CHARACTERIZATION OF PLATE IMAGES, PART 2 -- INTEGRATING SPHERE DENSITOMETRY

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Abstract

This paper and it's predecessor "Characterization of Plate Image, Fact or Fantasy," (Cavin, 1996), now called Part 1 -- 0/45^0 Densitometers, report on the use of photometric devices to characterize metal plate halftone images.

Part 1 - 0/45^0 Densitometers reported on results of different 0/45^0 densitometers to measure dot area of metal plates. The design included a variety of plates and grain surfaces. Results were poor.

Part 2 -- Integrating Sphere Densitometers reports on results of different integrating sphere spectrophotometers to measure dot area of metal plates. Specular component included and excluded was examined. A 0/45^0 densitometer was also included in the design. Various plates with differing grain surfaces were measured. The conclusions of Part 1 concerning 0/45^0 densitometer are confirmed in Part 2. In addition, the variability of density as stated by densitometer manufacturers was used to determine the range of dot area that could be expected when measuring tint patches. The use of statistics has disclosed the following conclusions based on seven null hypotheses that are discussed in depth in the experimental section of the paper:

1. Based on **manufacturers' published tolerances for density** of 0/45^0 densitometers, percent dot area cannot definitively be measured.

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2. Based on **measurements of images on grained metal plates** using $0/45^0$ densitometers, percent dot area cannot definitively be measured.
3. Based on **measurements of images on grained metal plates** using integrating sphere spectrophotometers, percent dot area calculations from derived spectral densities is too variable to measure metal plates.
4. Spectrophotometry is less variable than $0/45^0$ densitometry.
5. Depending on the spectrophotometer manufacturer, specular excluded integrating sphere measurements are preferred.
6. Small dot values below 10% are difficult to read using either RD45 or integrating sphere devices.
7. Tint measurement from smooth grained plates are more variable than medium or rough plates.

Background

A user will, in time, change vendors or select different plates exhibiting different grain surfaces from the same vendor (long or short run plates). The same instrument must be able to read all tint values from a variety of different grain surfaces. Part 1 - $0/45^0$ Densitometers discloses the futility of using $0/45^0$ densitometry for measuring images on metal printing plates. The variability caused by the interaction of tint value and instrument placement, relative to the grain direction, was identified as one of the sources of difficulty.

This paper reports on integrating sphere reflection spectrophotometers as densitometers for measuring plate images on many surfaces. Cross over to Part 1 of this series is facilitated by the use of a $0/45^0$ densitometer from the same manufacturer and model number. For purposes of this paper the specular included and excluded measurements from a single instrument are considered to be two different instruments.

Introduction

Today, the traditional method of determining proper lithographic film to plate exposure uses a gray scale and/or microlines (Fisch, 1986a). Film dot area values are used as a reference for comparison to the printed sheet. The increasing use of digital direct to plate technology, without a film intermediate, forces the user to find alternative, affordable, facile, techniques to measure plate images. Additionally, the dot changes size during plate making in an analog work flow (Fisch, 1996). Should the digital image file be altered to insure it matches that of a collateral analog produced image? Whether the answer to this question is a yes or no, someone should be able to "read" the image on a digitally exposed plate to qualify plate dot area.

As in Part 1, the viewpoint of this paper is that of a manufacturer and vendor of plate materials and of the end user of imaged metal lithographic plates. Our position is that our most discriminating customers should have the capability of precisely, consistently and economically measuring images on metal printing plates each of which having a different grain pattern. The combination of tint level, plate surface topography, and instrument/grain orientation has been shown to influence plate dot size when measured using $0/45^0$ densitometry (Cavin, 1996; Zelley, 1972; Pearson, 1981a; Pearson 1981b). Therefore, it is important to know the level of instrument accuracy and bias per desired tint level, plate surface and instrument to plate orientation for various reflection measurement devices.

