An Investigation of the Dot-Reproduction Process Capability for Computer-to-Plate (CTP) Printing Plates

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Abstract: Compared with the conventional printing method, the CTP technology can save manpower, chemical pollution, and production time for printers. The main considerations of a CTP investment consist of its production time, cost and dot-reproduction quality. Therefore, the stability of the CTP plates and their quality of tone reproduction are the two major concerns. This research was an experimental study in nature and intended to investigate the differences on the dot-reproduction quality and consistency among two major CTP plates and one conventional Presensitized (PS) plate in Taiwan's printing market.

The results not only provide the printing industry in Taiwan with an evaluation of adapting CTP technologies, but also reveal the comparisons on the stability and quality of dot reproduction between CTP and conventional PS plates.

The plate materials for the experiment included a Silver Halide plate, Photopolymer plate, and PS plate. A digital test form and control bar was designed for the two CTP plates, and a film generalized from the digital test form was developed for burning the PS plates. Forty plates for each type of the two CTP and PS plates were made and their images were measured by a plate-reading spectrodensitometer. The process capability based on the dot gain size, print contrast, and solid ink density was determined statistically. The results exposed the differences in the process capability based on the tone reproduction for the two CTP plates. The study also investigated the differences in tone reproduction between the conventional PS lithographic plate and CTP plates.

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1. Introduction

The main purpose of the printing industry is to provide services and manufacture products that communicate visually. Its processes allow a high-quality image to be reproduced in large quantities at a reasonable cost. Hird (1995, p. 9) indicated that the printing industry is now one of the largest services organizations in the world. It is a growth industry. This means it manufactures more products using more advanced technologies than it did the previous year. The industry is constantly developing more sophisticated methods to meet the needs of the growing population. It has invented numerous significant breakthroughs in technology. One of the significant breakthroughs is the innovation of CTP (Computer-to-Plate) systems in the prepress stage. CTP has been one of the buzzwords of the printing industry since DRUPA 1995 in Germany, where somewhere in the region of 30 different CTP solutions were exhibited, causing a great deal of interest and speculation.

1.1 Statement of the Problem

Computer-to-plate (CTP) has progressed significantly since the DRUPA exhibition in 1995. According to Andrew Tribute (1999) at Seybold Publications, a limited number of CTP devices were in use in 1995, probably less than 100 units around the world. Mr. Tribute also indicated that the printing industry has nearly 2000 CTP units in use worldwide. Romano and Cary (1998) explained that most users indicated the benefits of CTP come in two primary areas: faster time from file to plate and faster makeready. Overall, users are finding more peripheral benefits for CTP in terms of turnaround, digital workflow, and the handling of shorter runs. There is no doubt that CTP technology has become an important component of a standard graphic arts workflow and will continue to remain one of the hottest topics in the printing industry. Then, the remaining question is "which CTP plate material and system is best for you?"

1.2 Need for the Study

Southworth (1996, February) stated that when choosing a CTP unit, three things to consider are *dot size variation, resolution, and image line width.* Among them, dot size variation is the most critical factor affecting color balance, gray balance, and clean color. In addition, many literatures agree that one of the most important factors of choosing a CTP unit is its process consistency, and dot size variation is the key to process consistency. Without a consistent CTP process, a printer cannot achieve the desired print output characteristics. Therefore, there is a great need to study the process consistency and capability for various types of CTP plates by evaluating their dot area variation. According to GRACoL 2.0 (General Requirements for Applications in Commercial Offset Lithography version 2.0) published by GCA in 1998, there are three crucial input variables for the offset printers to achieve optimum output print characteristics: solid ink density (SID), print contrast (PC), and total dot gain (DG). These three characteristics are the most commonly measured values associated with dot area variation for lithographic printers.

1.3 Purposes of the Study

The main purposes of this study were to 1) investigate the process stability and capability for commonly used CTP plates in Taiwan and 2) compare the process stability and capability of CTP plates with those of conventional PS (Presensitized) plates, in terms of solid ink density, print contrast, and total dot gain. The CTP plates used in this experiment were silver-halide and photopolymer aluminum-based plates. One widely used presensitized plate was studied for the purpose of comparing its performance with the CTP plates.

1.4 Assumptions of the Study

The following assumptions were made in the study:

1. There were no operator effects on dot-reproduction quality for the plates, although there was only one well trained operator who operated each plate system.
2. The plates used in the study were all stored and shipped under the recommended conditions by the manufacturers before the experiment.

1.5 Limitations of the Study

The following limitations are important to interpret the conclusions and recommendations of this study:

1. Due to the lack of the plate material and output device in Taiwan at the time of the experiment, the popular thermal CTP plate was not studied in this experiment.
2. Due to the time and expense constraints, there were only forty black plates reproduced for each type of the three plates.
3. Each plate reading was a mean value of five measurements from the spectrodensitometer.
4. All dot area values on the plates were measured by the Murray-Davies equation and the measuring procedures were determined based on the recommendations of the spectrodensitometer manufacturer.
5. The material, production, and labor costs for the plates were not studied. The main interest of the study was on the dot-reproduction consistency for the plates.
6. The major limitation of the study was the measuring instrument. Due to the lack of a portable instrument such as ACME Plate Dot Reader or Centurfax CCDot as recommended by GATF's senior researcher John T. Lind (1999,

May/June), this study uses a X-Rite 528 Spectrodensitometer to read the plates.

2. Review of Related Literature

In lithographic printing systems, Computer-to-plate (CTP) is generally defined as exposing an offset printing plate directly from an electronic master. Indeed, a complete CTP system would include the following digital procedures:

1. using a software application to compose several single-page layouts,
2. utilizing an imposition software to accomplish the overall job layout based on the desired finish size and binding requirements,
3. employing a platesetter to output the plates by exposing dots directly onto the plates using a laser light source, and
4. the plates are developed chemically and ready for printing.

It is well accepted that computer-to-plate is finally a maturing technology and it is the print production technology of the future. It is a completely electronic system that produces printing plates for direct mounting on the printing press without the use of film. With computer-to-plate technology, art is digitally transferred directly from the computer to the printing plate, making the image on the plate a potentially more accurate reproduction than one done from film. Computer-to-plate reduces the plate making process into minutes instead of hours.

2.1 CTP vs. Conventional Methods

Computer-to-plate systems and technology continues to remain one of the hottest topics in the printing industry over the past few years. One advantage of using CTP is that it eliminates the prepress steps of exposing and developing films, stripping films and platemaking; most are manual tasks. Compared with traditional methods, the production time using CTP technology is much faster. All documents and files are electronically processed in CTP systems, eliminating several time consuming and labor-intensive steps in the process. By eliminating film, and by using CTP, printers get first-generation printing plates with better resolution and fewer possibilities for plate errors.

Going filmless eliminates the need to dispose of used photographic chemicals and silver-based films, as well as the cost of new supplies, the equipment and maintenance of that equipment. However, the changes attributable to just the CTP investment were (GCA Technical Committee Meeting Summary, 1998):

- Elimination of image setting
- Elimination of film processing
- Addition of soft proofing
- Transition to digital imposition proofing

2.2 What Does CTP Offer Printers?

CTP offers a number of time and money saving benefits to the printer. These include:
Simplifying workflow. It includes the elimination of film generation, reduced manpower, and reduction in material costs.
Reducing press make-ready times. With print runs getting shorter, printers are having to make-ready much more frequently. However, because CTP technology delivers a clean and first-generation dot directly onto the plate, the image quality is significantly improved. The valuable time spent on correction and deletion is greatly reduced.
Reducing delivery times to your customers. CTP combines two production processes into one, saving time and hassle, meaning that printers can pass on these faster turn-around times to their customers.
Higher quality print. As stated above, CTP technology delivers a clean and first-generation dot directly onto the plate, greatly improving the image quality and enabling printers to produce more accurate print, first time, every time. CTP plates have a sharper, more controllable spot. The customers will see the difference.
The ability to compete successfully in the short run color market. Faster and less expensive make-readies will enable printers to offer a more competitive service in shorter printing runs, whilst maintaining quality output.

