Print Quality Specifications of Sheetfed Offset Lithography in Taiwan

Dr. Yung-Cheng Hsieh*

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Abstract: Sheetfed offset lithography is the most widely used printing process by Taiwan's printing industry, but there are no industry-wide specifications for press control to assure consistent quality across printing plants. As printing becomes more of a commodity and less of an art, it is necessary to develop a print quality specification standard for Taiwan. The main purposes of the study were to construct the attribute profile for the high-quality sheetfed offset lithography industry of Taiwan, and to establish the print quality specifications based on the attribute profile.

More than fifty company members of the Printing Industry of Taiwan (PIT) were invited to participate in the study. Thirty-three companies, representing the north, central and the south of Taiwan submitted a total of 95 sets of printed samples for this study; 45 sets were printed on coated paper and 40 sets on uncoated paper.

Participants were provided with an original test form created specifically for this research on a CD-ROM in digital format or a set of conventional litho film to produce 100 sheets print according to their in-house density aim points. All submitted samples were then measured with spectrodensitometers on solid ink density, dot gain, print contrast, trapping, highlight dots, shadow dots, hue error, grayness, gray balance, L*a*b* values, etc. The print quality specifications of the sheetfed offset lithography were derived from the analysis of those measurements. Various subgroups of the specifications are also discussed in the paper.

*Associate Professor, Department of Graphic Communication Arts, Dean of Student Affairs, National Taiwan University of Arts, Taipei, Taiwan
E-mail: t0308@mail.ntua.edu.tw or hsiehisu@ms23.hinet.net

1. Introduction

Taiwan's admittance in to the WTO (World Trade Organization) in 2001 has force its printing industry to encounter global challenges. Competition from printers in North America, Europe, and Japan raises a question for Taiwan's printers: "*What is our print quality level in comparison with that of other nations*?" This is a particularly important question for the offset lithographic industry of Taiwan because it accounts for more than 70% of the total print production. Taiwan's printers must enhance their print quality to expand oversea market and draw international businesses.

Unfortunately there is no print quality specification and industry-wide standard available in Taiwan. In some developed countries, there are quality standards and/or print attribute specifications developed by their printing industries or research institutions, such as GRACoL, SWOP, ShOPS, SNAP, FIPP, UKONS, FORGRA, etc. Therefore the author was strongly motivated to submit a proposal to the National Science Council (NSC) of Taiwan to conduct this research for establishing a print quality specification standard for Taiwan's sheetfed offset lithographic industry. The proposal was granted and these print quality specifications were compiled to present a comprehensive profile of the print characteristics of the current high quality lithographic print industry of Taiwan.

1.1 Purposes of the Study

The author feels strongly that Taiwan's high quality lithographic printing industry needs a comprehensive profile of realistic quality specification. This research intended to construct the attribute profile for the sheetfed offset lithography industry of Taiwan, and to establish the print quality specifications based on the attribute profile.

1.2 Limitations of the Study

The following limitations must be considered when interpreting the results of this study:

1. The participants were not randomly selected; instead they volunteered to partake in the study.
2. No two printing systems were the same; they varied in machines, materials, and environmental conditions.
3. Participated companies had their own press crews; hence their working performances were uncontrolled and not investigated.
4. Pressroom temperature and relative humidity were not controlled; hence, they were not considered constant variables. Their effects for this research were not studied.
5. A wide variety of presses were employed for this research. The make, ages, numbers of units, and physical conditions of the presses differed. Their

effects on the results were not discussed.

6. The printing plates, blankets, fountain solution, and other press materials were not controlled. Their effects on the results of this study were not explored.
7. The in-house density aim-points differ; they were measured and controlled by the participants with their own densitometers.
8. The platemaking process and actual pressruns of the participants for this study were not observed due to budge and travel constraints.
9. Several brands and weights of paper were used for the study. Differences in the printing attributes of the individual stocks were not investigated; however, for final analyses the samples were divided into two subgroups, coated and uncoated paper.

2. Methodology

This study was designed to provide information useful for setting realistic print specifications for commercial offset lithography in Taiwan. Hence, these specifications must be derived from real-live operating parameters. To meet this requirement, the participants were asked to run their presses based on their in-house standard operating procedures and conditions. The dependent variables of this study include densitometric attributes such as solid ink density (SID), highlight dot reproduction, shadow dot reproduction, dot gain (DG), print contrast (PC), ink trapping, gray balance, and grayness, hue error.

2.1 Population and Samples

The target population of this study was high quality commercial sheetfed lithographic printers in Taiwan. The criteria for selecting the participants in this study as high quality are: the printers who are active member companies of PIT or PTRI; the printers have established themselves as commercially successful printers; the printers are quality conscious enough to have invested considerable time, materials, and effort in participating in this study with no monetary compensation.

The different types of printers participating in this study include those of direct mails, advertising brochures, books, annual publications, and other full-color print. They were asked to submit both coated and uncoated substrates, but not all of the participants submitted both stocks. Most of the printers have their own in-house platemaking facility. For those who did not have, they were asked to prepare the plates, either conventional PS or CTP plates, on their own.