Zelley (1972), describes optical measurement techniques used to characterize plate grain surface. Among these techniques are reflection analysis using integrating sphere, and angle reflectometry. He found that, "Each plate has special requirements for graining depending on its components and net results to be accomplished." For example, his recorded measurements illustrate the variability of photometric measurements versus rolling direction (note grain direction). Pearson (1981a), discussing instrument characterization of metal plate surfaces and half tone images, found that plate grain had a significant effect on plate tint measurement. "...it is immediately apparent that dot shape and integrity for the finer textured plate are substantially superior to those for the coarser plate." Pearson and Parker (1981b) found that, "Considering the 10 per cent image dots the tonal accuracy (median area) at the plate stage tended to decrease with deterioration of etch uniformity...the smallest dot size was most sensitive to metal plate topography, as might be expected. The 40 per cent image dot size was marginally less sensitive then the 10 per cent image dot while the 100 per cent were apparently unaffected by plate topography within the limits studied.... Results for the 10 per cent images showed that increased roughness caused an increase in both the range of pi ratio and the median value at the plate stage." (Note: in that paper a 10% dot was the smallest feature studied.)

Others, Fisch and Cavin (1986b), Romano (1996), Stanton et, al (1996) and Pope (1989), have used optical means, including image analysis devices, to characterize reflection materials.

As in this, and the previous paper of this series (Cavin, 1996), Stanton et, al (1996) used both image analysis and densitometry. Stanton's work did not, however, address the cause of the difference, plate grain. Additionally, statistical evidence was not shown of the tint size and plate measurements. Stanton, concludes that, "There was evidence in this study that the dot areas calculated from reflectance instruments on the printing plates were not always predictive of the dot areas that would be printed on paper."

Procedure

Measuring Devices Used

1. Incandescent source spectrophotometer, both specular included and excluded.*
2. Xenon source spectrophotometer, both specular included and excluded.*
3. 0 /45^0 densitometer as in Part 1.
4. Although data were also collected using reflectometry, both fixed and multi-angle, the analysis is extensive, therefore a future paper is contemplated.

* Since no integrating sphere reflection densitometers are commercially available, spectrophotometers were used. Status "T" density was computed using ISO TC42 Specifications 5/3 and 5/4 1995 from spectral reflectance. The values obtained were converted to percent dot area using the Murray Davies calculation (Murray, 1936). A Yule - Nielson (Yule, 1951) "n" factor was not employed.

Table 1
Instrument Characteristics

Instrument Code	Output	Geometry	Description
Spectro A IN	Spectral Reflectance	Integrating Sphere	Specular Included
Spectro A EX	Spectral Reflectance	Integrating Sphere	Specular Excluded
Spectro B IN	Spectral Reflectance	Integrating Sphere	Specular Included
Spectro B EX	Spectral Reflectance	Integrating Sphere	Specular Excluded
RD45	Density	0/45^0	Control

For the purpose of anonymity, manufacturers names have not been identified

Plates Used

Various manufacturers negative acting plate samples, representing smooth, medium, and rough surfaces, were analyzed in this test. They were imaged and hand processed according to manufacturer's specifications. The plates were not gummed.

Test Target

To insure consistency to Part 1 and minimize the differences between computer to plate devices, an analog film target was used to expose each of the plate samples.

Because the aperture of some instruments requires a larger tint target than 5 mm square patches, the UGRA Plate Control Wedge could not be used. Therefore, using an imagesetter, a new film target was constructed of 50 mm square 0, 5, 20, 40, 95 and 100% (solid) tint patches. To insure a hard dot, the film was contacted. This permitted the film target and plate to be same phase. The film halftone targets were calibrated using a duplicate of the instrument used in calibrating the UGRA Plate Control Wedge and RIT Microline Targets.

Film Tint Selections

1. The 5% and 95% tints were selected to provide highlight and shadow tints values. The 20% and 40% tints represent quarter and mid tone areas.
2. Microlines were not used since various vendors negative acting plates respond differently to microline exposure (Fisch, 1986a).
3. Single plate samples from each manufacturer were used to exclude the possibility of plate-to-plate variation.

Measuring Procedure

Table 2 lists the variables of the measurement procedure.

