POLARIZATION IN THE GRAPHIC ARTS
PRELIMINARY REPORT

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ABSTRACT

Can polarized densitometry readings of wet sheets at press side predict dry density readings better than nonpolarized? The paper describes a designed experiment run on a sheetfed press. The effect of measuring wet ink versus dry with and without polarized filter was done at three different ink density levels (high, medium and low), and with two paper surfaces (rough and glossy). Enough data is presented for a reader to replicate or expand the experiment. In addition, some of the practical considerations of doing critically timed measurements in a short time interval are described. While a conclusive answer to the question was not expected, this paper adds information in this matter.

INTRODUCTION

The dry back effect of measuring wet ink at press side is well known. The density measured immediately out of the press will decrease after the sheet is dry. Can polarized density measurements help equalize the difference? Would a polarized density reading taken immediately out of the press be closer to the dry measurement (polarized or nonpolarized)? The task of this designed research experiment was to throw some light on this question.

OVERVIEW OF THE EXPERIMENT

We did a simple direct experiment. We read solid patches of SWOP cyan wet, polarized and nonpolarized. We printed them at three levels of ink density using the SWOP patch to choose initial density targets. We put the sheets aside and let them dry for a couple of months, then did the same readings on the same spots. The design was a straight forward 2^4 factorial design. We achieved replications by using three sheets for each density target point. We weren't studying the repeatability of the press, so saved immeasurable trouble not trying to get identical density levels going back and forth from low through high density levels. We started low and moved high and collected our data in one press run.

SUMMARY OF THE OBSERVATIONS

Does a polarized filter reading of a wet ink predict the dry reading better than a nonpolarized reading? Maybe. Neither polarized nor nonpolarized measurements at press side are a perfect predictor of dry measurement. But it does appear that using polarized filters to do the wet reading may give some edge to predicting dry measurement of the same ink.

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The results of this designed experiment were viewed in two different ways. The first is a standard factorial interaction matrix report with accompanying confidence level numbers for "F" and "P" values. The second is a graph designed specifically for this experiment to show what the wet and dry differences look like on a chart.

A surprise finding was what happened between rough and glossy paper. Both polarized and nonpolarized acted the same way on the dry sheets, but they did not act the same way on the wet press sheets. For the dry press sheets, although the actual measurements were different (polarized numbers were generally higher than nonpolarized on the dry paper), both polarized and nonpolarized measurements showed the same up and down pattern (rough paper measured lower, glossy measured higher).

The differences showed up on the wet press sheets. Nonpolarized wet readings tended to minimize the differences between rough and glossy paper. Polarized wet readings exaggerated the differences between rough and glossy paper. Overall, though, the wet polarized readings on rough and glossy press sheets more closely represented the dry rough/glossy relationship (see chart C-1).

Review of the Factorial Interaction Matrix Report
This section discusses the results of the factorial analysis. All figures and charts discussed here are included later in this paper.

Looking at the interaction of ink, wet and dry with polarized vs. nonpolarized filter readings, statistical analysis shows a P-value of .059. What does that mean? If we were to say that 95% of the time we want to know that a number will predict the dry value better than if we didn't use a polarized filter, then we use a 95% confidence level and measure results against that. The P-value of .05 would correspond to this confidence level. The P-value of .059 relationship between wet, dry ink and polarized and nonpolarized readings isn't within this confidence level. But it almost is. And picking a 95% confidence level isn't a necessary target, though it is a good one. Maybe the 94% level would be good enough. Maybe the 95% level isn't nearly enough.

There appeared to be some, but not a major, advantage to measuring polarized both wet and dry. The wet measurement was somewhat closer to the dry measurement when both readings were done using a polarizing filter. This was true both when ink levels were at a medium center point and when they were at high or low levels. However, when the ink density levels were closer to SWOP center points, there was a slightly better edge to using wet polarized measurement as a predictor of the dry measurement than when ink levels were high or low.

Observations from the Center Point Medium Data
For the center point density level, the measurements behaved as expected; polarized readings were higher than nonpolarized. Glossy paper read higher than rough paper. Dry ink measured lower than wet ink. These expected results gave an experiential confidence to the other findings. In detail, the mean effects are:

The density increased .1402 from nonpolarized to polarized.