More than 50 high quality commercial sheetfed lithographic printers were recommended by the PIT or PTRI. They were called and invited to participate in the experiment by the author. Total of 33 companies representing 21 from the north, 4 from central and 8 from the south of Taiwan submitted a total of 95 sets of printed samples for this study; 45 sets were printed on coated paper and 40 sets on uncoated paper. Each participant was asked to submit at least 100 printed sheets on both coated and uncoated stocks respectively. Each stock was then systematically randomly selected for a sample of 35 sheets each. The information about the participants (categorized by the company location and type of paper used) and their submitted sample sizes are displayed in Table 1.

Table 1. The information about the participants and their sample sizes

Location		**North**	**Central**	**South**	**Total**
No. of Participants		21 companies	4 companies	8companies	33 companies
No. of Sets Submitted	Coated	30 sets	7 sets	8 sets	45 sets
	Uncoated	25 sets	7 sets	8 sets	40 sets
No. of Sheets Sampled	Coated	1050 (30×35)	245 (7×35)	280 (8×35)	1575 sheets
	Uncoated	875 (25×35)	245 (7×35)	280 (8×35)	1400 sheets

2.2 The Test Form

A digital four-color test form was designed for this study (See Appendix I). The test form is 25x35-in. press form which includes test targets and photographic images. The photographs on the test form are GATF test images that emphasize different color reproduction challenges. The other process characterization targets of the test form include:

- PTRI color control bar
- GATF six-color two tiered control bars: one is a repeating series of solid CMYK ink patches; the other contains tints, overprints, and star targets.
- Ink coverage target
- IT8.7/3
- CMYKRGB and 3K solid patches
- Tone scales of CMYKOG
- Color correction target
- Gray balance chart
- CMYKRGB and 4K tint patches of 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 100%
- CMYK tint patches of highlights (1%~10%) and shadows (90%~100%)
- Micro line target

The test form was available in either CD-ROM containing TIFF files, or conventional film. A service bureau produced ten sets of conventional film in one day. The imagesetter utilized to output the film for this study was calibrated and linearized before the research. The imagesetter was Screen FT-R 3050, and the measurement of dot area on the film was done with an X-Rite® 341 transmission densitometer. This densitometer was also used for the imagesetter calibration and linearization. Before distributing the film to the participants, the study examined and measured 50% dots on the film to ensure the linearization of the film. Both the service bureau that produced the film and the participants who requested the CD-Rom version were asked not to apply any compensation curves to the test form.

2.3 Research Procedure

After receiving the test form, participants were asked to output the file at 175 lpi screen ruling. In addition, they were also requested to complete a questionnaire that was designed to survey the local high-quality printing companies to establish the attribute profile for sheetfed lithography industry of Taiwan. The questionnaire consists of two categories: *company basic information* including location, age, current numbers of employees, current assets, previous year revenue, and prepress and press equipment; and *pressrun related information* such as type of press machine, ink, print color sequence, type of plates (PS vs. CTP), type of coated paper, type of uncoated paper, and pressroom temperature and relative humidity.

For those who requested conventional film, there was no opportunity to inspect their printing plates. The participants were asked to print only to their in-house density aim-points; proofs of the test form were not supplied. After target densities were achieved across the press, 100 sampled were labeled and sent to the author. Each participant was asked to submit at least two stocks, one coated and one uncoated paper. All participants used four- or six-color presses to print the test form for the research. The weight of the paper was limited to 150 to 175 lb for the coated and 100 to 125 lb for the uncoated stocks. It took more than six months for the collection process, from contacting potential participants to receiving the printed samples.

2.4 Data Collection

One hundred printed sheets were submitted from each press run and 35 of them were systematically randomly sampled. A total of 1575 printed sheets for the coated and 1400 for the uncoated stock were sampled for this study. Status "T" density readings were made from these samples, with a GretagMacbeth D118C color reflection densitometer using Murray-Davies equation (n=1), on the solid ink density, highlight dot areas (1%, 2%, 3%, 4%, 5%), shadow dot areas (95%, 96%, 97%, 98%, 99%), regular dot areas (10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%), 75% print contrast, ink trapping, and hue error & grayness. Colorimetric readings were made with an X-Rite 530 reflection spectrodensitometer to measure L*a*b* color and 80% gray balance. SPSS 11 and Minitab 13 statistical software packages were used for analyses. Due to the time constraint, it is important to note that each specific patch on the sampled sheets was read only one time.

3. Overall Results

This section reports the overall results and findings obtained through analyses of the data. Each sub-section gives a brief description of a particular print attribute and its specifications.

3.1 Questionnaire Results

This section describes the results of the questionnaire survey which reveal the characteristics and printing conditions of the participating companies. There were 34 high quality sheetfed lithographic printers who participated in this research but one of them was excluded due to the excessive density of solids. Among these 33 participants, 21 (63.6%) companies were located in the north, 4 (12.1%) from the central, and 8 (24.2%) from the south. No participant from the east coast of the island was represented. For more details see Table 1. Table 2 categorizes the participants by how long the company has been established. A high percentage of companies have been in business between 21-30 years (33.3%). Table 3 categorizes the participants by the numbers of employees; it shows that approximately half of the participants (48.5%) have less than 25 employees.

