.

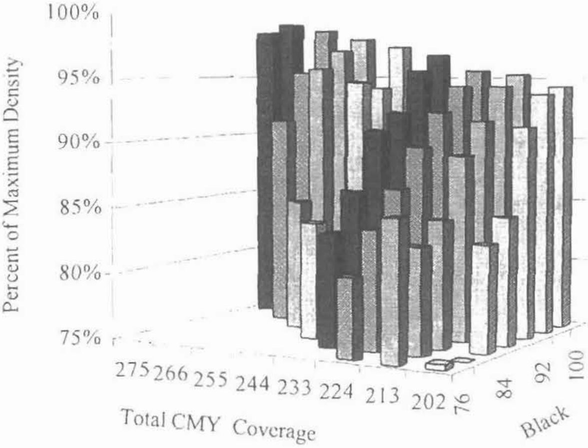


Figure 7. Density vs. total area coverage for 150-lpi.

The average slopes were calculated for the x and y axes. For black ink the slope was 0.015, while for the combined CMY axis the slope was only 0.002. This shows that a much more pronounced increase in density will result from increasing the black ink value as opposed to increasing the CMY values.

For gloss coated paper, not much loss in total density occurs if the total area of coverage is limited to 320% assuming that black ink is 90% or greater. The maximum shadow might consist of 90%K, 80%C, 74%M, and 74%Y.

Gray Balance

Maintaining good gray balance is important in creating realistic graphic images. There are no GRACoL gray balance guidelines, so the SWOP recommendations are used as a basis for comparison in this study. The SWOP CMY combinations are 25C/16M/16Y, 50C/39M/39Y, and 75C/63M/63Y to produce 25%, 50%, and 75% grays, respectively.

A gray balance chart was included on the test form to measure the CIELAB values of various CMY combinations The best CMY gray balance combinations were identified as the patches where the (a*, b*) coordinates were closest to the origin. Table 9 gives the three-color gray combinations for the most neutral squares for the gloss coated imagesetter group.

No appreciable differences between 150- and 175-lpi samples were noticed in the distributions of the most neutral gray patches. However, when the pattern of the most neutral squares was examined, a clear bimodal distribution between higher and lower yellow concentrations was observed, particularly at the 75% gray level.

Number of samples found with specified 3-color gray combinations								
25% gray			50% gray			75% gray		
CMY	150-lpi	175-lpi	CMY	150-lpi	175-lpi	CMY	150-lpi	175-lpi
25-19-19	3	1	50-45-45	1		75-69-57		1
25-18-15		1	50-43-43	2		75-69-59	1	
25-18-19	3	1	50-41-33	1		75-69-61	1	
25-17-19	1	1	50-41-37		1	75-69-65		1
25-16-13			50-41-41	1		75-67-57	1	
25-16-14	1		50-41-43	1	1	75-67-61	1	1
25-16-19	1	1	50-41-45	1		75-67-69	1	
25-15-13		1	50-39-33	1	1	75-65-67	1	
25-15-16	1		50-39-35		1	75-63-59		1
25-15-19		1	50-39-41	1		75-63-67		1
25-14-15	1		50-39-43	1	2	75-61-57	1	
25-14-18	1		50-37-41	1	1	75-61-61	1	
25-13-19	1		50-35-45	1		75-61-67		1
			50-33-33	1		75-61-69	1	1
						75-59-57	1	
						75-59-65	1	
						75-57-57	1	
						75-57-69	1	

Table 9. The most neutral three-color gray patches on gloss coated samples.

Chroma differences between the most neutral patches and the origin were calculated. Most of the selected patches were less than 3.0 chroma units from the origin. In the instances where larger chroma differences were found, the true most-neutral CMY combinations were outside of the range contained on the gray balance chart. This was most frequently of concern at the 25% gray value.

Based on this study, the best default CMY gray balance values for commercial offset lithography on gloss coated paper are: 25C/18M/19Y, 50C/41M/42Y, and 75C/65M/63Y.

Tertiary Colors
Six three-color patches were selected from the IT8 Basic Data Set for colorimetric analysis. The patches were chosen on the basis of hue and lightness to cover different areas of the CIELAB color space. The results from 150- and 175-lpi imagesetter samples on gloss coated papers were compared. Table 10 shows the average L*, a*, and b* values for these two subgroups and the differences between them.

Patch	175-lpi			150-lpi			Differences (175-150)		
	L	a*	b*	L	a*	b*	L	a*	b*
h-2	50.4	39.9	-3.5	52.4	39.0	-3.6	-2.0	1.0	0.1
h-7	68.6	-0.4	41.6	71.5	-1.7	41.2	-2.9	1.3	0.4
h-11	54.3	-19.3	-20.0	57.2	-19.0	-20.6	-2.9	-0.3	0.6
n-11	25.7	6.2	-12.3	28.4	5.8	-12.8	-2.7	0.4	0.5
n-12	32.7	-12.5	6.0	35.7	-12.2	5.8	-3.0	-0.3	0.3
n-13	30.8	12.5	11.2	33.9	12.1	11.1	-3.1	0.5	0.1

Table 10. L*a*b* values from tertiary patches.

