A Study to Verify SNAP (Specifications for Newsprint Advertising Production) Recommended Press Acceptance Test for Optimal Ink Density Reproduction

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Keywords: ink, density, aim values, tolerance, standard error, newspaper, advertising, SNAP

Abstract

Abstract: The SNAP organization (Specifications for Newsprint Advertising Production) provides guidelines and recommendations for optimal reproduction on newsprint substrates using cold-set offset lithography web presses. To assist the printing community to validate if new or augmented press equipment is capable of printing to the specification, SNAP publishes a "Lithographic Offset Press Acceptance Testing and Criteria for Acceptance" document that details:

a) Testing and press acceptance conditions
b) Description of acceptance testing
c) Suggested aim points and tolerances and
d) Test forms and testing procedure

Controlled press testing was conducted on multiple cold-set newspaper presses using these procedures and an analysis is done to validate compliance of the empirical results with Item c: Suggested aim points and tolerances. In addition to presenting the actual results of press acceptance tests, a statistical approach is utilized to identify standard errors and new tolerances for cyan, magenta, yellow and black densities across three production sequences:

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a) Cold Start (initial press startup with presets)
b) Mid-Production Speed and
c) Full Production Speed

Verification research is conducted with the test data set from two cold-set newspaper presses located in different locales. Printed samples were collected during the press acceptance test run per the test protocol. The test and protocol is designed to replicate daily print production conditions.

The analysis indicates that mean printed Status T optical density of the data set falls within the SNAP aim values recommended for reproduction on newsprint substrates using cold-set offset lithography web presses. Additionally, a more reliable statistical approach that defines optimal press performance tolerances using standard error is provided as an addition to the ±0.05 Status T optical density tolerance currently published in the SNAP documents.

Introduction

Newspapers are heavily invested in providing readers and advertisers with a daily printed product that has predictable, consistent and repeatable quality. Dow Jones recently increased the color capability on its newspaper presses to a minimum of forty-eight daily process color pages (available nationally) and up to eighty daily process color pages (available in some markets). Today's readers and advertisers are more sophisticated and expect a dynamic and colorful newspaper experience (Newspapers & Technology, 2010).

Part of Dow Jones' equipment modernization required acceptance testing to verify that the updated and newly installed national print platform can produce newspaper products that meet SNAP specifications. Acceptance testing was conducted using documented protocols that replicate the conditions used during daily manufacturing of newspaper products.

The Acceptance Test protocol included the calibration of press equipment (Mechanical and Electrical components), the verification of raw material used and the coordination of Acceptance Test press run. Listed are protocol items acknowledged for this study:

1) Mechanical and Electrical verification of installed equipment.

   a. Press – Manufacturer settings for plate lockup, unit impressions, roller durometer and stripes, tension system setup and folder setup.
   b. Press – Web control and performance to be consistent with press modifications according to manufacturer specifications.

c. Inking – Press Control System with supplied ink presets to achieve saleable copies equal or better according to manufacturer specifications, based on press modifications.
d. Inking – Ink control to be set accordingly to a 0-10% increment. Ink to track linearly to press speed.
e. Dampening – Water pressure to be set a certain pressure regardless of demand, each spray bar to be regulated to manufacturers running specification. Spray bars to be mounted as per manufacturers specifications.

2) Raw Materials

a. Printing Ink – 25 to 70 poise (viscosity)
b. Neutral Dampening Solution – Brand specified with conductivity to be 1250 – 1450
c. Newsprint – 43 – 52 gram square meter (gsm) newsprint and having moisture content not less than 5% of water.
d. Blankets and Plates – Brand specific that had been tested and is in compliance with ink-water balance per manufacturer specifications.

3) Acceptance Test

a. Validate plates for run
b. Achieve Solid-Ink Density
c. There should be no indication on print copy of: dot slur, ghosting, ink starvation, worming or roller bounce, spray bar nozzle drip, spray bar spotting, spray bar flooding, ink toning, ink setoff.

The data collection and the analysis of the acceptance test were conducted in a centralized location. Five distinct items were reviewed:

1) Density
2) Registration
3) Ghosting
4) Ink Tint/ Tone
5) Visual Quality Inspection

Once the samples are measured for each criterion, the data is recorded into a data spreadsheet on a server. The data collection was performed using ISO calibrated lab equipment and documented protocols to ensure that the data results were repeatable. When the data collection is completed, an analysis of the data is conducted and a report of acceptance is drafted. The statistical analysis of the data was performed independently of the data collection process for each installed press system.

Assumptions

Recommendations published by the SNAP committee are documented in its "SNAP Cold Set Printing Standards" and "Lithographic Offset Press Acceptance Testing and Criteria for Acceptance" documents. These recommendations were developed using legacy data sets collected from the printed results of hundreds of newspaper printing operations. They are useful for printers and equipment manufacturers because they are universally accepted as the de-facto standard in the United States, and provide documented recommendations that assist printers to achieve print uniformity and repeatability even across many presses and locations.

Based on the results from "Acceptance Testing", Dow Jones' presses are in compliance with the SNAP organization specifications. Because this data set has been proven to be in compliance, and includes more than sufficient sample points and data points to provide statistically significant analysis, this data set can be used for the purposes of this study. Specifically, the verified data set is utilized to evaluate the SNAP recommendation for density aim values and tolerance limits. The aim values and tolerances are used to establish print uniformity throughout a production run (SNAP, 2011).

Status T Optical Density	**AIM Value** *(Optical Density Units)*
Cyan Solid (100%)	0.90
Magenta Solid (100%)	0.90
Yellow Solid (100%)	0.85
Black Solid (100%)	1.05
Density Tolerance for each color	+/- 0.05

Table 1: *SNAP Density Aim Values and Tolerance*

The sampling protocol SNAP recommends in its acceptance testing document is recognized as a sufficient sampling protocol that replicates the conditions for key events during a production run on newsprint substrates using cold-set offset lithography web presses.

The SNAP Acceptance test sampling protocol is illustrated (*Figure 1*). This model suggests sample points at press make-ready speed (also known as "cold start"), mid-production speed and full production speed intervals. This allows for flexibility in application of the sampling protocol to different press systems from various manufacturers that are designed with different maximum production speed capabilities.

Problem Statement

The SNAP recommendation to use Status T optical ink density (100% dot) targets of ±0.05 for each color is an arbitrary tolerance. It does not assist the press oper-

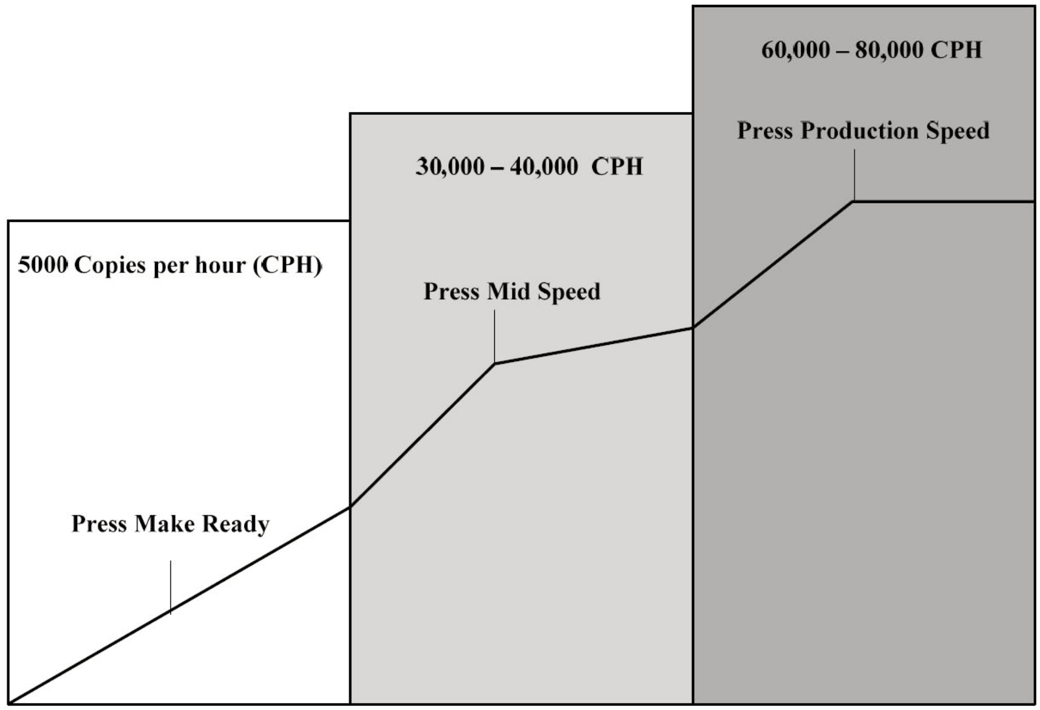


Figure 1: *SNAP Press Sampling Model for Acceptance*

ator in optimizing ink adjustments during the production cycle, and possibly leads to wasted printed copies. With the use of controlled test data, statistics can be applied to answer the following questions:

1. Can optimal press performance ranges be determined with help of statistical analysis?
2. Can the ink adjustments on press be optimized to achieve best possible print quality, web control and productivity?
3. Is there an opportunity for the print industry to adopt a new statistical approach to establish press capabilities?