Table 2. Years companies have been in business

Age Category	Number of Company	Percentage
Less than 10 years	5	15.2%
11-20 years	6	18.2%
21-30 years	11	33.3%
31-40 years	2	6.1%
41-50 years	5	15.2%
More than 50 years	4	12.1%

Table 3. Company employee numbers

Category	Number of Company	Percentage
Less than 25 employees	16	48.5%
26-50 employees	6	18.2%
51-100 employees	7	21.3%
101-200 employees	1	3.0%
201-300 employees	2	6.0%
More than 300 employees	1	3.0%

Most scanners owned by the participants are Dainippon Screen, Linotype-Hell, Agfa, and Fuji; Agfa, Scitex, Appollo, Screen, and Heidelberg are the imagesetters used to run for daily production. There are seven participants in this study who owns CTP systems that include Heidelberg, CreoScites, Cymbolic, etc. Of the 45 coated sets, 30 of them (66.7%) were printed with PS plates, 9 with thermal CTP, 3 with photopolymer CTP, and 3 with silver-halide CTP.

According to the survey, the printing systems used to run this study include

Heidelberg, Mitsubishi, Komori, Akiyama, Man Roland, KBA, and Planeta. For details see Figure 1.

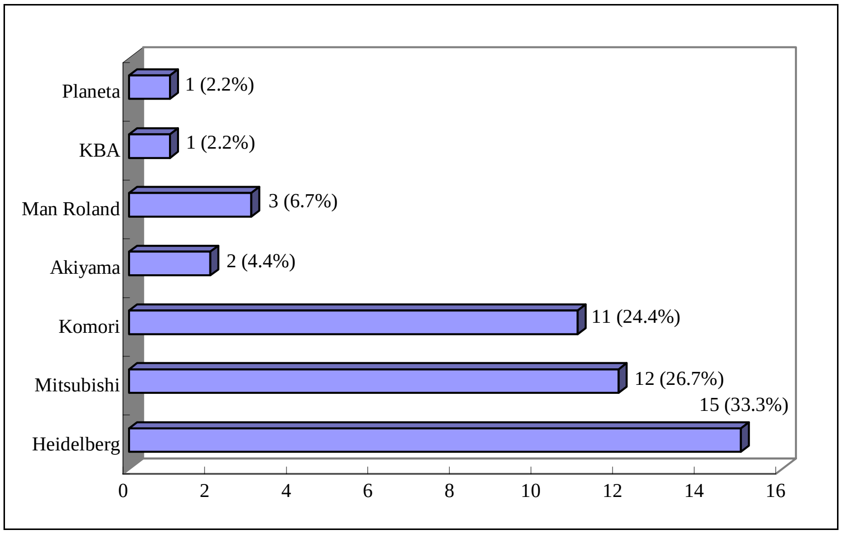

Figure 1. The printing systems used for this study

89% submitted coated sets and 90% submitted uncoated sets were print with K-C-M-Y color sequence, followed by K-M-C-Y and others. Japanese inks such as DIC, Tiger, Butterfly, Toyo, 4CS, Hyeco, etc were used by the participants. The paper used for this study included three types of coated paper: gloss, matte, and double sided coated: and three types of uncoated paper: wood-free printing & writing grade A and grade B, and machine finished. None of samples were printed with stochastic screens or hybrid screens.

3.2 Data Interpretation

This section mainly discusses the descriptive statistics of the data. The averages or "means" are given as a value ± another value. The number after the "±" is the "margin of error" of the mean calculation. For this study the margin of error is a statistical precision evaluation of derived from computing the 95% confidence interval of the mean.

In the specification tables shown, standard deviations (S.D.) are also provided. The SD is a statistical measure of how closely the industry, as a whole, is clustered around the mean value. A large SD indicates that the industry prints within a relatively wide range; a SD indicates that the industry prints a much tighter range around the mean value.

3.3 Solid Ink Density (SID)

In the printing industry, density usually refers to the ability of a print to absorb light. Generally, the darker a process color is to the eye, the higher the density. In terms of quality, monitoring SID during a press run is essential when comparing any printed material. Many research reports have indicated that SID has a greater influence on dot gain than any other factors. The higher the SID printed for a given condition, the more the midtone gained in density. As the midtone gets darker, shadow contrast decreases and the shadows get denser. Increasing the ink on the paper may therefore not give the desired result to a reproduction.

In this study, the participants were instructed to print their established in-house specification at 175 lpi. SIDs were measured after all of the printed sheets were received and sampled. Table 4 shows the SIDs of the coated and uncoated stocks. The average in-house SID of coated paper were 1.39 for yellow (Y), 1.25 for magenta (M), 1.69 for cyan (C), and 1.71 for black (K). The average SIDs of uncoated stocks were 1.03 for Y, 0.95 for M, 1.11 for C, and 1.11 for K.