The P-value of .000 indicates this is not by chance. Polarized filter readings can be expected to be higher than nonpolarized readings. However, this number is the average of all readings, wet and dry, at low, medium and high density levels. It does not separate out the wet and dry differences, nor the paper differences.

From rough to glossy paper, the density increased .03 points. The P-value of .034 indicates this also is not by chance. Glossy paper can be expected to produce densitometer measurements somewhat higher than rough-surfaced paper. This number is also an average that includes all measurements, polarized and not, wet and dry measurements.

From wet to dry ink, the density decreased .0553 points. The P-value of .000 indicated this is not a chance result. This average includes both rough and dry paper, polarized and nonpolarized measurements.

These averages are interesting, but do not address the main question: will a press operator get better prediction of dry measurement by using a polarized filter? The following interaction tables were more enlightening.

Interaction of Wet/Dry Ink with Pol/Nonpol Filter

Dry Ink	1.1737	1.3402
Wet Ink	1.2553	1.3692
	Nonpolarized	Polarized

.0816	Nonpolarized wet to dry change
.029	Polarized wet to dry change
.0526	Polarized is closer to dry by this number.

That .05 number is an average of the three ink levels and the two paper surfaces. So the .05 edge the polarized measurement is showing includes rough and glossy papers and all three ink density levels. Overall, polarized measurement was .0601 closer between rough and gloss, but that includes both wet and dry measurements. (See the "Interaction of Paper Finish and Polarized Measure" chart later in this paper.)

Review of the Mirror Image Graphic Report

It would be an oversimplification to say that polarized measurements were .05 closer wet to dry than nonpolarized. The measurements simply did not act the same at all ink density levels and for both of the papers studied. By the time the information was dissected into its appropriate slots, it became so precise that it was less than useful in a practical sense. We needed a way of looking at the data that would account for all the conditions studied. We needed a way to see the overview that would also allow the separate elements to be seen more distinctly.

To accomplish this, we developed what I will call the "Mirror Image Chart". Cricket Graph software was used to produce a graph from a vertical column of data. Data was arranged and charted in such a way that a perfect correlation from wet to dry measurements would produce a mirror image from the left to the right side of the chart.

If the data points A, B, C, D, E for wet and dry measurements were arranged in a vertical column top to bottom of (wet) A, B, C, D, E (dry) E, D, C, B, A, and if the wet measurements were a perfect match for the dry, this chart (Chart A-1) would result.

Chart A-1

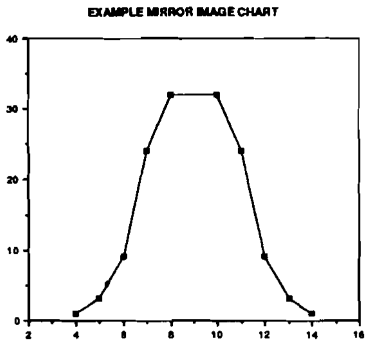
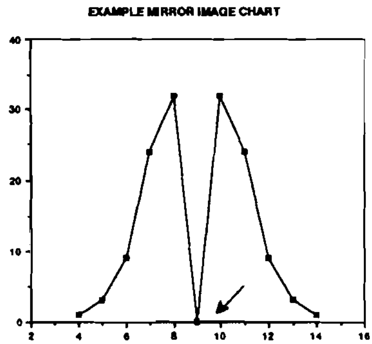


Chart A-2



Real life data is not perfect. The actual wet and dry measurements taken for the experiment were not a perfect match wet to dry. That made this bell-shaped chart hard to read. It was difficult to see where the wet and dry data was separated. A simple device solved this. A zero value was placed in the column between the wet and dry measurements. The data looked like this top to bottom: (wet) A, B, C, D, E, 0, (dry) E, D, C, B, A. The resulting chart plotted a nose-dive line at the zero point (see Chart A-2). Since the point separated the wet and dry data, and the data was arranged in mirror image, wet to dry, seeing the comparison became easier. For the actual experimental data, this technique also compressed the data graph, removing some of the 'noise'. That was due to the way Cricket Graph scales data graphs. Cricket Graph provides dynamic scaling for graphs, and when the range of the data was increased by adding the zero point, the compression was a natural outcome.

The press data was arranged in the vertical column in this order.