Measurements were made on 5 days for each of the 5 devices described in Table 1. Three metal plates, each with six tint patches, were measured with all devices on all five days.

Every patch was measured at 3 different instrument-to-plate grain orientation. These orientations are 0, 45, and 90 degrees.

Repetition (method) was done in two ways.

1. Singular Angular--Three repetitions were made at each of the 3 orientation angles. The device orientation relative to plate grain angle was changed between each measurement. Thus, the measurements were made at 0,45,90,0,45,90,0,45,90 resulting in 9 measurements.

2. Repetitive Angular--Three repetitions were made at each of the 3 orientation angles. In this method, the device orientation relative to plate grain angle was not changed between each of the 3 repetitions. The instrument was lifted from the plate and repositioned after each individual measurement. Care was taken to insure the correct orientation of the device to grain direction. The order of these measurements were 0,0,0,45,45,45,90,90,90 which resulted in 9 measurements.

Table 2
Measurement Variables

Var Name	Var Points						# of Meas
Method	(Singular)		(Repetitive)				
	0,0,0		0,45,90				18
	45,45,45		0,45,90				
	90,90,90		0,45,90				
Tint Level(6)	0	5	20	40	95	100	108
Plate(3)	Smooth		Medium		Rough		324
Instrument(5)	A in	A ex	B in	B ex	RD		1620
Day(5)	M	T	W	Th	F		8100

Experimental

Analysis

The Null Hypothesis of the Mean will be used to prove or disprove the following statements. They will be discussed individually.

1 Based on manufacturers' published tolerances for density of $0/45^0$ densitometers, percent dot area can definitively be measured.
2. Based on measurements of images on grained metal plates using a $0/45^0$ densitometer, percent dot area can definitively be measured.
3. Based on measurements of images on grained metal plates using integrating sphere spectrophotometers, percent dot area can with confidence be measured.
4. The variability of percent dot area measurement with a $0/45^0$ densitometer is equal to the variability of integrating sphere spectrophotometers when used as densitometers.
5. The variability of percent dot area measurement with specular component included is equal to the variability of specular component excluded for metal plate measurements.
6. Dot size does not affect measurement variability.
7. Plate surface does not affect measurement variability.

Null Hyp #1: **Based on manufacturers' published tolerances for density of $0/45^0$ densitometers, percent dot area can definitively be measured.**

Result: **False**

Density tolerances were obtained from the densitometer data sheets. Using these tolerances, the dot area ranges were calculated for nominal tint values. No actual measurements were done. The results are listed in Table 3. Since no measurements were done, the results are independent of a particular plate or instrument. The calculated ranges of dot areas around the 5%, 20%, and 40% levels are unacceptable. $0/45^0$ densitometers should not be used to characterize half tone images on grained metal plates.

Table 3
% Dot Area Variability Based on Densitometer Manufacturer's Tolerances

Nom Plate Dot Area	Equivalent Plate Density	Range ±0.02 Density	Equiv. % Dot Area Range from	to
5%	0.34	0.32 to 0.36	1.7%	12.6%
20%	0.39	0.37 to 0.41	15.2%	24.9%
40%	0.47	0.45 to 0.49	33.5%	41.7%
95%	0.94	0.92 to 0.96	94.6%	96.6%

Null Hyp #2 **Based on measurements of images on grained metal plates using a $0/45^0$ densitometer, percent dot area can definitively be measured.**

Result: **False**

This experiment is intended to verify the conclusions for Part 1 in which 4 densitometers were used to collect 792 data points. In Part 2, one densitometer was used, producing 1620 measurements. Table 4 lists the means and standard deviations of these 1620 measurements. Since analysis variance tests indicated both the plate surface and tint patch level to be the most significant, they are broken out in Table 4. The variability is unacceptable especially on smooth plates.