Table 4. Solid ink density

Coated (1575 samples)		
Color	Solid Ink Density	Standard Deviation
Y	1.3937 ± 0.0095	0.19234
M	1.2512 ± 0.0062	0.12600
C	1.6856 ± 0.0119	0.24111
K	1.7098 ± 0.0152	0.30647
Uncoated (1400 samples)		
Color	Solid Ink Density	Standard Deviation
Y	1.0342 ± 0.0078	0.15034
M	0.9464 ± 0.0066	0.12645
C	1.1086 ± 0.0084	0.16091
K	1.1075 ± 0.0102	0.19402

3.4 Dot Reproduction

This section discusses the dot reproduction results in highlights, shadows, and regular dots. In this study, highlight dots consist of small areas of halftone dots on the test form with percentage values of 1-5%, and shadow dots consist of halftone dots with percentage values of 95-99%, both in 1% increments. Highlight and shadow dot reproductions provide very useful information by indicating the last reproducible dots in highlight and shadow tones, and identifying possible platemaking and press errors. The regular dots were defined as the halftone dots on the test form with percentage values of 10-90%, in 10% increments. In the regular dot reproduction analyses, dot gain (tonal value increase) was discussed instead of dot area because dot gain becomes obvious after 10% tints. Dot gain was calculated using "% print dot - % film dot".

Highlight Dot Reproduction

As shown in Table 5 for coated paper, 1-3% dot areas of cyan and black were generally greater than those of magenta and yellow. For the 4% and 5% dot areas, black and yellow had greater percentage values than magenta or cyan. Unlike the coated samples, no noticeable pattern in the uncoated paper was observed. The dot gain sizes of the uncoated samples were greater than those of the coated samples at all five tone values in all four ink colors. The overall highlight (1-5% tones) dot gain values of the coated paper for any color were less than 3%, and less than 5% for the uncoated paper. It is important to note that the SD values of the dot areas for the coated paper were smaller than those of the uncoated paper at all five tone values in all four ink colors. Figure 2 shows the tone reproduction curve of highlight dots; dot gains appeared to be noticeable after the 2% original film dot levels and the dot gain sizes increased as the tone values increased.

Table 5. Dot areas of highlights

		Coated		Uncoated	
Tone	Color	Dot Area	S.D.	Dot Area	S.D.
1% Dots	Y	1.0890 ± 0.0611	1.2216	1.3343 ± 0.0823	1.5689
	M	1.1045 ± 0.0579	1.1581	1.3779 ± 0.0830	1.5815
	C	1.2487 ± 0.0693	1.3868	1.5236 ± 0.0923	1.7603
	K	1.1494 ± 0.0601	1.2026	1.3750 ± 0.0841	1.6037
2% Dots	Y	2.0507 ± 0.0972	1.9450	2.3450 ± 0.1314	2.5055
	M	2.0883 ± 0.0872	1.7449	2.5971 ± 0.1281	2.4432
	C	2.2149 ± 0.0961	1.9218	2.5264 ± 0.1342	2.5587
	K	2.2175 ± 0.0946	1.8925	2.5800 ± 0.1305	2.4896
3% Dots	Y	3.9987 ± 0.1239	2.4780	4.6007 ± 0.1687	3.2176
	M	4.1162 ± 0.1066	2.1327	5.0436 ± 0.1575	3.0042
	C	4.2117 ± 0.1173	2.3464	4.6743 ± 0.1648	3.1434
	K	4.2630 ± 0.1216	2.4328	4.9429 ± 0.1711	3.2637
4% Dots	Y	5.9091 ± 0.1216	2.4321	6.8864 ± 0.1699	3.2401
	M	5.5390 ± 0.1103	2.2050	6.6379 ± 0.1628	3.1043
	C	5.7909 ± 0.1233	2.4665	6.4043 ± 0.1700	3.2430
	K	5.9143 ± 0.1229	2.4583	6.8650 ± 0.1792	3.4173
5% Dots	Y	7.8779 ± 0.1269	2.5387	9.1236 ± 0.1778	3.3907
	M	7.3649 ± 0.1080	2.1607	8.7093 ± 0.1716	3.2736
	C	7.7422 ± 0.1216	2.4323	8.5007 ± 0.1741	3.3208
	K	7.8273 ± 0.1302	2.6050	9.1357 ± 0.1933	3.6866