However, according to Miles Southworth (1997, July), almost every CTP user reports that CTP is working well, and some of the benefits reported at the *Direct! Conference* sponsored by Graphic Communications Association (GCA) are:

- Make-readies are shorter.
- Waste has been reduced.
- Internal fit is no longer a problem, because images fit.
- Register is easier.
- Color comes to OK faster.
- Heavier inking can be achieved without the middletone darkening.
- More saturated colors are possible.
- The plates seem to print cleaner with cleaner background.
- A plate remake can be remade quickly from saved digital files, reducing press downtime.
- In some cases, the investment in CTP attracted customers.

2.3 The Barriers to CTP Investment and Adoption

The two disadvantages are that 1) the platesetter and service contract costs are probably higher than conventional platemaking, and 2) the computer operators are most likely higher paid than the stripper. Therefore, the cost may not be that different (Southworth, 1997). In addition, some barriers to CTP investment and adoption reported at the technical committee meeting of *Digits! Dot! Presses: The CTP Forum*, sponsored by Graphic Communications Association (GCA) in November 1998, are (GCA Technical Committee Meeting Summary, 1998):

- Marketing — including the complex trapping issues, extensive pickup of existing film, and complexity of assembly. The required skill set for CTP was not available.
- Workflow — digital data is required from customers and there are new OPI/Trapping, and Imposition requirements. If the printer was not already providing digital prepress services (e.g., direct to film) then they were not ready to make the investment in CTP.
- Skill Sets — there are not enough PostScript professionals on the market and usually the customers also require training in providing good digital files.
- Investment — beside the cost of the equipment there is also the cost of training and setup to consider.

2.4 WHO needs CTP?

Enabling technologies are the key factors determining the suitability of CTP to the printing production environment. Consider for example: Your level of experience with digital data and ability to manage a digital workflow. The type of work you are doing and the amount of work being supplied in digital form. Your confidence in digital proofing and your press formats. It is essential to have experience in digital workflow, including proofing and pre-press processes before introducing CTP - because a CTP operation requires all of the plate elements to be processed exclusively in digital form. For B1/B2 press users to be considering a digital plate workflow whilst minimizing any technical risk, you need to be comfortable in imaging completely digital imposed film work. For A3/B3 press users, the technology is ready and so are the users; over 12% of A3/B3 imaging devices sold this year in America will be CTP units. Those companies most suited to CTP are typically working under tight deadlines, looking to reduce total labor and material costs and improve quality and consistency.

3. Methodology

This study was an experimental research in nature and intended to investigate the differences in the dot-reproduction consistency between two major CTP plates and one conventional Presensitized (PS) plate in the industry. The plate materials for the experiment were a Silver halide plate, Photopolymer plate, and PS plate. A digital test form was designed for the two CTP plates, and a film generalized from the digital test form was prepared for burning the PS plate.

Forty plates for each of the two CTP and PS plates were made. Thus, a total of 120 plates were studied and they were measured by a plate-reading spectrodensitometer (X-Rite 528). The process capability based on the solid ink density, dot gain size, and print contrast was determined statistically. The results exposed the differences in the process capability based on the tone reproduction for the two CTP plates. The study also investigated the differences in tone reproduction between conventional PS lithographic plates and CTP plates.

3.1 Variables

The dependent variables of the study were the relative process capability ratio (PCR) and process capability (Cp) of the dot reproduction for the CTP and PS plates. The Cp was computed statistically from the spectrodensitometry readings of the dot gain percentage (DG), solid ink density (SID), and print contrast (PC) by Minitab software package version 12. The independent variables were the types of plates, including sliver halide, photopolymer, and PS. The controlled variables included digital test form, spectrodensitometer, room temperature and relative humidity for each platemaking operation, and operator for each platemaking process. It should be noted that the plate-making operational procedures were standardized based on the manufacture's recommendations during the experiment for each platesetter. In addition, the imagesetter that output the film for making the PS plates was linearized and compensation curves were not applied to the test form. The correct amount of time to expose the PS plates was determined by a UGRA Plate Control Wedge. Table 1 exhibits the plate materials for this experiment.

Table 1. The experimental materials

Plate Type	Manufacturer	Output Devices
Silver halide (AgX) CTP	A	A's Platemanager A's Lithostar LP150
Photopolymer CTP	B	B's PlateJet 8 B's LP-850p
Conventional PS	C	C's PS800ES C's DU800

3.2 Measuring Procedures

After collecting all 120 plates (3*40), an X-Rite 528 Spectrodensitometer was used to read the dot areas (DA) on the 25%, 50%, and 75% tints, solid ink density (SID), as well as print contrast (PC). Each specific area on the plates was measured five times for the purpose of reducing measuring error. Thus, the following analyses were made based on the average of the five readings for each measured attribute.

4. Results and Findings

This section reports the results and findings gained through analyses of the data obtained from the experiment. The software packages employed to analyze the data were SPSS 8.0 and Minitab 12.0.

4.1 Descriptive Statistics

Table 2 shows that descriptive statistics for all variables. It indicates that the mean solid ink density (SID) of PS and photopolymer plates are very close (.915, .914) and both greater than that of the silver halide (AgX) plate (0.718). For the mean dot gain percentage at 75% tint, the AgX plate has the least amount of dot gain (4.94%), followed by the PS (6.46%) and photopolymer plates (11.66%). For the mean dot gain percentage at 50% tint, the AgX plate has the least amount of dot gain (4.40%), followed by PS (8.87%) and photopolymer plate (13.34%). For the mean dot gain percentage at 25% tint, the AgX plate has the least amount of dot gain (2.53%), followed by the PS (3.92%) and photopolymer plates (7.27%). Even though the silver halide plate yielded the smallest amount of dot gain in all three tonal values, its dot gain dispersion is the largest among the three plates in all three tonal values. In other words, the silver halide plate is less consistent in dot gain than the other two plates, regardless of the size of it.

Table 2. Descriptive statistics

Observed Attribute	N	Min.	Max.	Mean	Std. Dev.	Skew	Kurtosis
Solid Ink Density of AgX	40	.610	.75	.71775	.0231	-2.754	11.659
Solid Ink Density of PS	40	.895	.98	.91503	.0124	2.902	13.581
Solid Ink Density of Photopolymer	40	.898	.94	.91448	.0100	.639	.242
75% Dot Gain for AgX	40	1.00	10.80	4.9400	3.0450	.322	-1.447
75% Dot Gain for PS	40	5.74	7.12	6.4610	.3397	-.059	-.474
75% Dot Gain for Photopolymer	40	7.86	12.48	11.6605	.8931	-2.624	8.313
50% Dot Gain for AgX	40	.80	9.60	4.4025	2.4363	.191	-1.199
50% Dot Gain for PS	40	7.10	9.84	8.8705	.5472	-.796	1.529
50% Dot Gain for Photopolymer	40	10.64	14.12	13.3370	.6170	-2.249	8.507
25% Dot Gain for AgX	40	.60	4.40	2.5255	1.1411	.049	-1.114
25% Dot Gain for PS	40	2.58	5.72	3.9150	.6706	.222	.628
25% Dot Gain for Photopolymer	40	5.32	8.02	7.2695	.5430	-1.349	3.320
Print Contrast for AgX	40	23.80	31.20	27.5350	1.4318	-.151	.826
Print Contrast for PS	40	30.22	31.44	30.8255	.2963	.125	-.052
Print Contrast for Photopolymer	40	19.28	21.42	20.4750	.4455	-.644	.979

Print contrast is an increasingly popular process control parameter because it is a value that printers wish to maximize (Stanton & Hutton, 1999). It represents the tonal range of the shadows of a print, and is influenced by both density and dot gain. In this study, the PS plate has the greatest print contrast value (30.83%), followed by the AgX (27.54%) and photopolymer plates (20.48%), as shown in Table 2.