Symbols: Ink Density Level
- L = Low
- M = Medium (Pseudo Center Point)
- H = High

Paper Finish
- R = Rough
- G = Glossy

Ink Wet/Dry
- W = Wet
- D = Dry

LRW LGW MRW MGW HRW HGW CENTER HGD HRD MGD MRD LGD LRD	One column contained polarized measurements. A second contained nonpolarized measurements.

The "Mirror Image" charts that resulted are below.

The nonpolarized data:

Chart B-1

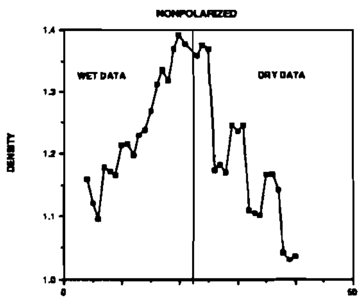
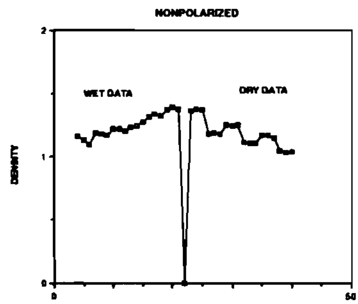


Chart B2



The polarized data:

Chart D-1

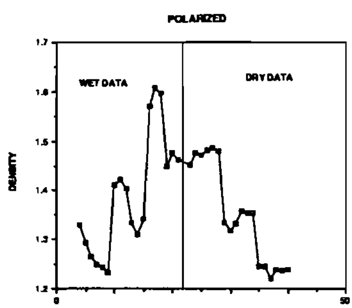
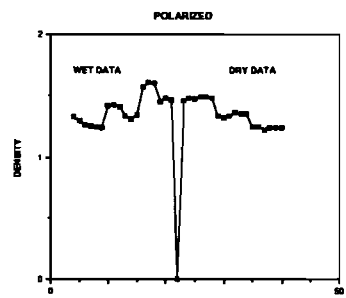


Chart D-2



Comparison Charts:

Chart C-1

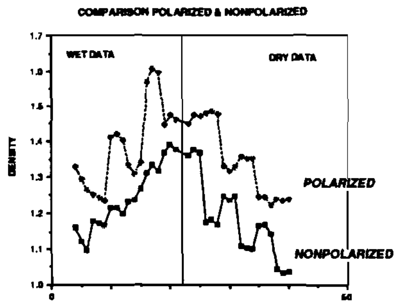
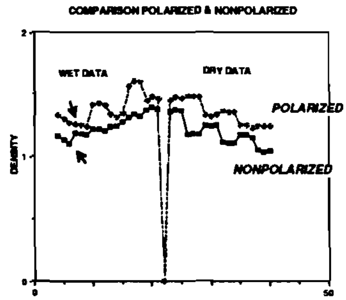


Chart C-2



EXPERIMENTAL MATERIAL

Measuring instrument: Gretag SPM 100 Spectrophotometer

Press:	Heidelberg GTOz	
Paper:	Glossy:	80# Glossy enamel, 8.5"x11" Mead Zellerbach White MOE Gloss
	Rough:	20# White cockle, 8.5"x11" Plain Sulfite Bond, sub 20, short white cockle
Ink:	Process cyan:	Sinclair Valentine Sinvalith II Process Blue Cyan #88101 Batch M-51645, 8/14/90
Blanket:	Reeves Vulcan 2000 compressible	
Fountain:	1 gallon Handshy, 35 ml Allinone etch, 10 ml yellow, 15 ml gum	

THE EXPERIMENTAL DESIGN

Description of the Design

The design was a 2^4 factorial design. The initial design was set up in classic plus/minus form. Data was rearranged after the run for computer analysis. Three replications were made. Rather than run the complete experiment going from low, medium to high press densities with two papers three times, three samples were collected once at the targeted density points. Replication by triplicate press runs was not necessary since the experiment was focused on the results of measuring at target densities, not on the characteristics of the press run. More data than is shown here was collected and saved for further study.