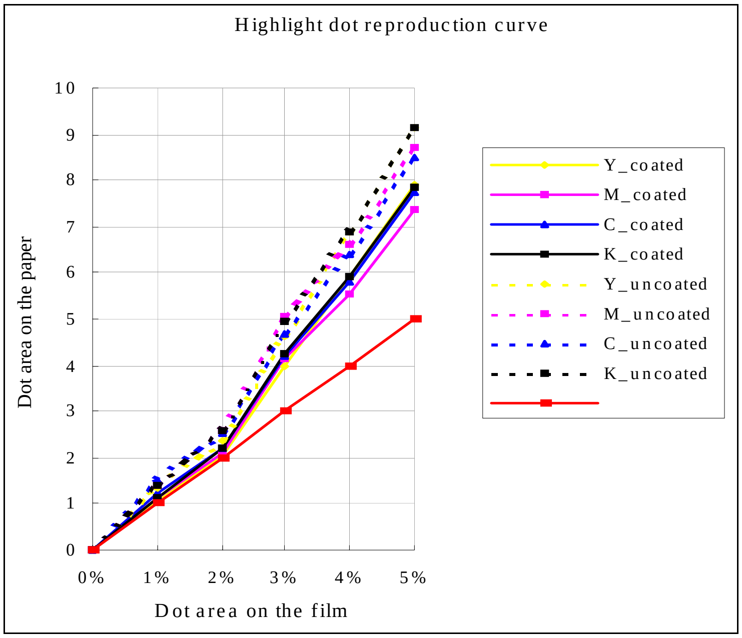

Figure 2. Dot reproduction curve of highlights

Shadow Dot Reproduction

The purpose of evaluating shadow dot reproduction is to examine what the maximum dots that a printing process can print. In Table 6 the overall dot gain sizes for the shadow dots (95-99% tone values) were less than 3 % for the coated paper and less than 4% for the uncoated paper in all four ink colors. In addition, their SD values of dot areas were all less than 2%. The average values of dot area measurements shows that black ink color had the largest dot areas at 95-98% tone values, followed by yellow, magenta, and cyan colors for both the coated and uncoated paper. It is interesting that the SD values of dot areas for the coated paper were not always smaller than those for uncoated paper at all five tints in all four colors, as found in the highlight dots. In fact, more than half of the SD values of the coated paper were greater than those of the uncoated paper. The shadow dot reproduction curve in Figure 3 reveals that the dot gain sizes decreased as the tone values increased and the values became unnoticeable (less than 1%) after the 98% tints.

Table 6. Dot areas of shadows

		Coated		Uncoated	
Tone	Color	Dot Area	S.D.	Dot Area	S.D.
95% Dots	Y	97.963 ± 0.0735	1.491	98.155 ± 0.0740	1.404
	M	97.561 ± 0.0715	1.451	97.668 ± 0.0715	1.363
	C	97.474 ± 0.0795	1.606	97.119 ± 0.0885	1.692
	K	98.048 ± 0.0785	1.583	98.411 ± 0.0650	1.241
96% Dots	Y	98.316 ± 0.0660	1.338	98.487 ± 0.0635	1.209
	M	98.141 ± 0.0650	1.320	98.156 ± 0.0660	1.259
	C	97.925 ± 0.0735	1.486	97.577 ± 0.0810	1.549
	K	98.549 ± 0.0675	1.368	98.710 ± 0.0570	1.084
97% Dots	Y	98.708 ± 0.0570	1.152	98.750 ± 0.0550	1.056
	M	98.598 ± 0.0560	1.138	98.529 ± 0.0595	1.135
	C	98.368 ± 0.0665	1.349	97.985 ± 0.0750	1.424
	K	98.919 ± 0.0545	1.097	98.997 ± 0.0480	0.916
98% Dots	Y	99.323 ± 0.0385	0.782	99.194 ± 0.0425	0.817
	M	99.195 ± 0.0410	0.830	99.117 ± 0.0460	0.872
	C	99.003 ± 0.0470	0.954	98.703 ± 0.0540	1.029
	K	99.412 ± 0.0380	0.764	99.466 ± 0.0385	0.736
99% Dots	Y	99.597 ± 0.0270	0.540	99.379 ± 0.0385	0.732
	M	99.632 ± 0.0265	0.534	99.459 ± 0.0355	0.675
	C	99.537 ± 0.0320	0.641	99.166 ± 0.0405	0.776
	K	99.830 ± 0.0185	0.392	99.727 ± 0.0305	0.582

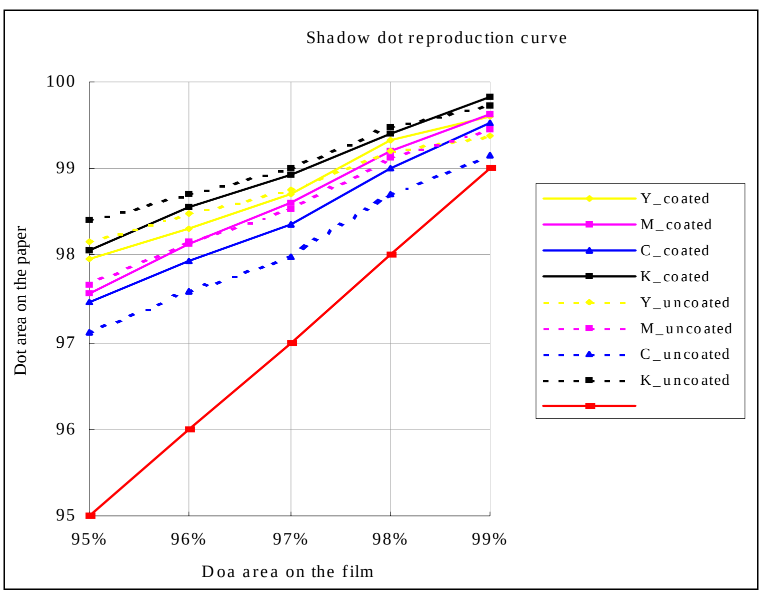

Figure 3. Dot reproduction curve of shadows

Regular Dot Reproduction

The dot gain curves of for 10%-90% dots are exhibited in Figure 4. It shows the uncoated paper had greater dot gain than the coated paper at all tone values in all colors. Furthermore, it shows there are two commonalities between the two stocks: (1) the greatest dot gain occurred at 40-60% film dots, and (2) black ink color had the greatest dot gain amount and magenta had the least.