Solid ink density (SID). Table 3 displays the ANOVA table of the solid ink density for the three plates. It shows that there is a significant difference in mean SID among the three plates (p value $< \alpha = .05$). Figure 1 exhibits the boxplot of the solid ink density for the three plates. It implies that the silver halide plate has the poorest performance on solid ink density based on its mean and standard deviation value.

Table 3. Analysis of Variance of the solid ink density for the plates

Source	DF	SS	MS	F	P
Factor	2	1.034913	0.517456	1967.55	0.000*
Error	117	0.030770	0.000263		
Total	119	1.065683			

* significant at $\alpha = 0.05$

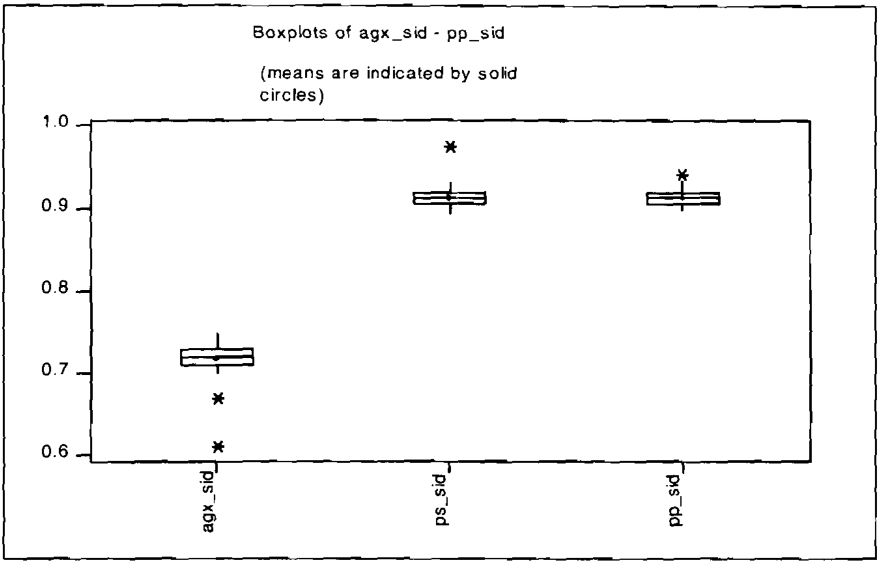

Figure 1. Boxplot of the solid ink density for the plates

Dot gain percentage at 75% tint (75 DG). Table 4 displays the ANOVA table of the dot gain percentage at 75% tint for the three plates. It shows that there is a significant difference in mean dot gain percentage at 75% tint among the three plates (p value < α = .05). Figure 2 exhibits the boxplot of the dot gain percentage at 75% tint for the three plates. It shows that the AgX plate has the least amount of dot gain size at 75% tint, but its variation is the greatest among the three plates. In other words, the silver halide plate might not be able to deliver consistent dot gain at 75% tint, compared with the other two plates.

Table 4. ANOVA for the dot gain percentage at 75% tint of the plates

Source	DF	SS	MS	F	P
Factor	2	993.51	496.76	146.32	0.000*
Error	117	397.22	3.40		
Total	119	1390.74			

* significant at $\alpha = 0.05$

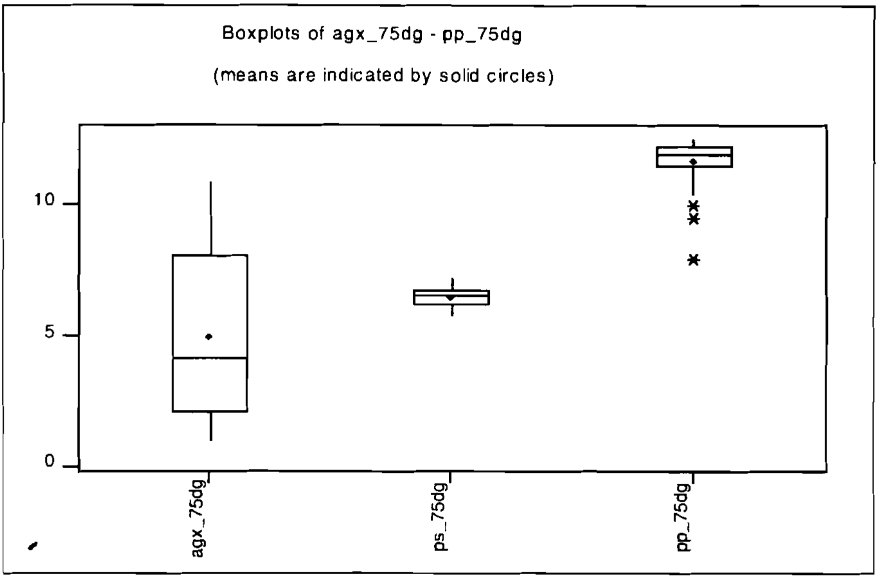

Figure 2. Boxplot of the dot gain percentage at 75% tint for the plates

Dot gain percentage at 50% tint (50 DG). Table 5 displays the ANOVA table of the dot gain percentage at 50% tint for the three plates. It also shows that there is a significant difference in mean dot gain percentage at 50% tint among the three plates (p value < α = .05). Figure 3 exhibits the boxplot of the dot gain percentage at 50% tint for the three plates. It suggests that the AgX plate has the smallest mean dot gain percentage at 50% tint, but its variation is the greatest among the three plates. Again, the silver halide plate could not deliver consistent dot gain at 50% tint, compared with the other two plates.

Table 5. ANOVA for the dot gain percentage at 50% tint of the plates

Source	DF	SS	MS	F	P
Factor	2	1596.51	798.25	361.98	0.000*
Error	117	258.01	2.21		
Total	119	1854.52			

* significant at $\alpha = 0.05$

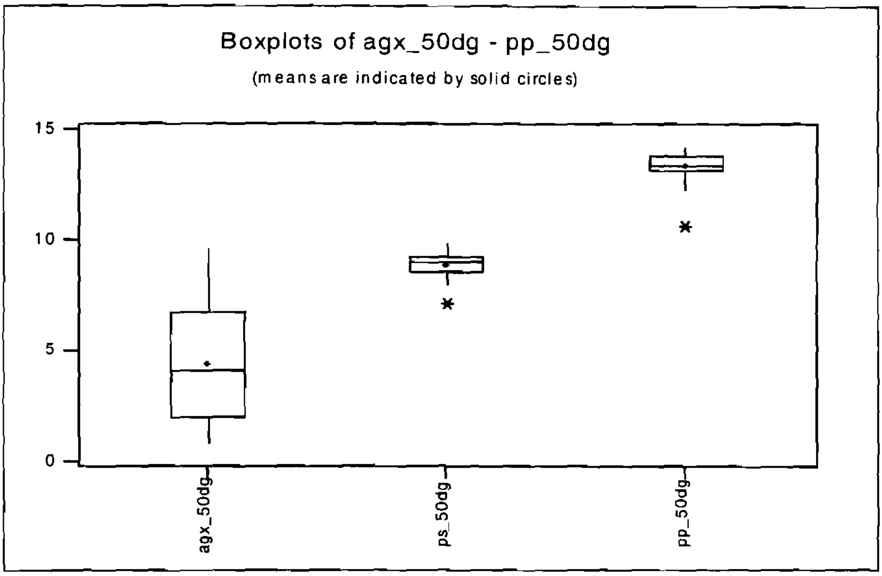

Figure 3. Boxplot of the dot gain percentage at 50% tint for the plates

Dot gain percentage at 25% tint (25 DG). Table 6 displays the ANOVA table of the dot gain percentage at 25% tint for the three plates. It indicates that there is a significant difference in mean dot gain percentage at 25% tint among the three plates (p value < α = .05). Figure 4 displays the boxplot of the dot gain percentage at 25% tint for the three plates. It shows that the silver halide plate has the smallest mean dot gain percentage at 25% tint, but its variation is the largest among the three plates. Thus the silver halide plate could not produce consistent dot gain at 25% tint, compared with the other two plates.