Literature Review

SNAP addresses various production parameters, one in particular is solid ink densities (SID) and testing a press system to print consistent SID is an important criterion (*Brehm & Cheeseman, 2009, p.1*). The procedures and test format have become a topic of interest for SNAP members in recent discussions. The SNAP committee addresses fundamental issues that affect print sites individually. The goal in developing the SNAP recommendations is to achieve consistent repeatable quality from site-to-site. In 2011, SNAP member Ragy Isaac discloses a “big gap in coldest process standardization pertaining to press acceptance”. He makes known the illogical testing process which SNAP subscribed to and, along with a SNAP sub-team, introduces a testing format for the SNAP program entitled “Lithographic Offset Press Acceptance Testing and Criteria for Acceptance”. This protocol is structured to assess press equipment in four sections: Testing and Acceptance Conditions; Description of Acceptance Testing; Suggested Aim Points and Tolerances; Forms and Testing Procedures (*Isaac, 2011, p1*).

The goal for SNAP press acceptance solid-ink density, concerning color reproduction is the following: Solid ink densities are determined by printing the solid color and measuring the result with a densitometer. The values measure the relative amount of ink applied to the substrate. For balanced color reproduction, recommended aims for solid ink densities are: Cyan- 0.90; Magenta- 0.90; Yellow- 0.85; Black- 1.05. Tolerances of +/- 0.05" (*SNAP, 2011*).

These AIM values and tolerances have been established as the recommended specifications for cold-set print manufacturing and ultimately determine whether press equipment adheres to SNAP or not. In question to the SNAP recommendation tolerances, Bassinger discusses (*GATF Test Form/ Analysis User Guide*) how these tolerances are quite useful but have been assigned to the printing industry somewhat arbitrarily as process control limits. This question's the true usefulness of given solid ink density tolerances (+/- 0.05) and suggests that a density variation should be investigated properly in order to provide operators information concerning press capabilities. He states that "judicious adjustments counteract changing conditions on the press and reduce variability" (*Bassinger, 1997, 4-4, 4-5*).

The opportunity to benchmark a press, utilizing the recommendations from the SNAP committee and testing format from Ragy Isaac does provide some insight into how equipment, machines and tooling operate correctly.

Rizzo observes that once an installation is benchmarked it requires proper equipment maintenance, determination of output capabilities and measuring and monitoring quality through process control activities (*Rizzo, 2008, p. 103*). Seymour & Stanton discuss the challenges in process control with respect to tolerances for newspaper printers in *An Analysis of the Current Status of Process Control for Color Reproduction in Newspapers*. Based on his evaluation and analysis, SNAP target specifications were not achieved by a majority of contributing printers tested and they questioned whether printers could meet SNAP specifications in their daily production environments (*Seymour & Stanton, 2011, p.13*).

With process control being the objective for all printers, Bassinger offers a recommendation: "More reasonable process control aim points are plus or minus two standard deviations from the mean. In this case, an out-of-tolerance reading would only have a five percent chance of occurring due to the random variations of the process. If the density windows described by plus or minus two standard deviations seem unacceptably wide, decrease the variability of the system before tighter process control limits are specified. This is accomplished by eliminating sources of variability" (*Bassinger, 1997, 4-5*).

Methodology

SNAP acceptance testing document defines the guidelines for data collection in this study. The purpose of the print acceptance test was to verify that the press system meets the criteria for print quality, web control and productivity. In addition, the testing verifies that color webs meet registration, web control, print quality and low coverage image specifications. To support this study, a five-section eighty-page broadsheet product was printed at multiple speeds on two Dow Jones presses.

Once press operators achieved the specified solid ink densities and water settings, the press maintained those densities (measured with densitometers) for all plate positions, at all production speeds and run lengths. The entire press system was operated as a single, homogeneous press system. This includes all mono leads, process color leads, and spot color unit to unit leads under the folder leads or any combination thereof and all other leads supported on the press. The range of acceptability for the entire five-section eighty page broadsheet product and press performance is to meet the above detailed specifications with particular attention to the overall quality of the product including:

- Free of wrinkles,
- Crisp and square folds
- Free of cracking
- No web control problem
- Registration within specifications for tower units
- Margins stable and even and cutoffs stable and uniform throughout the product at all press speeds
- Minimal or no set-off
- Ink density specifications and performance per the specifications

The presses were started using auto sequence startup and consecutive copies were pulled during press startup at 300, 600 and 900 copy count on the clock. The press speed was accelerated to 30,000 copies per hour (CPH) to set registration using near center high plate position as the register key. Ink and water adjustments were made at this point to bring all colors within solid ink density target specifications. The press speed was further accelerated to 40,000 CPH and 60,000 CPH and samples were collected at varied press speed points for the analysis (*Figure 2*).

Solid ink density data was read from the SNAP form (*Figure 4*) printed on twenty pages based on the provided layout (*Figure 5*) at plants A and B, operating under controlled conditions. The data was collected using calibrated X-Rite Auto-Tracking densitometers (ATD News) (*Figure 3*). A press sheet is held securely to the track by vacuum holes while the scanning head travels the length of the press sheet on the scanning track. The ATD News instrument scans the solid ink density bars at the bottom of SNAP forms (*Figure 4*) and provides density

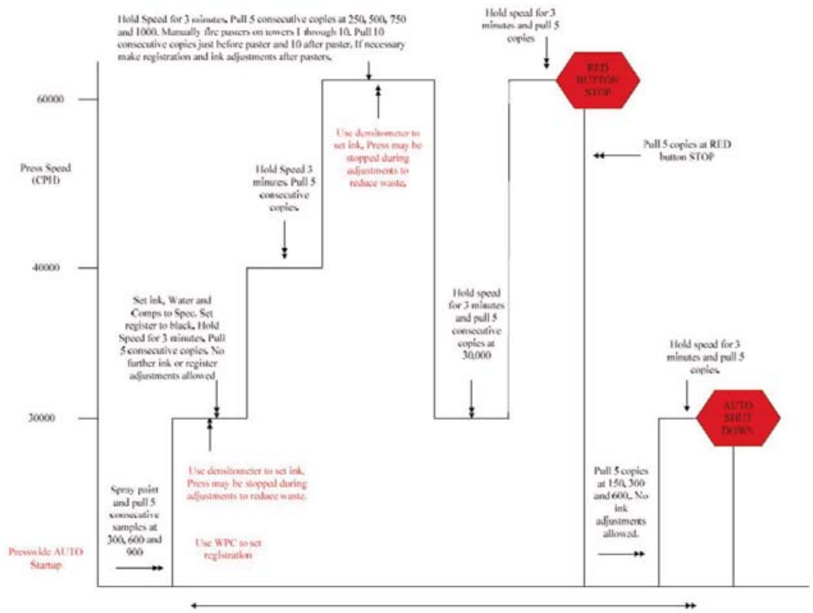


Figure 2: *Test Plan*

readings. The scanning head takes five measurements per inch and averages all readings across a user-defined zone at a rate of eight inches per second.

The broadsheet product was printed using web lead in snakes for Tower thread unattended from reel to roller front of angle bars per following press layout. The press layout (*Figure 5*) comprised ten towers (R1 through R10); four towers printed thirty-two color pages (R6, R7, R9 and R10) and the other six towers printed forty-eight black and white pages (R1 through R5, R8). The selected pages were (*Figure 6*):