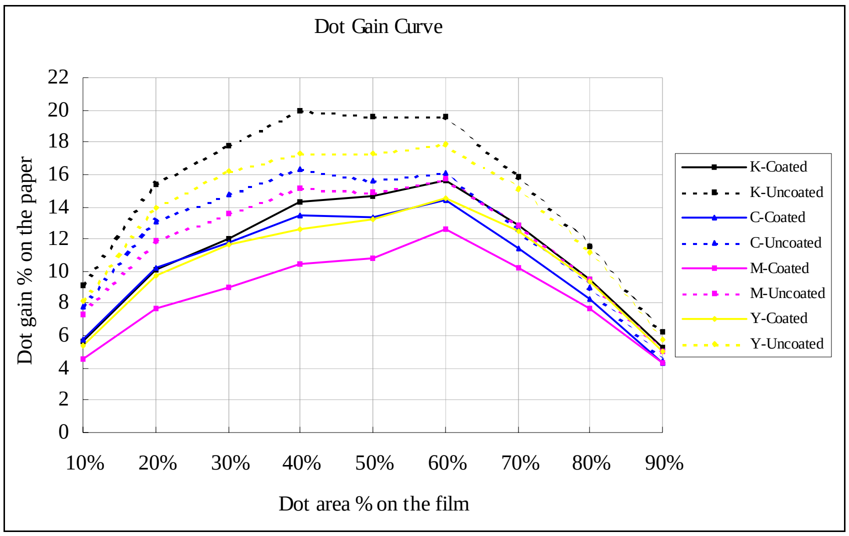

Figure 4. 10%~90% dot gain curve

Table 7 depicts the 10-90% dot gain statistics for the coated and uncoated samples. The average dot gain values of coated papers showed that cyan color had the greatest dot gain, followed by black, yellow, and magenta at 10% and 20% tone values; black color had the greatest dot gain values at 30%-90% tints. Moreover, at all tone values, the least amount of dot gain and its SD occurred in magenta. The largest SD value of dot gain was found in black for most of tone values.

The average dot gain values of the uncoated paper in Table 7 revealed that black color had the largest amount of dot gain size at all tone values (10-90%), followed by yellow, cyan, and magenta. In addition, the least amount of dot gain occurred in magenta at 10%-60% and in cyan at 70%-90%. Magenta also has the least amount of dot gain SD at all tone values, except 90% dots. The greatest SD value was found in either black or cyan at all of the nine tone levels.

Table 7. Statistics of 10%~90% dot gain values

		Coated Paper		Uncoated Paper	
Tone	Color	Dot Gain %	S.D.	Dot Gain %	S.D.
10% Dots	Y	5.4673 ± 0.1684	3.408	8.204 ± 0.2095	3.996
	M	4.5314 ± 0.1381	2.793	7.299 ± 0.2077	3.962
	C	5.7790 ± 0.1611	3.260	7.822 ± 0.2364	4.509
	K	5.6730 ± 0.1596	3.228	9.177 ± 0.2310	4.401
20% Dots	Y	9.7930 ± 0.2444	4.945	13.950 ± 0.2535	4.836
	M	7.7181 ± 0.1665	3.370	11.866 ± 0.2257	4.305
	C	10.213 ± 0.2265	4.582	13.159 ± 0.2675	5.101
	K	10.043 ± 0.2496	5.050	15.335 ± 0.3049	5.816
30% Dots	Y	11.620 ± 0.2943	5.955	16.216 ± 0.2775	5.292
	M	8.957 ± 0.203	4.107	13.576 ± 0.2349	4.481
	C	11.750 ± 0.2776	5.616	14.813 ± 0.2841	5.418
	K	12.074 ± 0.3222	6.517	17.826 ± 0.3301	6.296
40% Dots	Y	12.672 ± 0.3102	6.276	17.349 ± 0.2736	5.218
	M	10.494 ± 0.2226	4.503	15.089 ± 0.2405	4.586
	C	13.438 ± 0.2867	5.801	16.351 ± 0.2741	5.227
	K	14.328 ± 0.3611	7.306	19.974 ± 0.3354	6.397
50% Dots	Y	13.222 ± 0.3063	6.196	17.365 ± 0.2612	4.982
	M	10.814 ± 0.2247	4.546	14.881 ± 0.2350	4.482
	C	13.364 ± 0.2729	5.520	15.640 ± 0.2593	4.946
	K	14.711 ± 0.3470	7.020	19.600 ± 0.3228	6.157
60% Dots	Y	14.615 ± 0.275	5.564	17.971 ± 0.2281	4.350
	M	12.568 ± 0.1990	4.025	15.774 ± 0.2057	3.923
	C	14.435 ± 0.2564	5.188	16.064 ± 0.2423	4.622
	K	15.660 ± 0.2992	6.054	19.650 ± 0.2488	4.746
70% Dots	Y	12.495 ± 0.2539	5.136	15.206 ± 0.2036	3.884
	M	10.270 ± 0.1867	3.777	12.871 ± 0.1825	3.480
	C	11.472 ± 0.2300	4.653	12.666 ± 0.2149	4.098
	K	12.862 ± 0.2553	5.166	15.914 ± 0.2070	3.965
80% Dots	Y	9.365 ± 0.2050	4.148	11.236 ± 0.1584	3.022
	M	7.651 ± 0.1494	3.023	9.4379 ± 0.1418	2.705
	C	8.302 ± 0.1765	3.571	9.0564 ± 0.1688	3.218
	K	9.490 ± 0.1964	3.974	11.534 ± 0.1549	2.955
90% Dots	Y	5.036 ± 0.1372	2.775	5.8107 ± 0.1152	2.198
	M	4.279 ± 0.1146	2.318	5.0964 ± 0.1074	2.048
	C	4.314 ± 0.1221	2.470	4.4114 ± 0.1348	2.570
	K	5.310 ± 0.1307	2.643	6.2321 ± 0.1056	2.013