Table 6. ANOVA for the dot gain percentage at 25% tint of the plates

Source	DF	SS	MS	F	P
Factor	2	475.85	237.93	348.77	0.000*
Error	117	79.82	0.68		
Total	119	555.67			

* significant at $\alpha = 0.05$

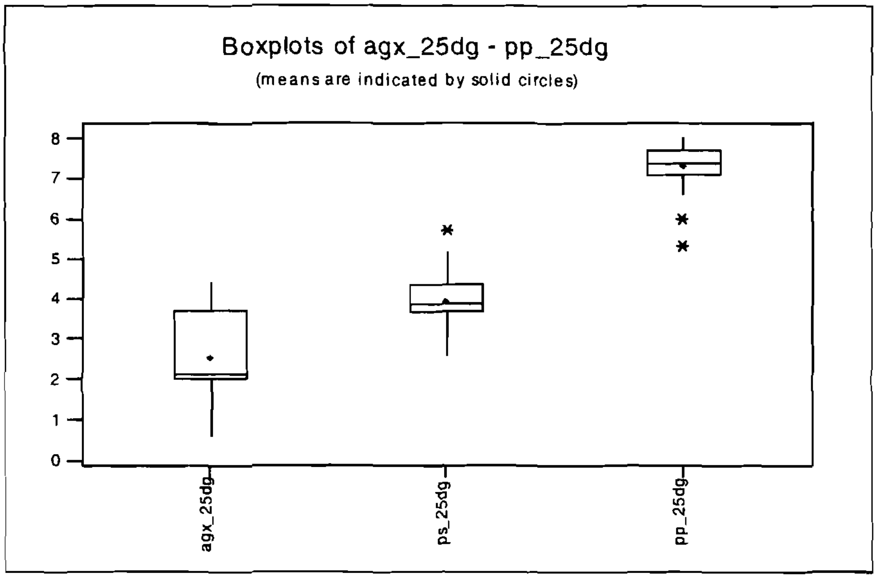

Figure 4. Boxplot of the dot gain percentage at 25% tint for the plates

Print contrast (PC). Table 7 displays the ANOVA table of the print contrast for the three plates. It indicates that there is a significant difference in mean print contrast among the three plates (p value < α = .05). Figure 5 presents the boxplot of the print contrast for the three plates. It shows that the PS plate has the best performance on print contrast since it has the largest mean value of print contrast, and its print-contrast variation is the smallest among the three plates.

Table 7. Analysis of Variance of the print contrast for the plates

Source	DF	SS	MS	F	P
Factor	2	2237.39	1118.70	1436.49	0.000*
Error	117	91.12	0.78		
Total	119	2328.50			

* significant at α = 0.05

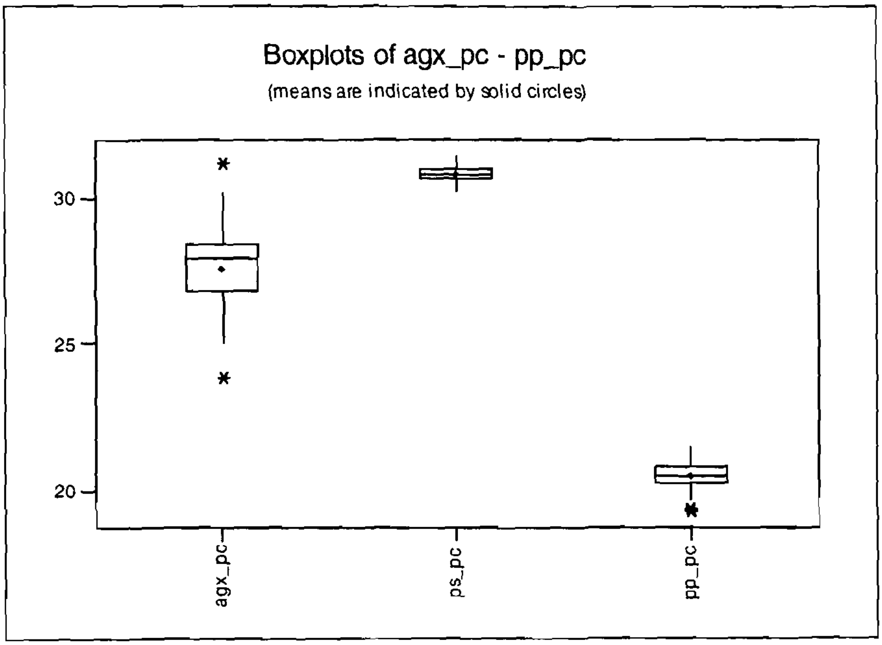

Figure 5. Boxplot of the print contrast for the plates

4.2 Summary of the Descriptive Statistics

Table 8 summarizes the results of the descriptive statistical analyses for the three plates. Based on Table 8, the following conclusions can be drawn:

1. The silver halide plate yielded the least amount of solid ink density and greatest dispersion of it among the three plates.
2. It is interesting to note that the silver halide plate produced the largest amount of dispersion on dot gain size in all three tints among the three plates, although it yielded the least amount of dot gain size.
3. The conventional PS plate produced the greatest amount of print contrast and least dispersion of it. It implies that the PS plate has the best performance in the tonal range of shadows among the three plates.

Table 8. A summary of the plate attribute for the three plates

		Silver halide	PS	Photopolymer
Solid Ink Density	Mean	.72	.92	.91
	Dispersion	.023	.012	.010
Dot Gain %at 75%	Mean	4.94	6.46	11.66
	Dispersion	3.045	.339	.893
Dot Gain % at 50%	Mean	4.40	8.87	13.34
	Dispersion	2.436	.547	.617
Dot Gain % at 25%	Mean	2.53	3.92	7.27
	Dispersion	1.141	.671	.543
Relative Print Contrast	Mean	27.54	30.83	20.48
	Dispersion	1.432	.296	.446

4.3 Plate Consistency and Capability Analyses

The section is to discuss the consistency and capability of the observed attributes for the three plates. The tools used to analyze the consistency for each variable are Individual Control Chart (I Chart), Moving Range Charts (MR Chart), and Capability Analysis.

Determination of the lower specification limits (LSL) and upper specification limits (USL). Due to the lack of historical parameters of LSL and USL for each plate attribute (solid ink density, dot gain, and print contrast), a method of determining the proper LSL and USL is necessary. In this study, the LSL and USL for each attribute are determined based on the following procedures (Montgomery, 1997, pp. 180-229):

1. Construct the trial I and MR control chart of each attribute for the three plates.
2. Examine every control chart; if it is in control, then use the lower control limit (LCL) and upper control limit (UCL) as the LSL and USL. If it is an out-of-control condition (for most cases), reconstruct the control chart after eliminating all out-of-control points in the initial charts to obtain the revised values for mean, LCL, and UCL.
3. For each attribute, the difference between revised LCL and UCL of each plate obtained in the previous step is computed and named $6\sigma_{revised}$, i.e., $UCL_{revised} - LCL_{revised} = 6\sigma_{revised}$. Then $3\sigma_{revised}$ for each plate is computed for the purpose of obtaining the "average $3\sigma_{revised}$" of the three plates, $3\hat{S}_{revised}$ namely, i.e.,
   $$3\hat{S}_{revised} = (3\sigma_{revised/AgX} + 3\sigma_{revised/PS} + 3\sigma_{revised/Photopolymer}) / 3.$$
4. For each attribute, the final LSL and USL are obtained by subtracting from and adding to the revised mean of each plate by $3\hat{S}_{revised}$, i.e.,
   $$LSL_{final} = Mean_{revised} - 3\hat{S}_{revised}$$
   $$USL_{final} = Mean_{revised} + 3\hat{S}_{revised}$$

5. The LSL_{final} and USL_{final} were then used to assess the relative Process Capability Ration (PCR) for the *revised* individual measurement control chart (I-Chart) of each attribute for the plates.