Color:
A10, A16, C2, C14, D1, D21, E3, E5

Black/White:
A8, A18, B7, B9, B11, C4, C5, C7, C12, D3, D6, D16

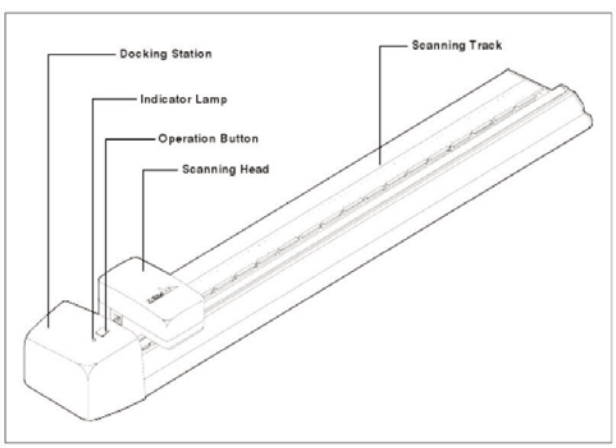


Figure 3: *X-Rite Auto Tracking Densitometer*

Figure 4: SNAP Form

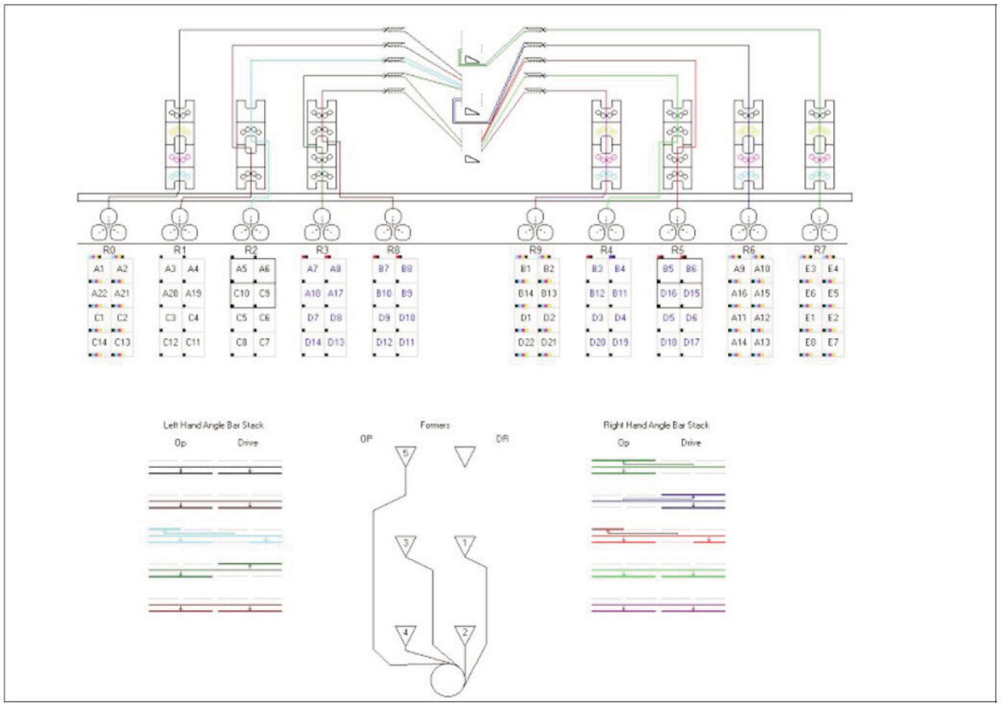


Figure 5: *Press Layout*

Data Analysis

The data analysis was carried out using Minitab and the R programming language; a script is also provided in this study

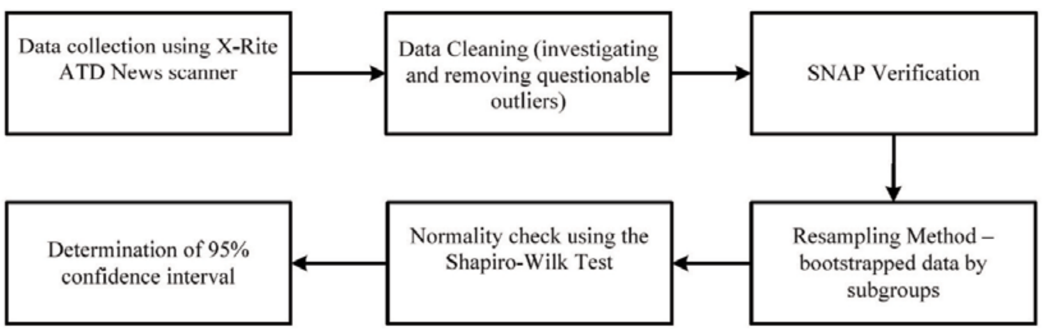


Figure 6: *Data Analysis Workflow*

1. Data Collection

One hundred percent dot solid ink density data was captured measuring the SNAP form (Figure 4) included in a five-section eighty page broadsheet printed product, containing thirty two color pages. A total of one hundred and four samples were collected based on the following setup:

- Two plants A and B.
- Three make-ready samples. (*Figure 1*)
- Three mid-speed samples. (*Figure 1*)
- Three production speed samples. (*Figure 1*)
- Three restart (warm press) samples.
- One mid-speed sample.
- Four copies each.

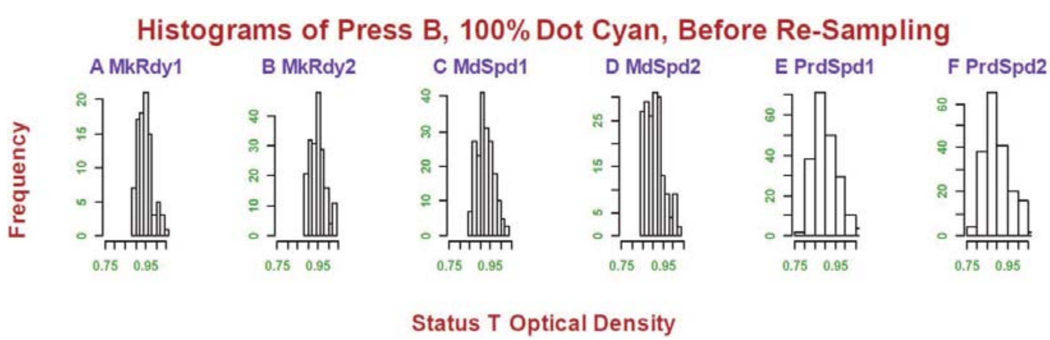
The data was measured using two calibrated X-Rite ATD News auto-tracking densitometers. For this study, were only included in the analysis the following samples:

- Two plants A and B.
- Three make-ready samples. (*Figure 1*)
- Three mid-speed samples. (*Figure 1*)
- Three production speed samples. (*Figure 1*)
- Four copies each

2. Data Cleaning

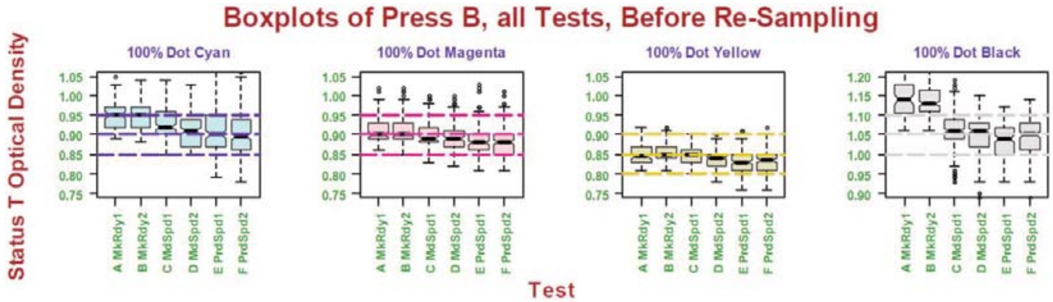
Each ink density reading with an X-Rite Auto-Tracking densitometer includes eight distinct values from the eight columns on the SNAP form (Figure 4). The data collected for this study only included the middle six columns from each reading to exclude the starved density on the edge of the form (Figure 4). The data was then compiled by plant, color, and test/press speed. Questionable outliers, usually due to data processing or equipment malfunction, were duly removed after thorough investigation. The final dataset comprised forty-eight unbalanced subgroups:

- Two plants A and B.
- Six tests / press speeds
  - Two make-ready
  - Two mid-speed
  - Two production speed
- Four colors CMYK



Graph 1: *Sample Histograms before Re-Sampling*

SNAP Verification



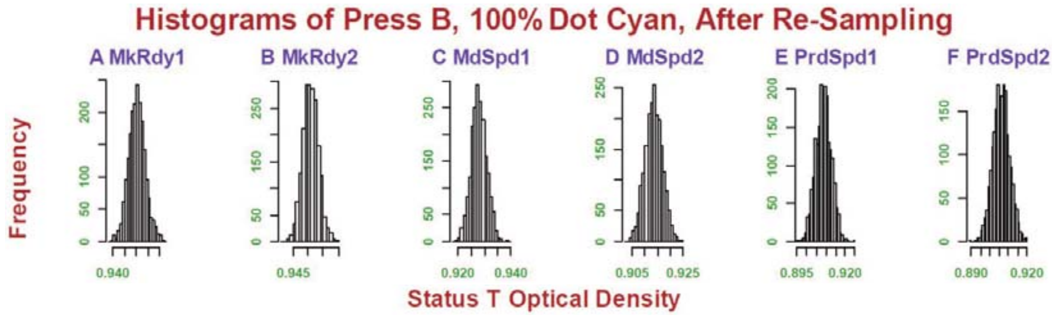
Graph 2: *Sample Box Plots before Re-Sampling*

3. Re-sampling

In an effort to avoid the normality assumption and to determine the distribution of the sample mean, this study resorted to the bootstrapping technique. Bootstrapping is a general approach to statistical inference based on building a sampling distribution for a statistic by re-sampling from the data at hand. The term ‘bootstrapping’(*Efron 1979*), is an allusion to the expression ‘pulling oneself up by one’s bootstraps’; using the sample data as a population from which repeated samples are drawn.

Suppose a sample $S=\{x_1,x_2,\ldots,x_n\}$ is drawn from a population $P=\{X_1,X_2,\ldots,X_N\}$ where N is much larger than n and S is a simple random sample from P. Now suppose the statistic $T=t(S)$ is an estimate of the corresponding population parameter $\theta=t(P)$. Bootstrapping allows estimating the sampling distribution of the statistic empirically without making assumptions about the form of the population, and without deriving the sampling distribution explicitly. The idea is to proceed to draw a sample of size n from among the elements of S with replacement, resulting in a bootstrap sample $S^*_1=\{x^*_{11},x^*_{12},\ldots,x^*_{1n}\}$. It is necessary to sample with replacement to avoid reproducing the original sample S. The procedure is repeated B times, two thousand times in this study (*Appendix 2*). The b^{th} bootstrap sample is then denoted $S^*_b=\{X^*_{b1},X^*_{b2},\ldots,X^*_{bn}\}$.