The Collection Design

EFFECTS/CONDITIONS

Density:	High
Density:	Medium (Pseudo Center Point)
Density:	Low
Paper: Glossy	High
Paper: Rough	Low
Measured Condition: Dry	High
Measured Condition: Wet	Low
Filter: Polarized	High
Filter: Nonpolarized	Low

Alpha Coding:

Position 1: Density level (High, Medium, Low)
Position 2: Paper surface (Glossy, Rough)
Position 3: Ink condition during measuring (Dry, Wet)
Position 4: Measuring filter (Polarized or Nonpolarized)
e.g., LRWN = Low density, Rough paper, Wet ink, Nonpolarized

(This matrix was run three times for replication.)

ALPHA	binary	binary	binary	binary
LRWN	-1	-1	-1	-1
LRDN	-1	-1	+1	-1
LRWP	-1	-1	-1	+1
LRDP	-1	-1	+1	+1
HRWN	+1	-1	-1	-1
HRDN	+1	-1	+1	-1
HRWP	+1	-1	-1	+1
HRDP	+1	-1	+1	+1
LGWN	-1	+1	-1	-1
LGDN	-1	+1	+1	-1
LGWP	-1	+1	-1	+1
LGDP	-1	+1	+1	+1
HGWN	+1	+1	-1	-1
HGDN	+1	+1	+1	-1
HGWP	+1	+1	-1	+1
HGDP	+1	+1	+1	+1
MRWN	0	-1	-1	-1
MRDN	0	-1	+1	-1
MRWP	0	-1	-1	+1
MRDP	0	-1	+1	+1
MGWN	0	+1	-1	-1
MGDN	0	+1	+1	-1
MGWP	0	+1	-1	+1
MGDP	0	+1	+1	+1

It was obvious that the classic factorial design was not the best order to use for the actual press run. The quick change of paper, ink levels, and instrument filter necessary to match factorial order would create a nearly impossible task. Since we were studying the results of measuring at target densities, and not the press, we decided to start with the ink at its anticipated lowest level and plan to gradually increase the level during the run. We would pull off sheets and measure them when they happened to fall within the target ranges.

The Analysis Design

FACTORS	ALPHA	BINARY	RAW DATA
HIGH/LOW DATA- no center points	**'=====**	**'=====**	**'=====**
Low density, Rough paper, Wet, Nonpolarized	LRWN 2 3	'- - - -	1.159 1.121 1.095
High density, Rough paper, Wet, Nonpolarized	HRWN 2 3	'+ - - -	1.311 1.335 1.318
Low density, Glossy paper, Wet, Nonpolarized	LGWN 2 3	'- + - -	1.178 1.172 1.165
High density, Glossy paper, Wet, Nonpolarized	HGWN 2 3	'+ + - -	1.369 1.392 1.377
Low density, Rough paper, Dry, Nonpolarized	LRDN 2 3	'- - + -	1.042 1.031 1.035
High density, Rough paper, Dry, Nonpolarized	HRDN 2 3	'+ - + -	1.173 1.183 1.17
Low density, Glossy paper, Dry, Nonpolarized	LGDN 2 3	' - + + -	1.167 1.168 1.143
High density, Glossy paper, Dry, Nonpolarized	HGDN 2 3	'+ + + -	1.359 1.376 1.369
Low density, Rough paper, Wet, Polarized	LRWP 2 3	'- - - +	1.329 1.292 1.264
High density, Rough paper, Wet, Polarized	HRWP 2 3	'+ - - +	1.57 1.607 1.596

Low density, Glossy paper, Wet, Polarized	LGWP 2 3	'- + - +	1.249 1.242 1.233
High density, Glossy paper, Wet, Polarized	HGWP 2 3	'+ + - +	1.447 1.476 1.462
Low density, Rough paper, Dry, Polarized	LRDP 2 3	'- - + +	1.238 1.237 1.239
High density, Rough paper, Dry, Polarized	HRDP 2 3	'+ - + +	1.482 1.486 1.479
Low density, Glossy paper, Dry, Polarized	LGDP 2 3	'- + + +	1.244 1.245 1.221
High density, Glossy paper, Dry, Polarized	HGDP 2 3	'+ + + +	1.451 1.476 1.471