The LSL_{final} and USL_{final} for each plate attribute computed based on the above procedures are exhibited in Table 9, and the revised I-Charts for solid ink density, dot gain at 50% tint, and print contrast are displayed in Appendix 1, Appendix 2, and Appendix 3. It is important to note the relative PCR of dot gain was compared only at the 50% tint patch simply because the maximum amount of dot gain usually occurred at 50% dots.

Table 9. The LSL_{final} and USL_{final} for each attribute for the three plates

	AgX		PS		Photopolymer	
	LSL_{final}	USL_{final}	LSL_{final}	USL_{final}	LSL_{final}	USL_{final}
Solid Ink Density	0.6946	0.7490	0.8863	0.9407	0.8866	0.9410
Dot Gain at 50% Tint	1.6705	7.1355	6.1835	11.6485	10.6775	16.1425
Print Contrast	25.9717	29.1083	29.2617	32.3983	18.9117	22.0483

Interpretation of the relative PCR (Cp or Pp). In capability analysis, overall capability depicts how the process is actually performing relative to the specification limits. Potential capability depicts how the process could perform relative to the specification limits, if shifts and drifts could be eliminated. The difference between the two represents the opportunity for improvement. Without both overall and potential estimates, it is hard to identify the size of the opportunity. The capability analyses display the value of Cp (or Pp) on the figures to represent the relative PCR for the three plates. This is a measure of how capable a process is of meeting specifications. A Cp index (PCR) of 1 means that a process is exactly capable of meeting specifications, while less than 1 means that it is outside specification limits. Ideally, one would like to see a Cp much larger than 1, because the larger the index, the more capable the process. Some practitioners consider *1.33* to be a minimum acceptable value for this statistic, and few believe that a value less than 1 is acceptable.

Capability analysis for solid ink density (sid). The capability analyses of solid ink density for the three plates are exhibited in Figure 6 (AgX), Figure 7 (PS), and Figure 8 (Photopolymer). As shown in those figures, the PS plate has the largest relative PCR (Cp = 1.17), followed by the photopolymer (Cp = 1.04) and AgX (Cp = 0.84) plates. Therefore, this study concludes that the PS plate was the most capable of producing consistent solid ink density among the three plates in terms of relative PCR. In combination with the result shown in Table 8 (the PS plate delivered the largest solid ink density value), it is concluded that the PS plate had the best performance in solid ink density, in terms of its quality and capability.

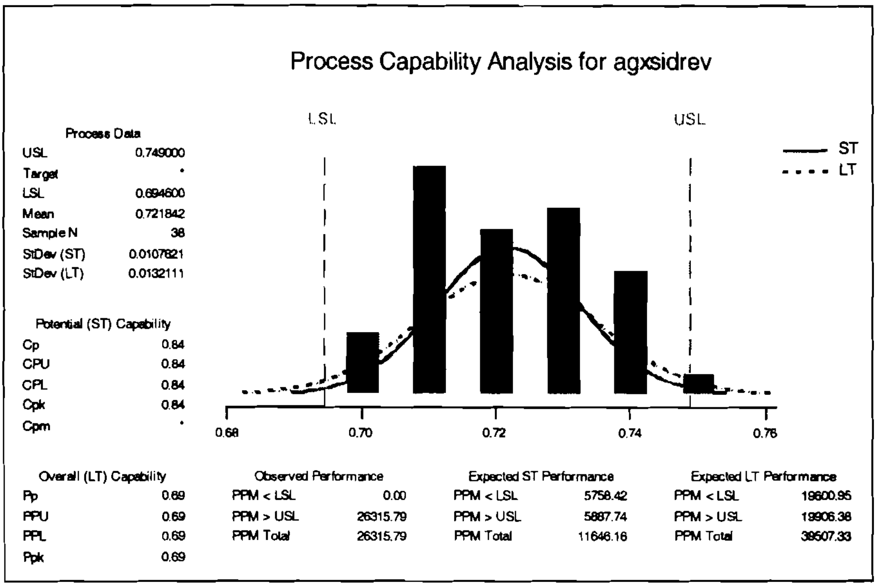

Figure 6. Process capability analysis of solid ink density for the AgX plate

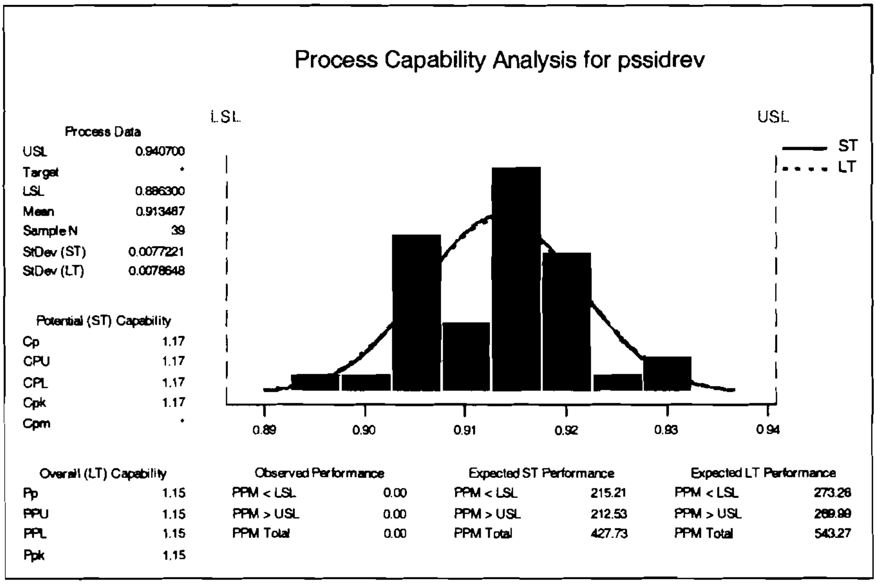

Figure 7. Process capability analysis of solid ink density for the PS plate

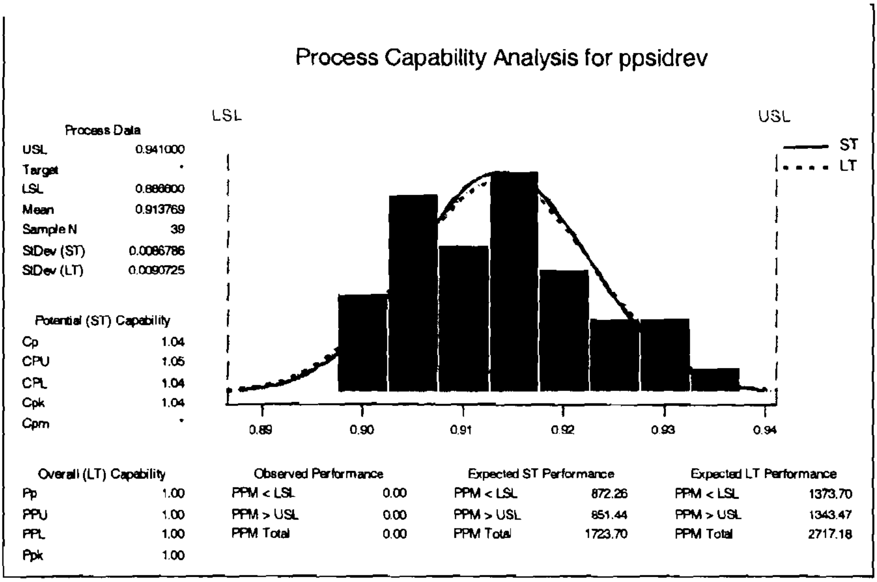

Figure 8. Process capability analysis of solid ink density for photopolymer plate