The population is to the sample as the sample is to the bootstrap samples. The average of the bootstrap statistic estimates the population mean; similarly the estimated bootstrap variance estimates the standard error. There are two sources of errors in bootstrapping inference however, one of which is a sampling error produced by failing to enumerate all bootstrap samples. This source of error can be controlled by making B sufficiently large.



Graph 3: *Sample Histograms after Re-Sampling*

Normality Testing

This study also aims to determine the associated margins of errors and confidence intervals; each subgroup was therefore tested for normality post bootstrapping using the Shapiro-Wilk method, which method works well with sample sizes of two thousand or less. The Shapiro-Wilk test calculates a W statistic that tests whether a random sample comes from a normal distribution. Small values of W are evidence of departure from normality. The W statistic is calculated as follow:

$$W = \frac{\left(\sum_{i=1}^{n} a_i x_{(i)}\right)^2}{\sum_{i=1}^{n}(x_i - \overline{x})^2} \qquad \textit{Equation 1}$$

where $x_{(i)}$ are the sample values and ai the constants generated from the means, variances and covariance of the order statistics of a sample of size n from a normal distribution. The normal theory interval assumes that the statistic T is normally distributed and uses the bootstrap estimate of sampling variance, and perhaps of bias, to construct a 100(1-α) percent confidence interval of the form:

$$\theta = (T - \hat{B}^*) \mp z_{1-\frac{\alpha}{2}} \widehat{SE}^*(T^*) \qquad \textit{Equation 2}$$

Where Ê*(T*) is the bootstrap estimate of the average of T, SE*(T*) is the bootstrap estimate of the standard error of T, and $z_{1-\alpha/2}$ is the 1-α/2 quartile of the standard normal distribution. $z_{1-\alpha/2}$=1.96 for a ninety-five confidence interval where α = .05.

Plant	Color	Test	p Value
A	C	Make Ready 1	0.4131
A	C	Make Ready 2	0.8846
A	C	Mid Speed 1	0.8633
A	C	Mid Speed 2	0.5298
A	C	Production Speed	0.4724
A	C	Production Speed	0.2370
A	M	Make Ready 1	0.4282
A	M	Make Ready 2	0.0953
A	M	Mid Speed 1	0.2382
A	M	Mid Speed 2	0.3201
A	M	Production Speed	0.1879
A	M	Production Speed	0.1161
A	Y	Make Ready 1	0.0911
A	Y	Make Ready 2	0.2264
A	Y	Mid Speed 1	0.5015
A	Y	Mid Speed 2	0.2268
A	Y	Production Speed	0.4042
A	Y	Production Speed	0.5969
A	K	Make Ready 1	0.2924
A	K	Make Ready 2	0.7266
A	K	Mid Speed 1	0.3959
A	K	Mid Speed 2	0.3916
A	K	Production Speed	0.2524
A	K	Production Speed	0.5824

Plant	Color	Test	p Value
B	C	Make Ready 1	0.0066
B	C	Make Ready 2	0.9362
B	C	Mid Speed 1	0.1082
B	C	Mid Speed 2	0.0276
B	C	Production Speed	0.8735
B	C	Production Speed	0.9576
B	M	Make Ready 1	0.0289
B	M	Make Ready 2	0.0345
B	M	Mid Speed 1	0.8492
B	M	Mid Speed 2	0.0045
B	M	Production Speed	0.1945
B	M	Production Speed	0.0815
B	Y	Make Ready 1	0.0005
B	Y	Make Ready 2	0.4805
B	Y	Mid Speed 1	0.2813
B	Y	Mid Speed 2	0.3364
B	Y	Production Speed	0.3163
B	Y	Production Speed	0.1984
B	K	Make Ready 1	0.0097
B	K	Make Ready 2	0.1328
B	K	Mid Speed 1	0.5865
B	K	Mid Speed 2	0.0054
B	K	Production Speed	0.4165
B	K	Production Speed	0.0901

Table 2: *P-Values*

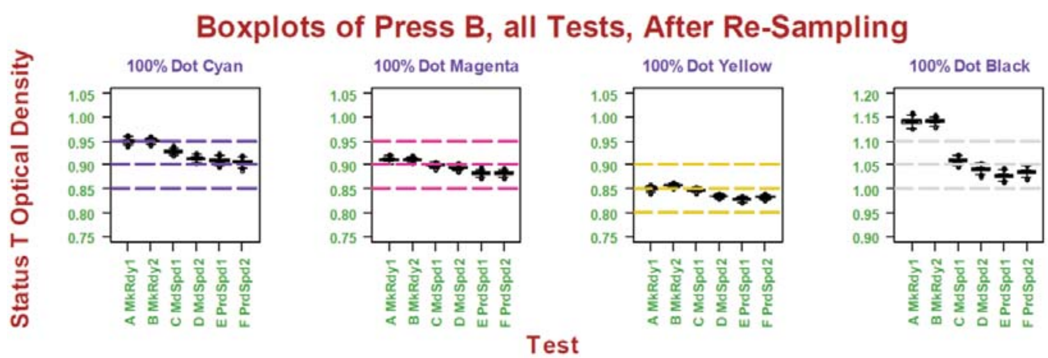
4. Confidence Intervals

Based on ninety six thousand bootstrapped sample points, this study is ninety-five percent confident that with respect to plants, colors and press speeds (Figure 1, Table 3, Appendix 1):

- Solid in density means are within SNAP recommended ranges, except for black at make-ready on press B
- Dow Jones determined ranges are smaller than the SNAP recommended ranges, except for black on press B

Plant	Color	Test	Means	SE	MOE	95% CI
A	C	Make Ready	0.9223	0.0020	0.0039	(0.9184, 0.9261)
A	C	Mid Speed	0.8912	0.0024	0.0047	(0.8865, 0.8959)
A	C	Production Speed	0.8844	0.0022	0.0044	(0.8801, 0.8888)
A	M	Make Ready	0.8628	0.0021	0.0042	(0.8586, 0.8670)
A	M	Mid Speed	0.8777	0.0017	0.0034	(0.8811, 0.8744)
A	M	Production Speed	0.8711	0.0020	0.0040	(0.8671, 0.8750)
A	Y	Make Ready	0.8284	0.0012	0.0023	(0.8261, 0.8307)
A	Y	Mid Speed	0.8222	0.0010	0.0020	(0.8201, 0.8242)
A	Y	Production Speed	0.8157	0.0011	0.0021	(0.8136, 0.8179)
A	K	Make Ready	1.0629	0.0017	0.0034	(1.0596, 1.0663)
A	K	Mid Speed	1.0208	0.0022	0.0042	(1.0166, 1.0250)
A	K	Production Speed	1.0219	0.0022	0.0042	(1.0176, 1.0261)
B	C	Make Ready	0.9506	0.0021	0.0041	(0.9465, 0.9547)
B	C	Mid Speed	0.9208	0.0022	0.0043	(0.9165, 0.9251)
B	C	Production Speed	0.9072	0.0030	0.0059	(0.9013, 0.9132)
B	M	Make Ready	0.9114	0.0021	0.0041	(0.9073, 0.9155)
B	M	Mid Speed	0.8968	0.0019	0.0037	(0.8931, 0.9006)
B	M	Production Speed	0.8829	0.0022	0.0043	(0.8786, 0.8872)
B	Y	Make Ready	0.8544	0.0014	0.0027	(0.8518, 0.8571)
B	Y	Mid Speed	0.8414	0.0012	0.0024	(0.8389, 0.8438)
B	Y	Production Speed	0.8303	0.0016	0.0031	(0.8273, 0.8334)
B	K	Make Ready	1.1412	0.0029	0.0057	(1.1355, 1.1468)
B	K	Mid Speed	1.0506	0.0029	0.0057	(1.0449, 1.0562)
B	K	Production Speed	1.0318	0.0033	0.0064	(1.0254, 1.0382)

Table 3: *Descriptive Statistics*



Graph 4: *Sample Box Plots after Re-Sampling*

Conclusions

This study shows the procedures of an augmented cold-set offset lithographic web press achievement of SNAP's "suggested aim points and tolerances" as a recommendation for optimal reproduction on newsprint substrates. The included methodology illustrates the verification of printed samples in accordance to testing protocols, which replicate daily print production conditions at Dow Jones &

Company. The point of focus is printed Status T optical density, and the included analysis proves the studied presses are in compliance with SNAP's recommended aim values and tolerances of±0.05.

In addition to verifying SNAP's recommended targets, this study reveals a more reliable statistical approach for defining press capabilities with respect to Status T optical density for colors cyan, magenta, yellow and black using standard error. The results do not suggest new aim values and tolerances, but rather proposes the ability to identify the specific characteristics of a press. The two Dow Jones presses in this study achieved print quality, web control and productivity within Status T optical density ranges smaller than SNAP's aim tolerances.