3.5 Print Contrast

Print contrast (PC) is a print index that is calculated from the solid ink patches and 75% tint patches. The value relates to the degree of contrast between the three-quarter tone and the solid. In other words, it is a measure of shadow contrast and is the degree to which viewers can distinguish printed tones in the shadow area of a reproduction. PC is calculated in a manner that compares density reading differences between a three-quartertone tint area (usually a 75% or 80% tint) and a solid patch. The formula is:

$$\% \, PC = \frac{Ds - Dt}{Ds} \times 100$$

Ds = Density of the solid patch (including paper density)
Dt = Density of the three-quartertone patch (including paper density)

In general, the higher the print contrast the better the shadow detail rendition. According to Stanton and Hutton (1999a), print contrast has become a popular process control parameter since it was developed by FOGRA in Germany in the early 1980s as a means of determining the optimum inking levels for printing system. It is strongly influenced by both the solid ink density and the dot gain of the system. It is well known that as dot gain increases the print contrast decreases.

Table 8 shows the average print contrasts found in this study. For both coated and uncoated paper, the greatest print contrast was found in cyan color, 51.3% for coated and 37.2% for uncoated paper; the second largest print contrast value was found in black color, 50.9% and 33.0% for coated and uncoated paper, respectively. In addition, magenta color has the smallest SD values of print contrasts for both two paper samples.

Table 8. Statistics of print contrasts

	Coated Paper		Uncoated Paper	
Color	Print Contrast	S.D.	Print Contrast	S.D.
Y	42.702 ± 0.41	8.289	30.342 ± 0.36	6.805
M	42.696 ± 0.27	5.537	32.219 ± 0.30	5.662
C	51.314 ± 0.34	6.794	37.221 ± 0.34	6.469
K	50.898 ± 0.38	7.637	32.956 ± 0.38	7.164

3.6 Ink Trapping

Ink trapping values are measures of the transfer of an ink onto a previously printed surface compared to ink transfer on blank paper. In this study, blue, green, and red ink trapping were measured at solid ink patches since solid trapping is not influenced by the halftone structure. Ink trap on other tone values, such as 25%, 50%, and 75% were not measured. It was speculated that the trapping at lower tone values might be influenced by the dot structure.

The Preucil trapping equation (see the equation below) was used to measure ink trapping and the results are shown in Table 9. Since 89% submitted coated sets and 90% submitted uncoated sets were print with C-M-Y color sequence, the results were the trapping values for C-M-Y print sequence only. See Table 9.

$$\text{Trap }(\%) = \frac{D_{1+2} - D_1}{D_2} \times 100$$

where D_{1+2} = density of the overprint
D_1 = density of first color
D_2 = density of second color (Tritton, 1997).

Accepted trapping is generally somewhere between 75% and 95%; the higher the percentage is, the better the ink trapping. In Table 9, the average trapping values of coated paper were higher than those of uncoated paper in all of the red, green, and blue traps. Similarly, the SDs of the trap values for coated paper were higher than for uncoated paper. For both coated and uncoated paper, the green trap (cyan-yellow overprint) had the largest trap value, followed by blue (cyan-magenta overprint) and red trap (magenta-yellow overprint). The SDs of the trap values for both coated and uncoated paper were smallest in the green trap and largest in the blue trap.

Table 9. Ink trapping values statistics

	Coated Paper		Uncoated Paper	
Overprint	Trapping %	S.D.	Trapping %	S.D.
Red-MY	69.684 ± 0.29	5.478	55.090 ± 0.26	4.772
Green-CY	84.332 ± 0.25	4.820	81.249 ± 0.19	3.513
Blue-CM	82.626 ± 0.31	5.862	67.486 ± 0.32	5.726

Note: Printing color sequence: K-C-M-Y
Coated samples = 1400 (40 sets * 35 sheets)
Uncoated samples = 1260 (36 sets * 35 sheets)

3.7 Gray Balance

The gray balance of a printing system is widely recognized as a vital parameter in achieving high-quality color reproduction. Pobboravsky (1966) stated that gray balance is not only important for the accurate reproduction of neutrals in a print, but also important for the overall hue balance of the print. Hutton and Stanton (2000b) expressed that evaluating neutral in measurements of gray balance has been long a subjective task, but spectrophotometric measurement has been found to be a reliable alternative to visual appraisals.