<u>Capability analysis for dot gain at 50% tint.</u> Figure 9 (AgX), Figure 10 (PS), and Figure 11 (Photopolymer) provide a graphical presentation of the capability analyses of dot gain size at the midtone for the three plates. As shown in those figures, the photopolymer plate has the largest relative PCR (Cp = 2.01), followed by the PS (Cp = 1.85) and AgX (Cp = 0.43) plates. Therefore, this study concludes that the photopolymer plate was the most capable of producing consistent midtone dot area among the three plates in terms of relative PCR.

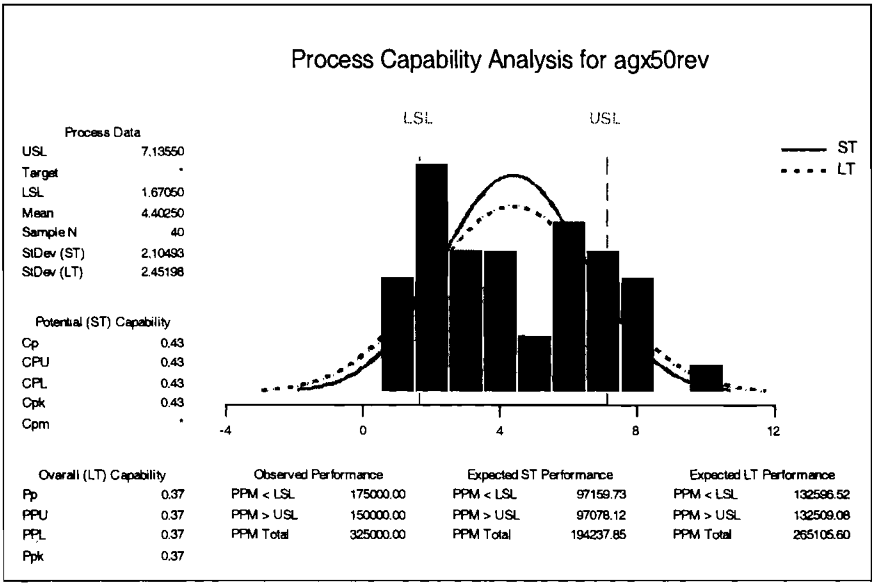

Figure 9. Process capability analysis of 50% dot gain for the AgX plate

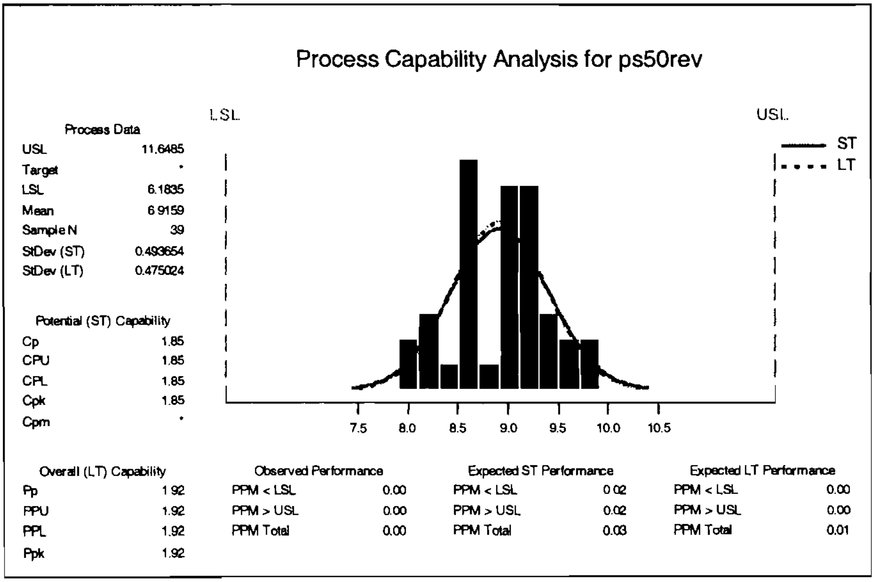

Figure 10. Process capability analysis of 50% dot gain for the PS plate

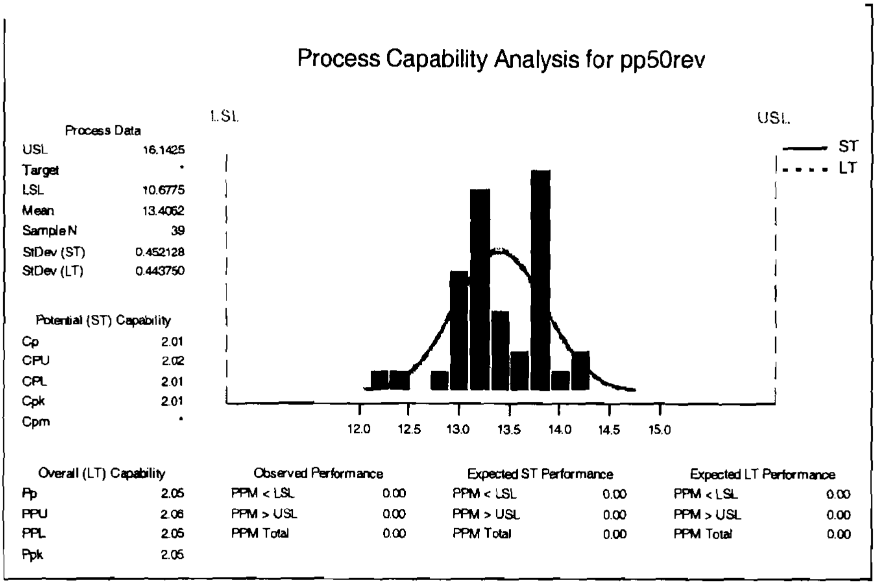

Figure 11. Process capability analysis of 50% dot gain for photopolymer plate

Capability analysis for print contrast (PC). Figure 12 (AgX), Figure 13 (PS), and Figure 14 (Photopolymer) provide a graphical presentation of the capability analyses of print contrast for the three plates. As shown in those figures, the PS plate has the largest relative PCR (Cp = 2.26), followed by the photopolymer (Cp = 1.30) and AgX (Cp = 0.56) plates. Therefore, this study concludes that the PS plate was the most capable of producing consistent print contrast among the three plates in terms of relative PCR. In combination with the result shown in Table 8 (the PS plate delivered the largest value of relative print contrast), it is concluded that the PS plate had the best performance in print contrast.