Standard error can be used to determine confidence intervals, and press-specific capabilities, based on chosen confidence levels (67%, 95%, etc). Knowing press-specific capabilities could be useful to operators in optimizing ink adjustments and achieving best possible press performance. In this study is included an R-Programming language script (*Appendix 3*), which can be added to the SNAP test protocol to help other printers determine the optimal performance ranges within their press systems, and/or establish maintenance programs.

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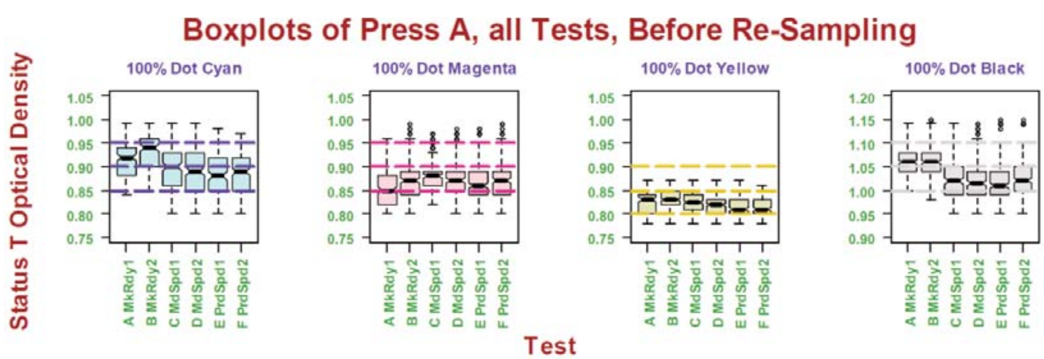
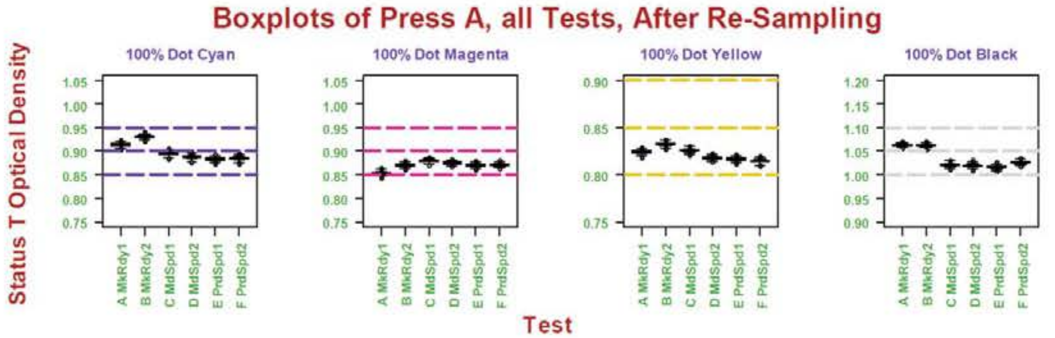
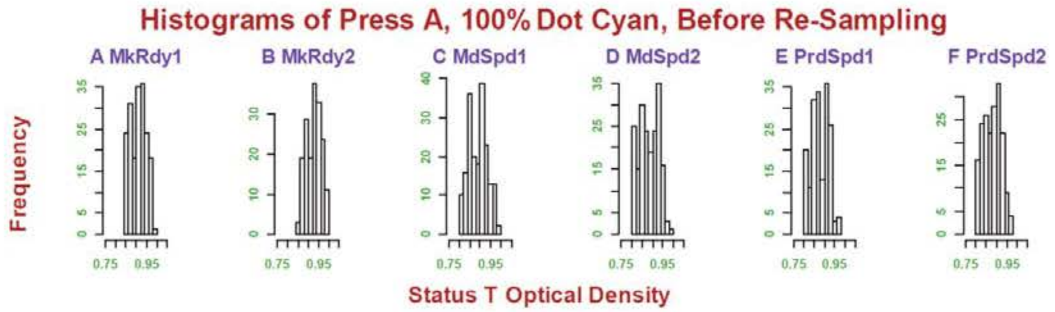
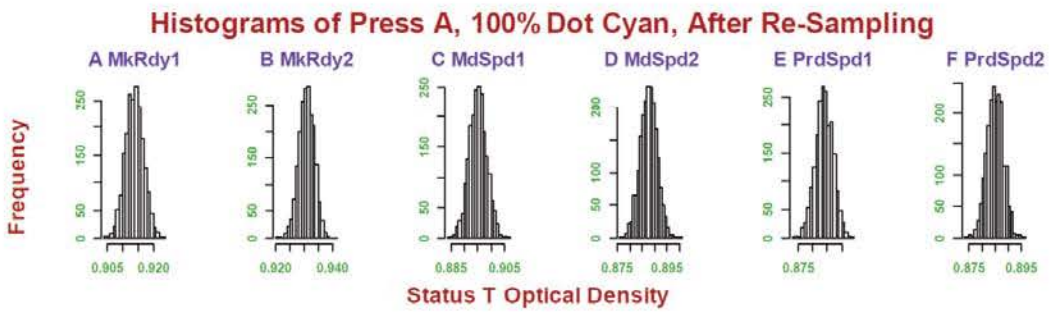
Appendix

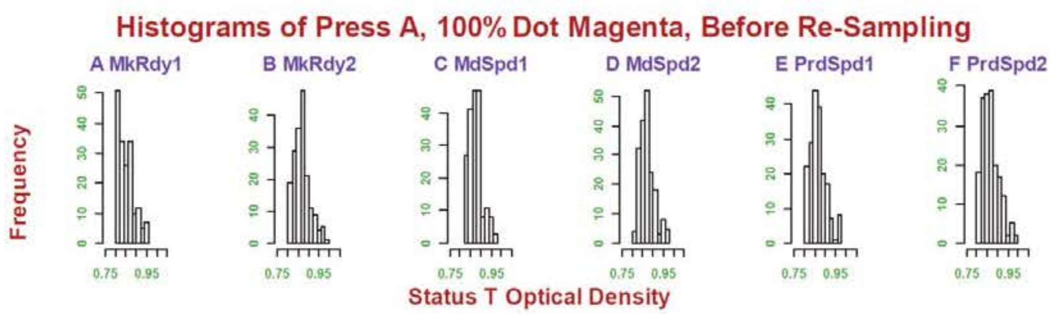
1. R Plots – Plant A

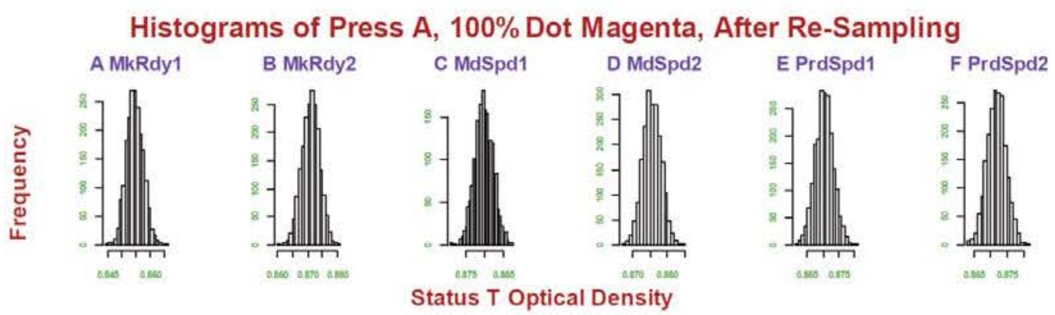


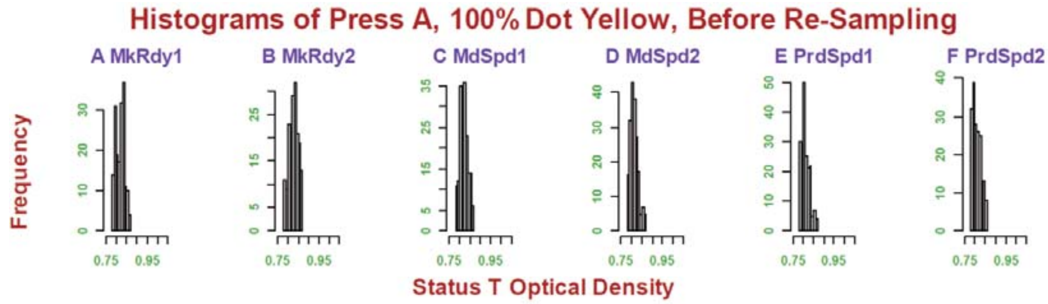

Boxplots of Press A, all Tests, After Re-Sampling
100% Dot Cyan
100% Dot Magenta
100% Dot Yellow
100% Dot Black
Status T Optical Density
A MkRdy1
B MkRdy2
C MdSpd1
D MdSpd2
E PrdSpd1
F PrdSpd2
Test