Dr. Stanton (1991) suggested that a gray balance chart should be used as a process standardization target for determining the three-color dot requirements for cyan, magenta, and yellow films to reproduce a neutral scale at four different tone values. He even mentioned that a densitometer or colorimeter can be used for measuring the Gray Balance Chart to investigate the colorimetric values of the squares selected as most neutral, or to measure various squares to find the most neutral squares (where the a* and b* values are closest to zero).

In this study, the GATF gray balance chart was included in the test form to measure the CIELAB values of various CMY combinations at 7%, 30%, 60%, and 80% tone levels. The chart consists of four matrices of squares with various combinations of CMY coverage. Each matrix represents a different tone level. Due to the time constraint, this research calculated only the best CMY combinations for 80% tone because the shadow gray balance varied more widely than the midtone and highlight gray balance. An X-Rite 530 was used to measure CIELAB values on each square of the shadow matrix of the gray balance chart. The best CMY gray balance combinations were then identified as the patches where the (a*, b*) coordinates were closest to zero (i.e., low chroma values). Most of the selected patches were less than ***3.8*** and ***2.8*** chroma units from the origin for the coated and uncoated paper, respectively. When the most neutral squares were identified, the appropriate dot values were recorded onto SPSS, and the square with the highest frequency was defined as the best CMY gray balance combination for the 80% tone level. The frequency analysis results show that the ***c80/m74/y66*** combination produced the most neutral gray for coated samples and the ***c80/m76/y78*** combination for uncoated samples. See Table 10. It is recommended that additional researches are necessary to further identify the CMY combinations that produce the most neutral gray for other tone levels.

Table 10. The most neutral 80% gray CMY combinations by press and paper type

Press Type			Paper Type	
Press	Coated	Uncoated	Coated	Uncoated
Heidelberg	c80/m76/y78	c80/m66/y78 c80/m76/y78	Gloss: c80/m74/y66	Wood Free A*: c80/m76/y78
Mitsubishi	c80/m66/y66	c80/m76/y78	Matte: c80/m66/y66	Wood Free B*: c80/m76/y78
Komori	c80/m78/y66	c80/m76/y78	Both Side: c80/m74/y66	Machine Finished: c80/m74/y74
Akiyama	c80/m78/y70	c80/m76/y78	*two different grades of wood free paper submitted	
Man Roland	c80/m74/y66	c80/m66/y72		

3.8 Hue Error and Grayness

Both hue error and grayness measurements are concerned with the color purity of an ink. Hue means the name of a color (i.e., magenta, yellow, red, etc.) and error applies to the deviation from the ideal color. Hue error refers to the amount of contamination (or color shift) that a particular pigment displays. The more hue error a pigment possesses, the more difficult it becomes to accurately reproduce certain colors. If a process color is contaminated by the other two colors, the result is gray. This is referred to as grayness; grayed inks are also commonly called “muddy.” The degree of grayness limits the ability of the pigment to reproduce clean secondary colors (Coudray, 1990). In this study, the hue errors and grayness of the process color ink were measured by taking readings off printed solid ink patches with a GretagMacbeth D118C densitometer using the Prucil equation developed at GATF. It is important to mention that hue error and grayness were used for comparative purposes only.

The overall results of the hue errors and grayness are displayed in Table 11. Both hue error and their grayness values of the coated paper were lower than those of the uncoated paper in all of the cyan, magenta, and yellow inks. Coudray (1997b) in his study suggested that typical hue error and grayness values for process color inks are as follows: yellow hue error to magenta = 2~5%, grayness = 2~5%; Magenta hue error to yellow = 35~74%, grayness = 9~15%; Cyan hue error to magenta = 18~26%, grayness = 18~26%.

Table 11. Statistics of hue error and grayness values

	Coated Paper		Uncoated Paper	
Color	Hue Error %	Grayness	Hue Error %	Grayness %
Y hue error to M	3.0019 ± 0.04	1.1276 ± 0.04	4.2814 ± 0.04	1.2086 ± 0.04
M hue error to Y	51.464 ± 0.19	4.8095 ± 0.05	56.211 ± 0.16	5.8336 ± 0.07
C hue error to M	26.234 ± 0.11	8.7283 ± 0.04	35.118 ± 0.15	12.962 ± 0.07

4 Conclusions

Specifications for high quality commercial sheetfed lithography in Taiwan have not been studied until this research. The results of this study provide the sheetfed offset lithographic printers in Taiwan a very useful and practical reference for comparing their own specifications with others across the country as well as with other countries. The detail specification values for the print attributes of this study are more than 300 A4 pages, and therefore, not fully presented in this paper. If you are interested in the results of this study, please write to the author at t0308@mail.ntua.edu.tw.

The result of this research is a set of realistic specifications, based on real-world operating parameters by major sheetfed offset lithographic printers in Taiwan. These specifications represent a coherent and attainable set of aim points and tolerances and are useful information for setting print specifications standards for commercial sheetfed offset lithography in Taiwan. Another distinguishing feature of this study is the involvement of the National Science Council (NSC) of Taiwan, which is ideally suitable for establishing these specifications for the sheetfed lithographic industry in Taiwan.

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Appendix I. Test Form of the Study