The largest differences were found in the L* values showing that the 175-lpi patches consistently printed darker than the 150-lpi ones. This is due to the higher dot gain levels of 175-line screens. The a* and b* values of the two screen rulings were nearly equal showing that there was no hue shift due to screen ruling. Figure 8 shows a plot of the a* and b* values for both 150- and 175-lpi gloss coated samples.

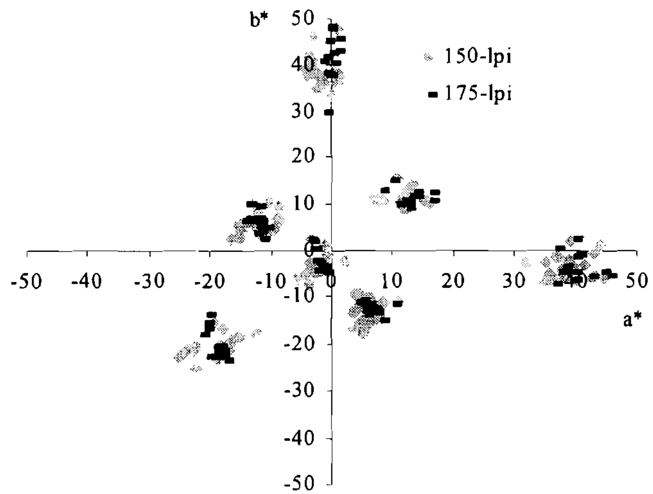


Figure 8. a*b* Distributions of selected tertiary colors.

The 150- and 175-lpi a*b* data points overlay each other for every tertiary color. This shows that no appreciable differences of hue or chroma are expected due to these two different screen rulings.

The average L*a*b* values were treated as the targets for each color. The delta-E differences were calculated between those targets and each measured sample. Table 11 shows the averages of these results.

Patch	Dot sizes of the selected patches				Avg. ΔE from target	
	Black	Cyan	Magenta	Yellow	150-lpi	175-lpi
h2	0	20	70	20	14.7	9.8
h7	0	20	20	70	31.0	13.4
h11	0	70	20	20	12.0	7.7
n11	70	40	40	0	12.8	8.0
n12	70	40	0	40	12.3	7.1
n13	70	0	40	40	11.0	8.5

Table 11. Delta-E differences from target values.

The reproduction of the selected tertiary colors was found to differ substantially between different printing systems. With the unexplained exception of patch h7 (20C, 20M, 70Y), the magnitudes of average delta-E variations were about equal for all colors. The average color difference values of about 12 delta-E units would provide a noticeable difference from the target color. This indicates that screen builds of trademark colors will not generally be matched unless special provisions are taken, such as adjusting the press to match a proof.

Conclusion

This study examined a range of atstributes from printed samples of a supplied test form. Both densitometric and colorimetric analysis were used to develop average values for establishing attainable specifications for high-quality commercial offset lithography. This study found average values for several print attributes, as summarized for gloss coated paper in Table 12.

<table>
<tr><th>Print Attributes</th><th>Black</th><th>Cyan</th><th>Magenta</th><th>Yellow</th><th rowspan="2">Ink Trapping</th></tr>
<tr><td>Density</td><td>1.62</td><td>1.33</td><td>1.39</td><td>0.98</td></tr>
<tr><td>Dryback</td><td>0.06</td><td>0.02</td><td>0.02</td><td>0.02</td><td rowspan="2">blue
72</td></tr>
<tr><td>Dot Gain</td><td>22</td><td>20</td><td>20</td><td>20</td></tr>
<tr><td>Print Contrast</td><td>39</td><td>37</td><td>37</td><td>28</td><td rowspan="2">green
89</td></tr>
<tr><td>25% Gray</td><td></td><td>25</td><td>18</td><td>19</td></tr>
<tr><td>50% Gray</td><td></td><td>50</td><td>41</td><td>42</td><td rowspan="3">red
76</td></tr>
<tr><td>75% Gray</td><td></td><td>75</td><td>65</td><td>63</td></tr>
<tr><td>Total Dot Area (320%)</td><td>90</td><td>82</td><td>74</td><td>74</td></tr>
</table>

Table 12. Average values for commercial offset lithography at 150 lpi on gloss coated papers.

The values in Table 12 are based on 150-lpi screens. If finer screens are used, the dot gains will be higher and the print contrasts will be lower. The values in Table 12 represent average conditions of a widely varied segment of the industry. If there is no need to adhere to the average conditions, then each company should strive to surpass these aim points. If the printing system for a commercial offset lithographic job is unknown, then the values above provide achievable targets for this industry segment.

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