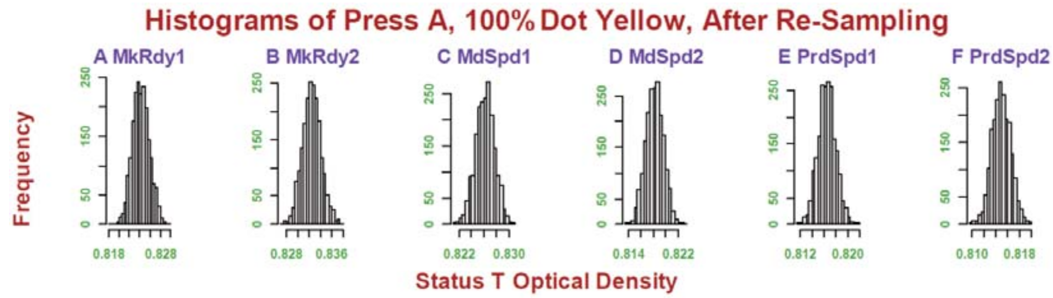

Histograms of Press A, 100% Dot Cyan, Before Re-Sampling
A MkRdy1
B MkRdy2
C MdSpd1
D MdSpd2
E PrdSpd1
F PrdSpd2
Frequency
Status T Optical Density

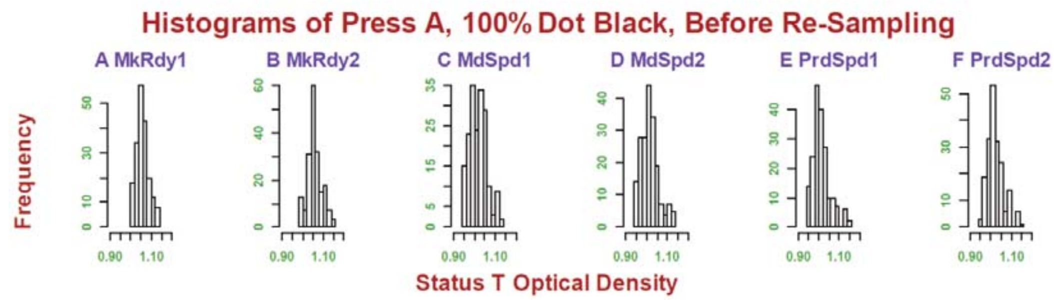

Histograms of Press A, 100% Dot Cyan, After Re-Sampling
A MkRdy1
B MkRdy2
C MdSpd1
D MdSpd2
E PrdSpd1
F PrdSpd2
Frequency
Status T Optical Density

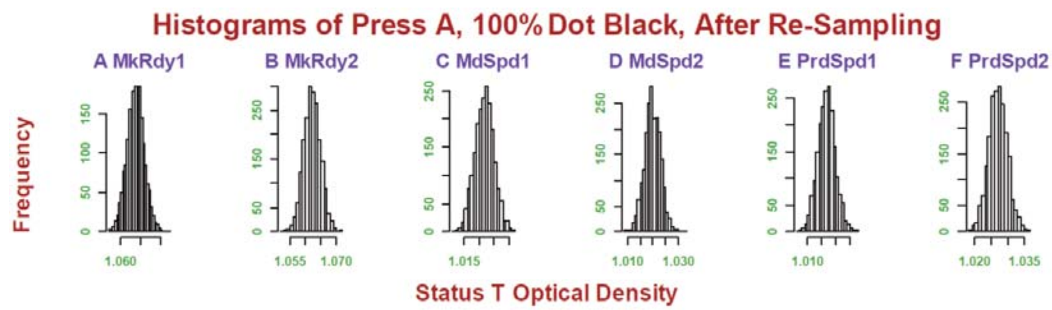

Histograms of Press A, 100% Dot Magenta, Before Re-Sampling
A MkRdy1
B MkRdy2
C MdSpd1
D MdSpd2
E PrdSpd1
F PrdSpd2
Frequency
Status T Optical Density


Histograms of Press A, 100% Dot Magenta, After Re-Sampling
A MkRdy1
B MkRdy2
C MdSpd1
D MdSpd2
E PrdSpd1
F PrdSpd2
Frequency
Status T Optical Density