CENTER POINT DATA -no high/low points	=====	=====	====
Med. density, Rough paper, Wet, Nonpolarized	MRWN 2 3	'- - -	1.214 1.215 1.198
Med. density, Glossy paper, Wet, Nonpolarized	MGWN 2 3	'+ - -	1.230 1.237 1.268
Med. density, Rough paper, Dry, Nonpolarized	MRDN 2 3	'- + -	1.109 1.104 1.101
Med. density, Glossy paper, Dry, Nonpolarized	MGDN 2 3	'+ + -	1.246 1.236 1.246
Med. density, Rough paper, Wet, Polarized	MRWP 2 3	'- - +	1.41 1.42 1.403
Med. density, Glossy paper, Wet, Polarized	MGWP 2 3	'+ - +	1.333 1.308 1.341

Med. density, Rough paper, Dry, Polarized	MRDP 2 3	'-++	1.357 1.352 1.352
Med. density, Glossy paper, Dry, Polarized	MGDP 2 3	'+++	1.333 1.317 1.33

COLLECTING THE DATA - THE PLAN

Press Stack
Paper was stacked in the press with the glossy paper to be printed with low density ink on top of the pile. Colored paper in between each type visually separated them.

TOP OF PILE
Glossy (Low Density Ink; larger stack for initial make ready)
Colored Paper
Rough (Low Density Ink)
Colored Paper
Glossy (Medium Density Ink)
Colored Paper
Rough (Medium Density Ink)
Colored Paper
Glossy (High Density Ink)
Colored Paper
Rough (High Density Ink)
Colored Paper
BOTTOM OF PILE

PRESS RUN
GLOSSY PAPER (Low Density Ink; larger stack for initial make ready)

Press:	Start make ready low density ink on glossy paper.
Research:	Measure with densitometer. Tell press if level is too low or too high.
Research:	Measure with densitometer. Tell press when proper density is reached.
Research:	Discard all sheets run to that point.
Press:	Continue to run until research gives the signal to go to the next density level. No press changes now.
Research:	Measure with spectrophotometer wet solid ink patches. Record densities. Label sheets. Store sheets. Signal to press to raise ink to next density level (to compensate for greater ink absorption by the rough paper).
Press:	At signal for next density level, run out the rest of the old paper.

ROUGH PAPER (Low Density Ink)

Press:	When new paper is running, raise density a small amount. Stop adjusting ink. Tell research adjustment has been done.

Press:	Wait until research measures and says whether density level needs to be raised, or is okay.
Research:	Measure with densitometer. Tell press if level is too low or too high.
Research:	Measure with densitometer. Tell press when proper density is reached.
Research:	Discard all sheets run to that point.
Press:	Run without change until research signals to go to next density level. No further press changes until signaled.
Research:	Measure with spectrophotometer wet solid ink patches. Record densities. Label sheets. Store sheets. Signal to press to raise ink to next density level.
Press:	At signal for next density level, run out the rest of the old paper.

Glossy Paper (Medium Ink Density)
Repeat
Rough Paper (Medium Ink Density)
Repeat
Glossy Paper (High Ink Density)
Repeat
Rough Paper (High Ink Density)
Repeat

Press: Press run is completed.

HOW THE DATA WAS COLLECTED - COLLECTION TECHNIQUES

The press sheets contained a nearly square solid shape with three notches running press-wise. The center notch was the one read for the experiment. Black paper was placed below the press sheets during measurements. The SPM100 was calibrated for both polarized and nonpolarized readings.

Density Target Numbers

A SWOP patch was read using the SPM100. Status T density was calculated on the SPM window. The resulting readings were used as the high and low targets. Medium or pseudo center point was calculated as the midpoint between these numbers. Tolerance around these numbers was set by which press sheets would be accepted or rejected. These were:

Low	1.16 - 1.20
Medium	1.25 - 1.29
High	1.35 - 1.39

As the press approached a target density, small stacks of sheets were pulled and read to evaluate whether they were in the proper density range. When they were found to be in the proper density range, three sheets were selected and immediately read while press wet. Both polarized and nonpolarized readings were done at that point. Preprinted identification labels were immediately fixed to the sheets from which data was gathered. And the data in the computer was labeled to match the labels on the press sheets.

HOW THE DATA WAS COLLECTED - LOGISTICS

Although the design matrix was simple, the process of gathering the wet data was not. We thought you might be interested in the logistics of making sure the readings were done immediately out of the press, so that we could verify that the wet readings were indeed wet. "How wet is wet" was a question we grappled with, and decided to circumvent by minimizing the time lag from ink impression to measurement.