Table 4
Mean and ±3 Standard Deviation
$0/45^0$ Densitometer

Surface	Mean DA	±3 SD
5% Nominal Dot		
Smooth	7.10	4.05
Medium	6.90	1.68
Rough	8.54	2.10
20% Nominal Dot		
Smooth	18.10	5.55
Medium	21.48	1.74
Rough	24.20	1.77
40% Nominal Dot		
Smooth	42.51	5.67
Medium	44.68	1.92

Rough	46.09	1.35
95% Nominal Dot		
Smooth	95.78	1.29
Medium	95.61	1.32
Rough	96.17	1.44

Null Hyp #3 **Based on measurements of images on grained metal plates using integrating sphere spectrophotometers, percent dot area can with confidence be measured.**

Result: **False**

Tolerances for density from integrating sphere spectrophotometers are not listed in the manufacturers' data sheets. Therefore, ranges were not computed. Table 5 illustrates the mean and ± 3 standard deviation for the integrating sphere spectrophotometers (described in Table 1). An analysis of variance showed both the plate surface and tint level patch to be significant variables.

Table 5
Mean & Standard Deviation
Integrating Sphere Spectrophotometers as Densitometers

	Spect A In		Spect A Ex		Spect B In		Spect B Ex	
Surface	Mean DA	±3 SD	Mean DA	±3 SD	Mean DA	±3 SD	Mean DA	±3 SD
	5% Nominal Dot							
Smooth	9.12	5.91	8.31	2.88	7.21	2.76	7.89	2.58
Medium	7.01	2.58	6.87	2.82	7.21	2.46	7.20	0.93
Rough	6.77	3.06	6.41	3.27	8.00	1.98	7.78	0.99
	20% Nominal Dot							
Smooth	21.81	2.91	21.80	2.76	21.92	2.70	22.10	1.50
Medium	22.07	2.22	21.99	2.07	22.25	2.07	22.26	0.54
Rough	23.33	3.75	22.82	3.66	23.58	3.45	23.27	1.20
	40% Nominal Dot							
Smooth	43.90	1.80	43.97	1.89	41.34	1.14	41.61	0.84
Medium	45.40	1.20	45.35	1.68	45.30	1.74	45.30	0.72
Rough	44.97	3.48	44.81	3.42	46.01	3.03	45.99	0.90
	95% Nominal Dot							
Smooth	95.88	1.02	95.96	0.90	95.64	1.14	95.60	0.39
Medium	96.24	1.29	96.17	1.35	95.85	1.35	95.80	0.84
Rough	95.70	2.40	96.06	3.55	95.37	1.89	95.41	0.84

Null Hyp #4: **The variability of percent dot area measurement with a $0/45^0$ densitometer is equal to the variability of integrating sphere spectrophotometers when used as densitometers.**

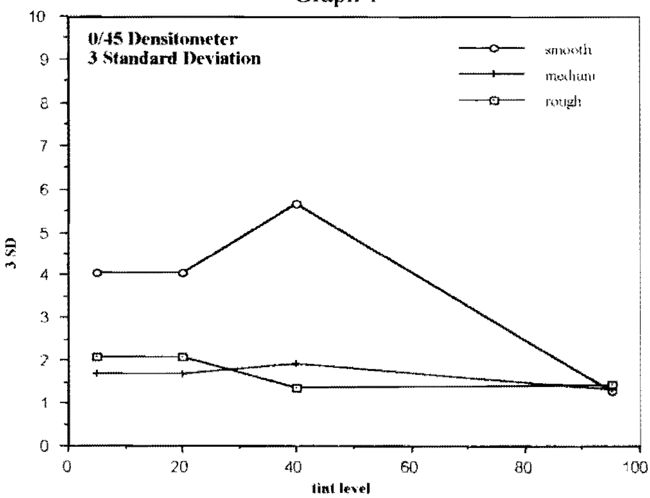
Result: **False**

Of the instruments tested, the variability of the integrating sphere specular excluded has lower variability than that of specular included devices or $0/45^0$ densitometer The variability of $0/45^0$ densitometers is particularly high for smooth plates. See Graph 1. See Table 6 and Graphs 1-5.