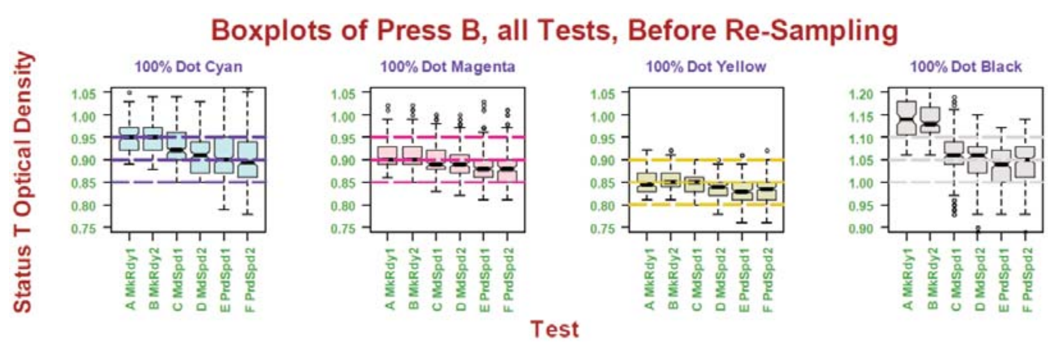


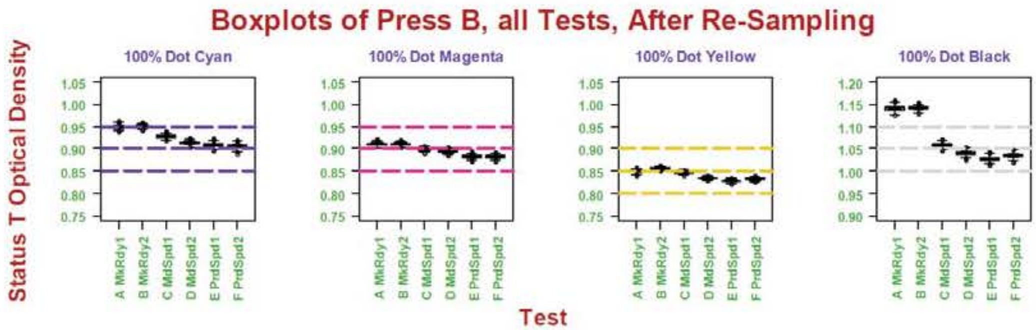


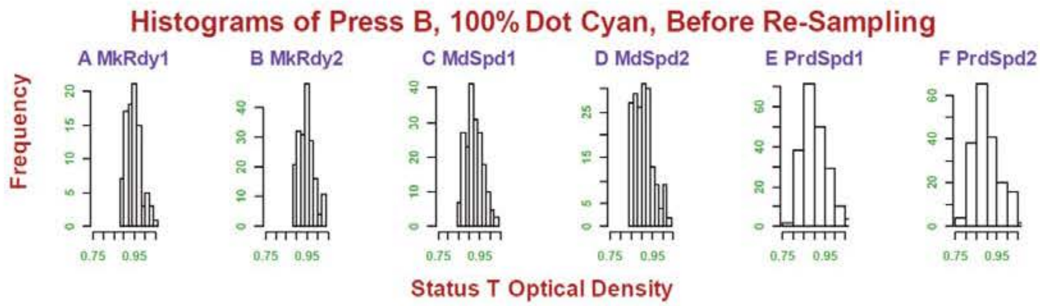


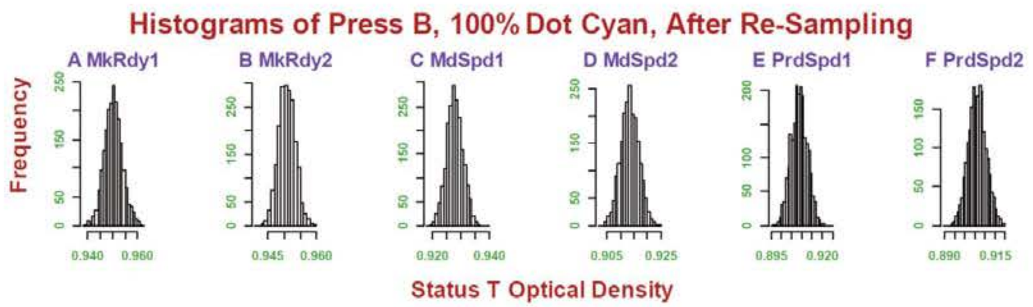


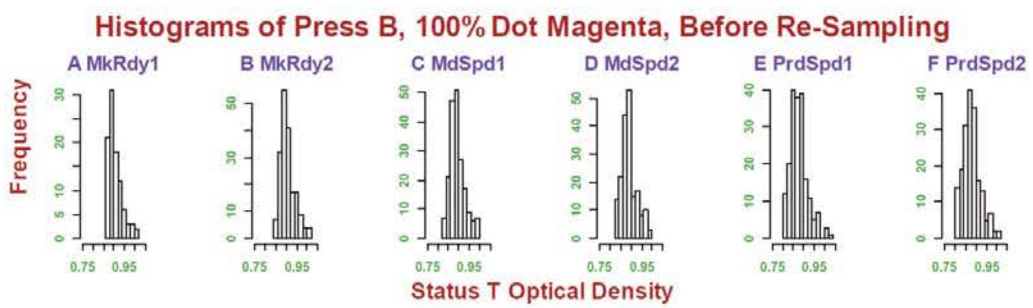
2. R Plots – Plant B

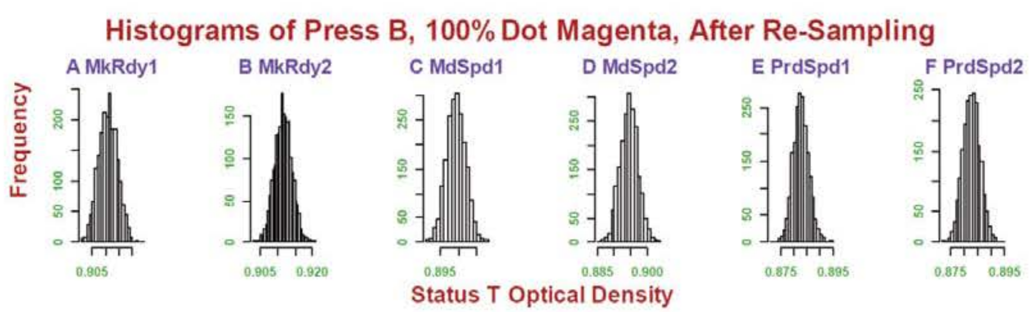


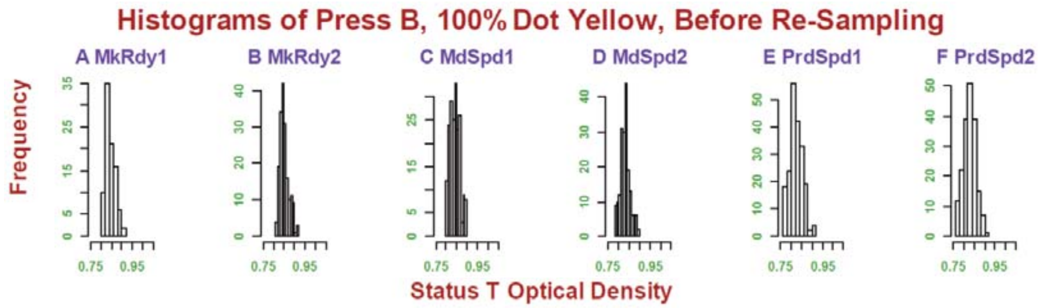

Boxplots of Press B, all Tests, After Re-Sampling
100% Dot Cyan
100% Dot Magenta
100% Dot Yellow
100% Dot Black
Status T Optical Density
A MkRdy1
B MkRdy2
C MdSpd1
D MdSpd2
E PrdSpd1
F PrdSpd2
Test

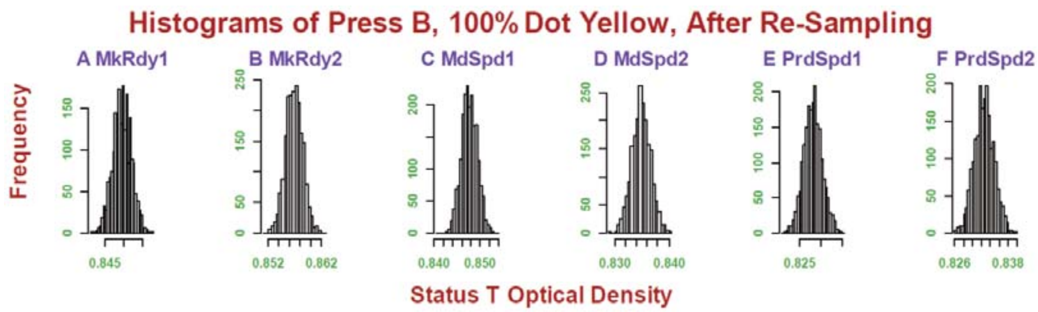

Histograms of Press B, 100% Dot Cyan, Before Re-Sampling
A MkRdy1
B MkRdy2
C MdSpd1
D MdSpd2
E PrdSpd1
F PrdSpd2
Frequency
Status T Optical Density

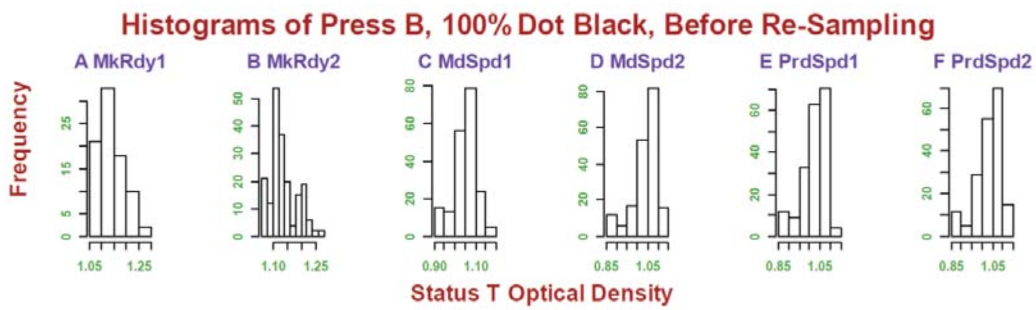

Histograms of Press B, 100% Dot Cyan, After Re-Sampling
A MkRdy1
B MkRdy2
C MdSpd1
D MdSpd2
E PrdSpd1
F PrdSpd2
Frequency
Status T Optical Density

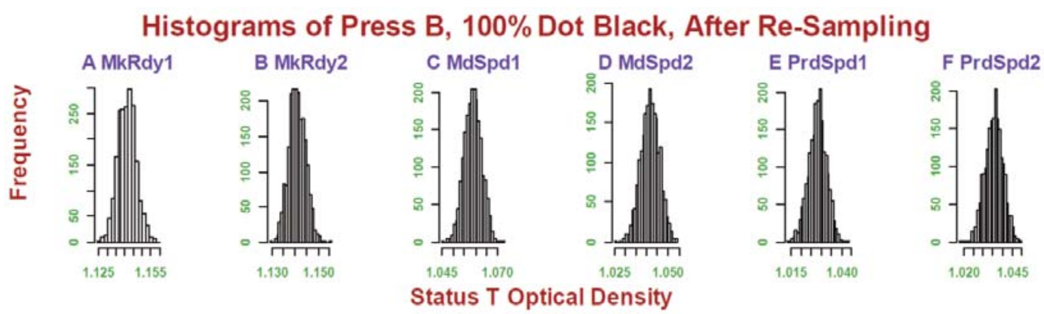

Histograms of Press B, 100% Dot Magenta, Before Re-Sampling
A MkRdy1
B MkRdy2
C MdSpd1
D MdSpd2
E PrdSpd1
F PrdSpd2
Frequency
Status T Optical Density


Histograms of Press B, 100% Dot Magenta, After Re-Sampling
A MkRdy1
B MkRdy2
C MdSpd1
D MdSpd2
E PrdSpd1
F PrdSpd2
Frequency
Status T Optical Density