Several paper tools were prepared ahead of the run; that helped tremendously. Since it was critical to make the measurements while the ink was undeniably wet, and to keep track of which physical sheet matched the computer stored readings, we predicted there would be a time crunch at press side. There was. Two of us attended the press run. Sharon Bartels' task was to take density measurements to evaluate whether the press sheets were in the target range, then reset the SPM to reflectance, and proper polarized filter setting, then capture the readings from three sheets in that range, label the physical sheet, key in the same label on the Macintosh, and store the computer file in the proper folder. We also kept track of the next target range, got the measured density numbers, communicated to the press operator whether to raise or lower the ink settings and discarded set-up sheets between each target range as it was reached. Things moved fast once sheets started coming out of the press. Concentration on the task was intense.

There were three paper tools that helped during this time. The first was a sheet of stick-on labels for each press sheet that was to be read. The label identified the density level, the actual measured density range and the type of paper that was to be used for that reading. An omission was that the labels did not indicate whether the sheet would be number 1, 2 or 3. Sharon hand wrote that data on the sheets.

The second was a wall chart, 11"x17" that summarized each of the paper/density combinations that would be run for the experiment. The required density range was printed with each paper/density level combination. As each part of the experiment was done, it was checked off of the chart. It would have been easy to get lost in the rush of the moment and not know which work had been done and which had not. This was a very useful tool.

The third was a set of 8.5"x11" sheets with one of the same paper/density conditions printed at the top. The rest of the sheet was filled with eighteen bold blank blocks. We used this sheet to communicate to the press operator the adjustment needed to reach the targeted density range.

The original plan called for switching back and forth between rough and glossy paper during the run. The thinking was that the lowest press density setting would be used for the Low/Glossy paper condition. We thought that when rough paper for the Low/Rough paper condition was run through the press at the same ink level, it would measure at a higher density. The press stack in the original design was planned to allow the press operator to make minimal increases in ink setting without having to lower and raise it to reach our target density ranges. That didn't work. We scrapped that whole plan almost immediately and ran with glossy paper until all glossy data was gathered, then did all the rough paper readings.

Most of the experiment time was consumed trying to hit the target density range. The experience made me long for the luxury of having done a process capability and identification study on the press used for the experiment. The lag time between adjustment of the press ink settings and the actual measured changes escaped us through most of the press run. We bounced back and forth lowering and raising the ink setting, racing to catch the proper density range as the measured density swung up and down. No other experience has brought home the concept that making an adjustment to a press system without knowing if it is already in a natural upswing or downswing mode is disastrous. We constantly overshot the densities we wanted by making adjustments at the wrong time. The press operator was skillful with his press, however, and we were able to get what we needed for the experiment. Sharon was skillful with the SPM and the Macintosh and was able to gather valid data. However, taking the dry readings later was a rather peaceful experience by comparison.

A cable was constructed to connect the SPM to a Macintosh SE. The modem connection on the back of the Mac was marked with a telephone icon. The Mac and the SPM were taken to a press side table on the morning of the press run.

The cable from the SPM to the Macintosh modem port had the following pin connections:

3 to 3
5 to 4
4 to 5

When the pin assignments are:

Looking at the face of the connector

<table>
<tr><th colspan="3">SPM DIN-pin</th><th colspan="4">Mac Mini-DIN</th></tr>
<tr><td></td><td>notch</td><td></td><td></td><td>notch</td><td></td><td></td></tr>
<tr><td>1</td><td></td><td>7</td><td>6</td><td>7</td><td></td><td>8</td></tr>
<tr><td></td><td>8</td><td></td><td>3</td><td>4</td><td></td><td>5</td></tr>
<tr><td>2</td><td></td><td>6</td><td></td><td>1</td><td>2</td><td></td></tr>
<tr><td>3</td><td></td><td>5</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>4</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

(Courtesy Sharon Bartels)

Capturing the Density Readings

The SPM was initially set to no polarized filter. Red Ryder was set to capture 18 screens, or as many screens of data as would be needed for each file to be created. This was a personal decision. Each reading could have been saved in a single file. Or all the readings could have been stored on a single file.

1. Red Ryder was started and set to 9600 baud, N81, half duplex 2. From the pop down 'File' menu of Red Ryder 'Capture incoming data to text file' was selected. Keyboard preference, CR, LF was chosen.
3. From the disk drive menu, a folder (previously placed on the disk drive) was chosen, and a name for the file to receive the input was keyed in (capture text file).