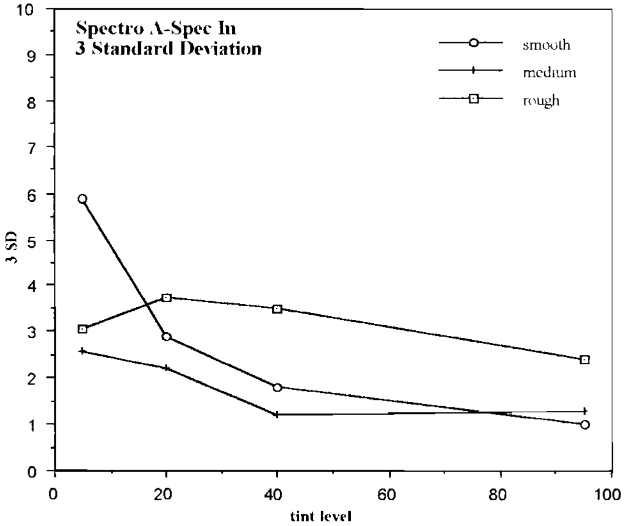
Table 6
Mean & Standard Deviation
Integrating Sphere/Spec Ex and $0/45^0$ Densitometer

	Spect A Ex		Spect B Ex		$0/45^0$ Density	
Surface	Mean DA	±3 SD	Mean DA	±3 SD	Mean DA	±3 SD
5% Nominal Dot						
Smooth	8.31	2.88	7.89	2.58	7.10	4.05
Medium	6.87	2.82	7.21	0.93	6.90	1.68
Rough	6.41	3.27	7.77	0.99	8.54	2.10
20% Nominal Dot						
Smooth	21.80	2.76	22.10	1.50	18.10	5.55
Medium	21.99	2.07	22.26	0.54	21.48	1.74
Rough	22.82	3.66	23.27	1.20	24.20	1.77
40% Nominal Dot						
Smooth	43.97	1.89	41.61	0.84	42.44	6.00
Medium	45.35	1.68	45.31	0.72	44.68	1.92
Rough	44.81	3.42	45.99	0.90	46.09	1.35
95% Nominal Dot						
Smooth	95.96	0.90	95.60	0.39	95.78	1.29
Medium	96.17	1.35	95.80	0.84	95.61	1.32
Rough	96.06	3.55	95.41	0.84	96.17	1.44