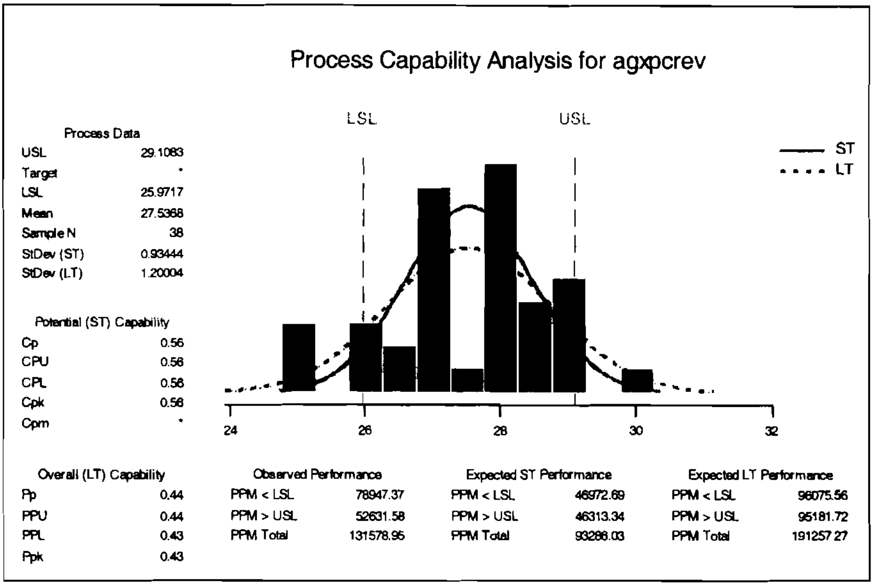

Figure 12. Process capability analysis of print contrast for the AgX plate

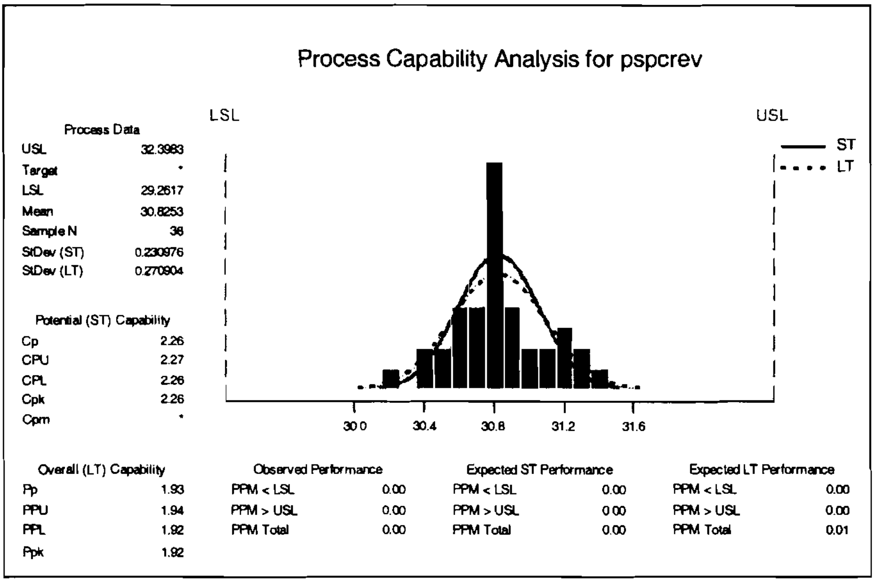

Figure 13. Process capability analysis of print contrast for the PS plate

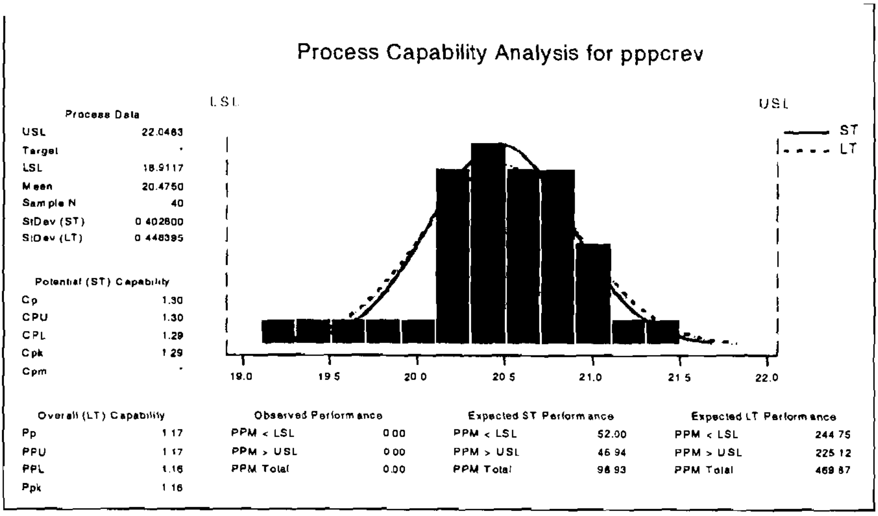

Figure 14. Process capability analysis of print contrast for photopolymer plate

Summary of the plate consistency and capability analyses. Based the presentation of Figure 6 to 14, Table 10 summarizes the capability performance, in terms of relative process capability ratio (PCR), in solid ink density, midtone dot gain, and print contrast for the three plates. As shown in Table 10, this study concludes that the silver halide was the least capable plate of delivering consistent results in solid ink density, midtone dot dots, and print contrast among the three plates (smallest Cp value). In addition, its Cp values for the three attributes are all smaller than 1; it implies that the silver halide plate is not even capable of producing consistent results in all observed attributes.

Table 10.The relative PCR (Cp value) for the plates

Cp value	Silver halide (AgX)	PS	Photopolymer
Solid Ink Density	0.84	**1.17**	1.04
Midtone Dot Gain	0.43	1.85	**2.01**
Print Contrast	0.56	**2.26**	1.30

Bold indicates the best in the category.

5. Conclusion

This study evaluated the consistency and capability performance on solid ink density, dot gain, and print contrast for two increasingly adopted CTP plates (silver halide and photopolymer) and one widely used PS lithographic plates in Taiwan. The production cost and their return-on-investment (ROI) were not examined in this study. Forty plates for each type of the three plates were made according to their own exposure and output process requirements. During the plate-making process, other non-relevant variables, such as room temperature, relative humidity, and operator, were held constant for each process to reduce the experimental biases. Spectrodensitometry measurement was recorded onto SPSS and Minitab software package to develop the descriptive statistics, control chart, and capability statistics of the each observed attribute for the three plates.

The analysis results are summarized in Table 11. As shown in Table 11, the mean solid ink density of the PS and photopolymer plates were very close (.915, .914) and both greater than that of the silver halide plate (0.718). In addition, the solid ink density for both the PS and photopolymer plates were less dispersed than the silver halide plate. The Cp value of the silver halide plate was the smallest (0.840 < 1) among the three. In other words, the AgX plate was not capable (Cp< 1) and the least capable of consistently delivering enough amount of solid ink density.

For the three-quarter-tone dot gain, the silver halide plate yielded the least amount of dot gain (4.94%), followed by the PS (6.46%) and photopolymer plates (11.66%). For the midtone dot gain, the silver halide plate produced the least amount of dot gain (4.40%), followed by the PS (8.87%) and photopolymer plates (13.34%). For the quartertone dot gain, the silver halide plate has the least amount of dot gain (2.53%), followed by the PS (3.92%) and photopolymer plates (7.27%). Even though the silver halide plate produced the smallest amount of dot gain in all three tonal values, its dot gain dispersion was the largest among the three plates in all three tonal values. Furthermore, the silver halide plate had the smallest Cp value (0.430 < 1) in midtone dot gain among the three plates; in other words, the silver halide had the worst performance in dot gain, in terms of the size and reproduction consistency of it.