4. The SPM was calibrated and the settings checked.
5. The SPM was positioned on the spot to be read and a reading was taken. (This did not send the readings to the computer. The next step was an important step to save the readings.)
6. The red 'Print' button on the SPM was pressed. This sent the reading to the computer (a screen dump to Red Ryder). It was displayed on the Red Ryder screen.
7. On the computer keyboard, identification for the press sheet just read was keyed in. It appeared on the Red Ryder screen immediately under the readings.
   NOTE: We found we could not backspace, so mistakes were corrected by adding more information noting the mistake. (When editing these files later, it was important to remember that the labels were UNDER the readings, not above them.)
8. Important: After keying in the identification for the readings, RETURN was pressed on the Macintosh keyboard to prepare the screen for the next set of readings.
9. The SPM filter was reset to polarized and the reading/capture sequence repeated.
10. A preprinted label was placed on the press sheet just read. It matched the identification keyed into Red Ryder.
11. After all readings were taken, from the Red Ryder pop down 'File' menu 'End Capture' was highlighted. Then 'Quit' was chosen by highlighting from the same 'File' menu.

Preparing the Data

12. Microsoft Word was opened on the Mac. And the output file for the raw data (the one containing the Red Ryder readings) was opened.
13. The 'Change' feature of the program was used to locate the four character sequences in the Red Ryder file (^010). That is: shift 6, zero, one, zero. These were 'removed' by choosing to replace it with nothing.
14 The 'Save As' feature was invoked to choose 'ASCII' save format. The file was saved with a name that did not contain spaces.

Converting the Reflectance Data to Density

15. A program, SPM100, written by Jim Huntsman was run to convert the raw reflectance data into rows collimated and sorted by spectral response. The data was saved in a new file coded as a 'reflectance' file. There were now three files for the data; the original Red Ryder raw data, the edited, cleaned ASCII file, and the SPM100-generated ordered reflectance data columns.
16. A program, QC Color, by Jim Huntsman was run using the file with the reflectance data columns to extract Status T density into a fourth file. The fourth file was rearranged in design matrix order and saved as a fifth file.

Data Analysis

17. The final (fifth) file containing Status T densities was used as input to FACT for statistical analysis. FACT, a program written by Fred Dalleska, generated the table data and statistical numbers contained in this report.

STATISTICAL CALCULATIONS FOR THE DATA

Mean Effect: Average of three measured points for one factor at high level less the average of three measured points for that factor at low level.

F-Ratio: The mean square divided by the error estimate at the 95% confidence level is the F-Ratio.

P-Value: The F-Ratio on statistical F tables yields the P-Value.

EVALUATION INSTRUMENT CONDITIONS FOR THIS STUDY

The SPM 100 was set as follows:

Reflectance Spectral Range
D50 illumination
2° observer
Absolute reflectance including paper
Polarized or nonpolarized according to the design matrix

STATISTICAL ANALYSIS

MEDIUM (CENTER) DENSITY DATA

CELL AVERAGES FOR THE FACTORS

FACTOR	LOW	Avg. Den.	HIGH	Avg. Den.
PAPER	Rough	1.269583	Gloss	1.299583
INK	Wet	1.312250	Dry	1.256917
FILTER	Nonpolarized	1.214500	Polarized	1.354667

INTERACTION OF PAPER FINISH WITH INK DRYNESS - CENTER ONLY

Glossy	1.3145	1.2847
Rough	1.3100	1.2292
	Wet Ink	Dry Ink

INTERACTION OF PAPER FINISH WITH POLARIZED/NON FILTER - CENTER

Glossy	1.2722	1.3270
Rough	1.1568	1.3823
	Nonpolarized	Polarized

INTERACTION OF POLARIZED/NON FILTER WITH INK DRYNESS - CENTER

Dry Ink	1.1737	1.3402
Wet Ink	1.2553	1.3692
	Nonpolarized	Polarized

MEDIUM INK DENSITY - CENTER LEVEL

FACTORS	MEAN EFFECT	F-RATIO	P-VALUE
FILTER: Polarized or non	.1402	116.662	.000
FILTER & PAPER	-.0853	43.239	.000
INK DRYNESS: Wet or dry	-.0553	18.181	.000
PAPER: Glossy or rough	.0300	5.344	.034
INK DRYNESS & FILTER	.0263	4.118	.059
PAPER & INK DRYNESS	.0255	3.861	.067
PAPER, INK DRYNESS & FILTER	.0028	.048	.830