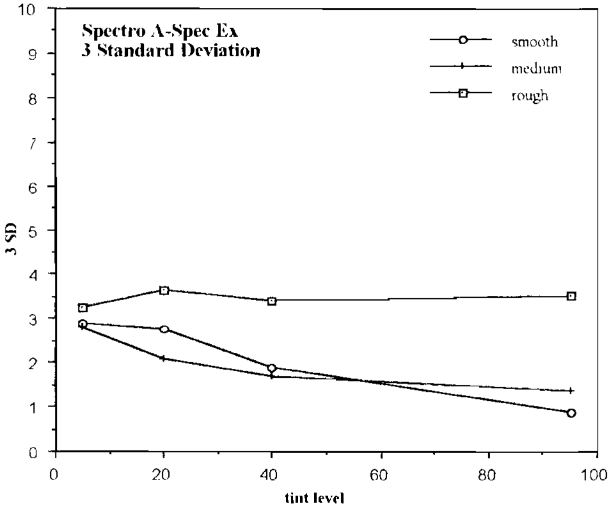
Graph 1



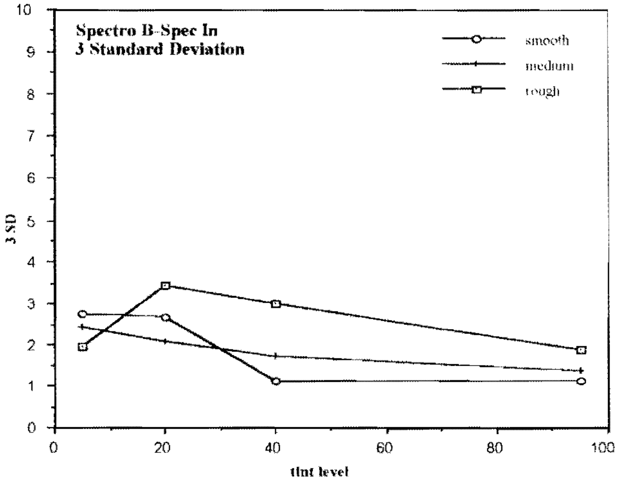
Graph 2



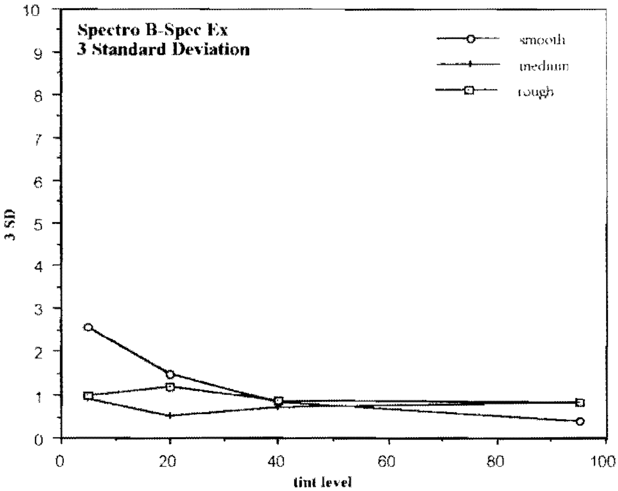
Graph 3



Graph 4



Graph 5



Null Hyp #5: **The variability of percent dot area measurement with specular component included is equal to the variability of specular component excluded for metal plate measurements.**

Result: **False**

This analysis produced mixed results. (See Table 5). The manufacturers of integrating sphere spectrophotometers employ different techniques to achieve specular excluded measurements. These techniques result in significant variability between devices. The data in Table 5 represents 6,480 measurements. Except for the smooth plates, Spectrophotometer A shows no significant difference in dot area variability between spec in and spec ex. See Graphs 2 and 3. However, Spectrophotometer B shows significant improvement in variability in spec ex. See Graphs 4 and 5. Therefore, for one of the two manufacturers, specular excluded is significantly better than specular included. The low variability of the Spectrophotometer B specular excluded indicates that measurements can be made without concern for instrument to plate grain surface.

Null Hyp #6: Dot size does not affect measurement variability.
Result: False

Tint level (dot size) is a major contributor to variability. In general, smaller dots are more variable. This is due in part to the variability inherent in density measurements using photometric devices. Additionally, at small dot sizes, more metal surface is exposed; hence specular components; therefore more variability. See Tables 4 and 5 and Graphs 1-5.

Null Hyp #7: Plate surface does not affect measurement variability.
Result: False

The measurements, using 0/45^0 densitometry, of the smooth surfaced plate is significantly more variable than medium or rough plates. See Tables 4 and 5 and Graphs 1-5. Contrary to 0/45^0 densitometry, spectrophotometers exhibit higher variability for rough plates. See Table 5 and Graphs 2-5.

CONCLUSIONS

An instrument should be useful for all plates put before it. Therefore the RD 45 Densitometer is not suited for reading halftone dots on metal plates having different plate grain surfaces.

Dot values below 10% are difficult to measure with confidence using either RD45 or integrating sphere spectrophotometers used as densitometers.

There are differences between manufacturer's densitometers and spectrophotometers.

Differences between specular included and excluded output from different spectrophotometer manufacturers.

Depending on manufacturer, specular excluded values appear to provide a better match between projected dot area and plate dot area values.

The use of density to compute percent dot area contributes to the variability of the resultant value.

Based on variability studies, one instrument (Spectrophotometer B, specular excluded) appears is satisfactory for measuring dot area of smooth, medium and rough grained plates.

The combination of integrating sphere spectrophotometry, specular excluded, and direct measurement of percent dot area should be explored. Further study is needed.

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