Table 11.Summary of the observed attributes for the three plates

Observed Attributes		Silver halide	PS	Photopolymer
SID	Mean of Solid Ink Density	.718	**.915**	**.914**
	Std. Dev. of Solid Ink Density	.023	**.012**	**.010**
Dot Gain	Mean of Dot Gain at 75% Tint	4.940	**6.461**	11.661
	Std. Dev. of Dot Gain at 75% Tint	3.045	**.339**	.893
	Mean of Dot Gain at 50% Tint	4.403	**8.871**	13.337
	Std. Dev. of Dot Gain at 50% Tint	2.436	**.547**	.617
	Mean of Dot Gain at 25% Tint	2.526	**3.915**	7.270
	Std. Dev. of Dot Gain at 25% Tint	1.141	**.671**	.543
PC	Mean of Print Contrast	27.535	**30.826**	20.475
	Std. Dev. of Print Contrast	1.432	**.296**	.446
PCR	Cp of Solid Ink Density	.840	**1.170**	1.040
	Cp of Midtone Dot Gain	.430	1.850	**2.010**
	Cp of Print Contrast	.560	**2.260**	1.300

Bold indicates the best performance in the group.

For the print contrast performance, the PS plate brought the greatest print contrast value (30.83%), followed by the AgX (27.54%) and photopolymer plate (20.48%), and its PC dispersion was the smallest among the three. In addition, the PS plate had the largest Cp value (2.26) among the three plates. Thus, the study concludes that the PS plate delivered the greatest and most consistent tonal range in shadows among the three types of plates.

It is important to note that the silver halide plate had the poorest performance in all the observed attributes, in terms of their average and standard deviation values. The most interesting finding is that the Cp value (relative PCR) of the silver halide plate was smaller than 1.00 in all the observed attributes. In other words, it was the least capable plate of delivering quality and consistent dots among the three plates. Finally, this study would like to recommend further researches on investigating the correlation between the plate and its print performance in more quality attributes for more types of CTP plates.

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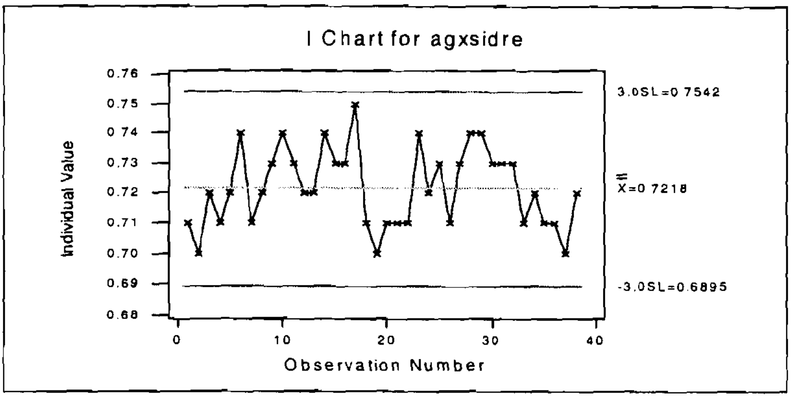
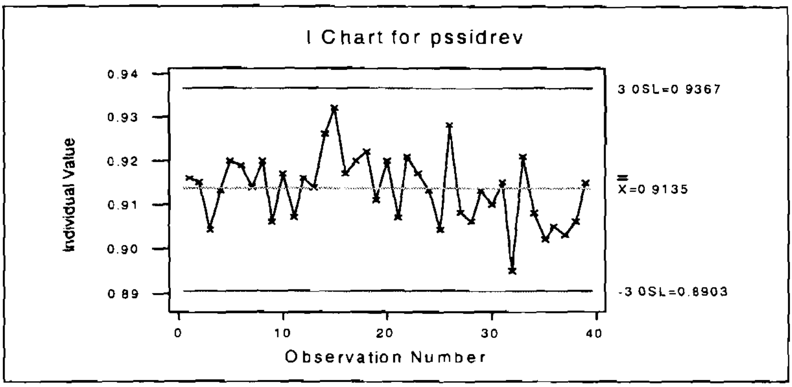
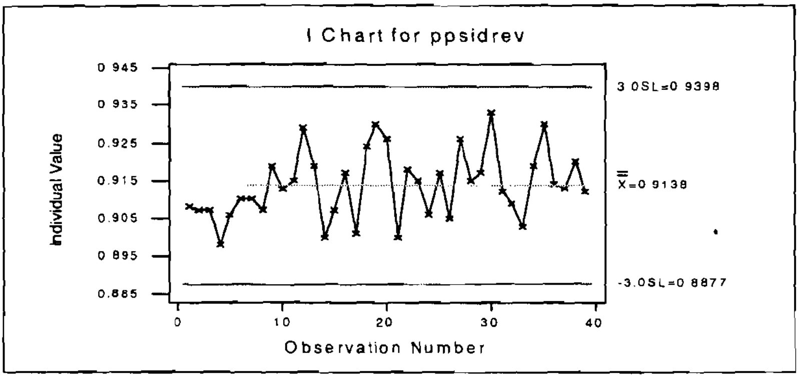
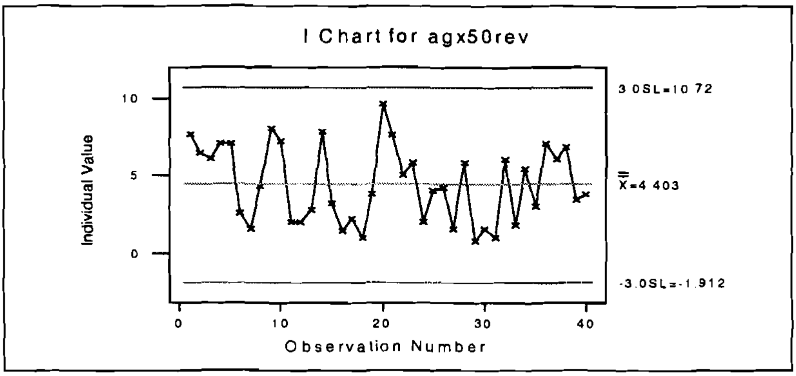
Appendix 1. Revised I-Charts for Solid Ink Density

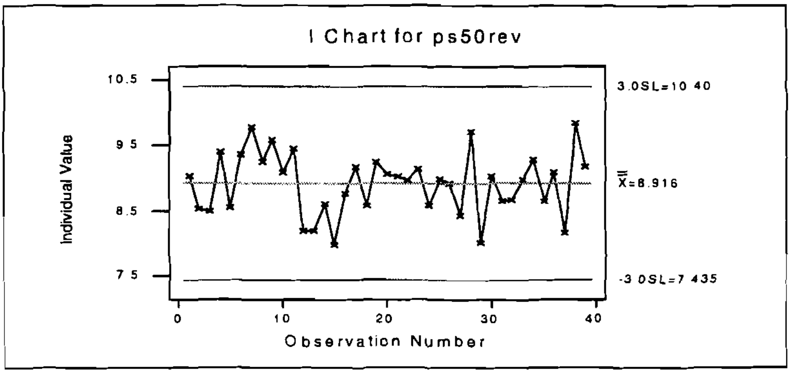


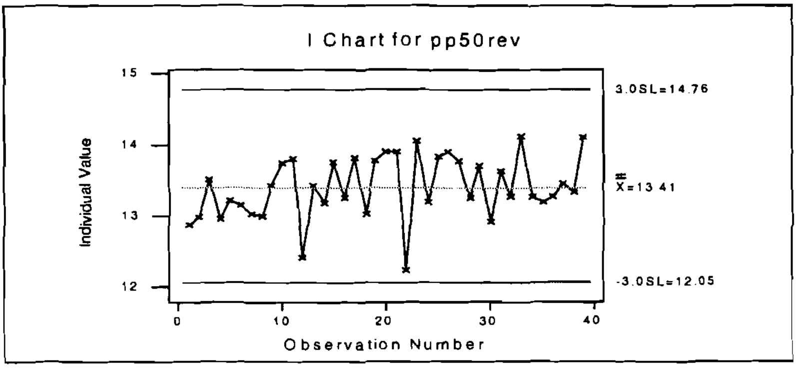




Appendix 2. Revised I-Charts for Dot Gain at 50% Tint







Appendix 3. Revised I-Charts for Print Contrast