Error estimate: From replication
Degrees of freedom: 16
Variance: .0010 (Denominator in F-Ratio)

The 95% confidence limits for the effects are +/- .0091

HIGH AND LOW DENSITY DATA

CELL AVERAGES FOR THE FACTORS

FACTOR	LOW	Avg. Den.	HIGH	Avg. Den.
DEN LEVEL	Low	1.187875	High	1.405625
PAPER	Rough	1.283000	Glossy	1.310500
INK	Wet	1.323292	Dry	1.270206
FILTER	Nonpolarized	1.217000	Polarized	1.376500

INTERACTION OF DENSITY LEVEL AND PAPER FINISH

High Density	1.3925	1.4187
Low Density	1.1735	1.2023
	Rough Paper	Glossy Paper

INTERACTION OF DENSITY LEVEL AND INK DRYNESS

High Density	1.4383	1.3729
Low Density	1.2082	1.1675
	Wet Ink	Dry Ink

INTERACTION OF DENSITY LEVEL AND FILTER

High Density	1.3110	1.5003
Low Density	1.1230	1.2527
	Nonpolarized	Polarized

INTERACTION OF PAPER FINISH AND INK DRYNESS

Glossy	1.3135	1.3075
Rough	1.3331	1.2329
	Wet Ink	Dry Ink

INTERACTION OF PAPER FINISH AND FILTER POLARIZED OR NON

Glossy	1.2696	1.3514
Rough	1.1644	1.4016
	Nonpolarized	Polarized

INTERACTION OF INK DRYNESS AND FILTER POLARIZED OR NON

Dry Ink	1.1847	1.3557
Wet Ink	1.2493	1.3972
	Nonpolarized	Polarized

Dry back from wet to dry ink took place as expected.
The effect of measuring polarized versus nonpolarized was a .17 density change for dry ink. The effect of measuring polarized versus polarized was a .14 density change for wet ink. The difference was pronounced at the dry measurements.

The change from wet to dry ink was .0646 for nonpolarized measurements. And the change from wet polarized to dry nonpolarized measurements was 21 points. However, the change from wet to dry was only .0415 for polarized measurements.

INK DENSITY AT HIGH AND LOW LEVELS

FACTORS	MEAN EFFECT	F-RATIO	P-VALUE
DENSITY LEVEL High or low	.2177	2401.845	.000
FILTER: Polarized or not	.1595	1288.692	.000
FILTER & PAPER	-.0777	305.561	.000
INK DRYNESS Wet or dry	-.0531	142.740	.000
PAPER & INK DRYNESS	.0471	112.296	.000

DENSITY & FILTER	.0297	44.833	.000
PAPER: Glossy or rough	.0275	38.308	.000
DENSITY & PAPER & FILTER	-.0214	23.234	.000
DENSITY & PAPER & INK DRYNESS	.0148	11.146	.002
DENSITY LEVEL & INK DRYNESS	.-0123	7.705	.009
INK DRYNESS & FILTER	.0116	6.797	.014
PAPER, INK DRYNESS & FILTER	-.0057	1.675	.205
DENSITY & INK DRYNESS & FILTER	.0017	.141	.710
DENSITY LEVEL & PAPER	-.0012	.079	.780
DENSITY LEVEL & PAPER & INK DRYNESS & PAPER	.0003	.006	.941
Error estimate: From replication Degrees of freedom: 32 Variance: .0002 (Denominator in F-Ratio) The 95% confidence limits for the effects are +/- .0091.			

CONCLUSIONS

Nonpolarized measurement of wet press sheets minimizes the difference between rough and glossy papers.

Polarized measurements of wet press sheets exaggerates the differences between rough and glossy papers.

Dry press sheets measure differently rough to glossy regardless of whether they are measured with a polarized filter or not. The polarized measurements on the dry sheet are generally higher than the nonpolarized.

Polarized measurements of wet press sheets differentiate between rough and glossy paper somewhat better than nonpolarized measurements, and therefore may, in some cases, better predict the dry measurement.

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