3. R Script

```
######################################################################
###################################
######                            Loading and Manipulating the Data
######
######################################################################
###################################
rm(list=ls())
data <- read.csv("DataModified.CSV", header=TRUE)
dataSplit <- split(data, list(data$Test, data$Color, data$Press))
```

```
TestComined <- c("A MkRdy1", "B MkRdy2", "C MdSpd1", "D MdSpd2", "E
PrdSpd1", "F PrdSpd2")
pressACyan <- as.vector(names(dataSplit)[grep("C.A",
as.character(names(dataSplit)))])
pressAMagenta <- as.vector(names(dataSplit)[grep("M.A",
as.character(names(dataSplit)))])
pressAYellow <- as.vector(names(dataSplit)[grep("Y.A",
as.character(names(dataSplit)))])
pressABlack <- as.vector(names(dataSplit)[grep("K.A",
as.character(names(dataSplit)))])

pressBCyan <- as.vector(names(dataSplit)[grep("C.B",
as.character(names(dataSplit)))])
pressBMagenta <- as.vector(names(dataSplit)[grep("M.B",
as.character(names(dataSplit)))])
pressBYellow <- as.vector(names(dataSplit)[grep("Y.B",
as.character(names(dataSplit)))])
pressBBlack <- as.vector(names(dataSplit)[grep("K.B",
as.character(names(dataSplit)))])

pressA <- c(pressACyan, pressAMagenta, pressAYellow, pressABlack)
pressB <-
as.vector(names(dataSplit)[grep("B$",as.character((names(dataSplit))))])

##################################################################
##################################
###### Separating the Data
######
##################################################################
##################################
dataMatrix <- lapply(dataSplit, "[[", 4)
plotLabels <- c("A MkRdy1", "B MkRdy2", "C MdSpd1", "D MdSpd2", "E
PrdSpd1", "F PrdSpd2")

cyanDataA <- dataMatrix[pressACyan]; names(cyanDataA) <- plotLabels
magentaDataA <- dataMatrix[pressAMagenta]; names(magentaDataA) <-
plotLabels
yellowDataA <- dataMatrix[pressAYellow]; names(yellowDataA) <- plotLabels
blackDataA <- dataMatrix[pressABlack]; names(blackDataA) <- plotLabels

cyanDataB <- dataMatrix[pressBCyan]; names(cyanDataB) <- plotLabels
magentaDataB <- dataMatrix[pressBMagenta]; names(magentaDataB) <-
plotLabels
```

```
yellowDataB <- dataMatrix[pressBYellow]; names(yellowDataB) <- plotLabels
blackDataB <- dataMatrix[pressBBlack]; names(blackDataB) <- plotLabels

####################################################################
##################################
######                                        Boxplots of Original Data
######
####################################################################
##################################
old_par <- par(no.readonly = TRUE)
par(mfrow=c(1,4))
par(mar=c(6,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.2, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)

boxplot(cyanDataA, main="100% Dot Cyan", notch=TRUE, las=2, col =
hcl(c(rep(200,6))),names=plotLabels, ylim=c(0.75,1.05))
abline(h=c(0.85, 0.90, 0.95), lty=5, col="blue", lwd=2)
boxplot(magentaDataA, main="100% Dot Magenta", notch=TRUE, las=2,
col=c(hcl(rep(0,6))), names=plotLabels, ylim=c(0.75,1.05))
abline(h=c(0.85, 0.90, 0.95), lty=5, col="magenta", lwd=2)
boxplot(yellowDataA, main="100% Dot Yellow", notch=TRUE, las=2, col =
c(hcl(rep(80,6))), names=plotLabels, ylim=c(0.75,1.05))
abline(h=c(0.80, 0.85, 0.90), lty=5, col="darkgoldenrod2", lwd=2)
boxplot(blackDataA, main="100% Dot Black", notch=TRUE, las=2,  col = "light-
grey", names=plotLabels, ylim=c(0.90,1.2))
abline(h=c(1, 1.05, 1.10), lty=5, col=8, lwd=2)
mtext("Test", side=1, cex = 1.2, col="firebrick",font=2, outer=TRUE)
mtext("Status T Optical Density", side=2, cex=1.2, col="firebrick", font=2,
outer=TRUE)
mtext("Boxplots of Press A, all Tests, Before Re-Sampling", side=3, line=0,
cex=1.5, col="firebrick", font=2, outer=TRUE)

##################################
win.graph()
par(mfrow=c(1,4))
par(mar=c(6,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.2, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
boxplot(cyanDataB, main="100% Dot Cyan", notch=TRUE, las=2, col =
hcl(c(rep(200,6))),names=plotLabels, ylim=c(0.75,1.05))
abline(h=c(0.85, 0.90, 0.95), lty=5, col="blue", lwd=2)
boxplot(magentaDataB, main="100% Dot Magenta", notch=TRUE, las=2, col =
c(hcl(rep(0,6))), names=plotLabels, ylim=c(0.75,1.05))
```

```
abline(h=c(0.85, 0.90, 0.95), lty=5, col="magenta", lwd=2)
boxplot(yellowDataB, main="100% Dot Yellow", notch=TRUE, las=2, col =
c(hcl(rep(80,6))), names=plotLabels, ylim=c(0.75,1.05))
abline(h=c(0.80, 0.85, 0.90), lty=5, col="darkgoldenrod2", lwd=2)
boxplot(blackDataB, main="100% Dot Black", notch=TRUE, las=2,  col = "light-
grey", names=plotLabels, ylim=c(0.9,1.2))
abline(h=c(1, 1.05, 1.10), lty=5, col=8, lwd=2)
mtext("Test", side=1, cex = 1.2, col="firebrick",font=2, outer=TRUE)
mtext("Status T Optical Density", side=2, cex=1.2, col="firebrick", font=2,
outer=TRUE)
mtext("Boxplots of Press B, all Tests, Before Re-Sampling", side=3, line=0,
cex=1.5, col="firebrick", font=2, outer=TRUE)

######################################################################
###################################
######                                   Histograms of Original Data
######
######################################################################
###################################
win.graph()
par(mfrow=c(1,6))

par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(cyanDataA[[x]], main=paste(x),
xlab="",xlim=c(.75,1.05), ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2,
outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press A, 100% Dot Cyan, Before Re-Sampling", side=3,
line=0, cex=1.5, col="firebrick", font=2, outer=TRUE)
###################################
win.graph()
par(mfrow=c(1,6))
par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(magentaDataA[[x]], main=paste(x),
xlab="",xlim=c(.75,1.05), ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2,
outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press A, 100% Dot Magenta, Before Re-Sampling", side=3,
```

```
line=0, cex=1.5, col="firebrick", font=2, outer=TRUE)
##################################
win.graph()
par(mfrow=c(1,6))
par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(yellowDataA[[x]], main=paste(x),
xlab="",xlim=c(.75,1.05), ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2,
outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press A, 100% Dot Yellow, Before Re-Sampling", side=3,
line=0, cex=1.5, col="firebrick", font=2, outer=TRUE)
##################################
win.graph()
par(mfrow=c(1,6))
par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(blackDataA[[x]], main=paste(x),
xlab="",xlim=c(.9,1.2), ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2,
outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press A, 100% Dot Black, Before Re-Sampling", side=3,
line=0, cex=1.5, col="firebrick", font=2, outer=TRUE)
####################################################################
Press B
win.graph()
par(mfrow=c(1,6))

par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(cyanDataB[[x]], main=paste(x),
xlab="",xlim=c(.75,1.05), ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2,
outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press B, 100% Dot Cyan, Before Re-Sampling", side=3,
line=0, cex=1.5, col="firebrick", font=2, outer=TRUE)
##################################
win.graph()
```

```
par(mfrow=c(1,6))
par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(magentaDataB[[x]], main=paste(x),
xlab="",xlim=c(.75,1.05), ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2,
outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press B, 100% Dot Magenta, Before Re-Sampling", side=3,
line=0, cex=1.5, col="firebrick", font=2, outer=TRUE)
##################################
win.graph()
par(mfrow=c(1,6))
par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(yellowDataB[[x]], main=paste(x),
xlab="",xlim=c(.75,1.05), ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2,
outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press B, 100% Dot Yellow, Before Re-Sampling", side=3,
line=0, cex=1.5, col="firebrick", font=2, outer=TRUE)
##################################
win.graph()
par(mfrow=c(1,6))
par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(blackDataB[[x]], main=paste(x), xlab="",
ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2,
outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press B, 100% Dot Black, Before Re-Sampling", side=3,
line=0, cex=1.5, col="firebrick", font=2, outer=TRUE)

####################################################################
##################################
######                    standard Error Before Bootstrapping
######
####################################################################
##################################
```

```
## Just for educational purposes, I am calculating the standard error OF THE MEAN before bootstrapping
## You divide by the square root of the ORIGINAL sample count
## The standard error does not change if the data is centered

## Please note that the standard error looks almost the same before booting and after booting
## because the original data appears to be normal.
dataCenteredStDev <- do.call(rbind, lapply(dataMatrix, sd))
dataLengthSquareRoot <- sqrt(do.call(rbind, lapply(dataMatrix,length)))
standardErrorNoBoot <- dataCenteredStDev/dataLengthSquareRoot
colnames(standardErrorNoBoot) <- "seNoBoot"; standardErrorNoBoot

##############################################################################################################
###### Standard Error After Bootstrapping #####
##############################################################################################################
## After bootstrapping the standard error is just the standard deviation of the bootstrapped data
Means <- lapply(1:48, function(x)
    (replicate(2000, mean(sample(dataMatrix[[x]],length(dataMatrix[[x]]), replace=TRUE)))))
names(Means) <- names(dataMatrix)
standardErrorBoot <- do.call(rbind, lapply(Means,sd))
rownames(standardErrorBoot) <- names(dataMatrix); colnames(standardErrorBoot) <- "seBoot"; standardErrorBoot

##############################################################################################################
## Normality: All p-values are high, you accept the null hypothesis of normailty assumption.
do.call(rbind, lapply(Means, shapiro.test))
##############################################################################################################
## Summary statistics
dataSummaryStatistics<- do.call(rbind, lapply(1:48, function(x) round(summary(Means[[x]]), digits=3)))
rownames(dataSummaryStatistics) <- names(dataMatrix)
dataSummaryStatistics

##############################################################################################################
```

```
#######                                    Separate the Bootstrapped data
##########
##################################################################
#################################
cyanDataBootA <- Means[pressACyan]; names(cyanDataBootA) <- plotLabels
magentaDataBootA <- Means[pressAMagenta]; names(magentaDataBootA) <-
plotLabels
yellowDataBootA <- Means[pressAYellow]; names(yellowDataBootA) <-
plotLabels
blackDataBootA <- Means[pressABlack]; names(blackDataBootA) <- plotLabels

cyanDataBootB <- Means[pressBCyan]; names(cyanDataBootB) <- plotLabels
magentaDataBootB <- Means[pressBMagenta]; names(magentaDataBootB) <-
plotLabels
yellowDataBootB <- Means[pressBYellow]; names(yellowDataBootB) <-
plotLabels
blackDataBootB <- Means[pressBBlack]; names(blackDataBootB) <- plotLabels

##################################################################
#################################
######                              Boxplots of Bootstrapped Centered Data
                                 #######
##################################################################
#################################
old_par <- par(no.readonly = TRUE)
par(mfrow=c(1,4))
par(mar=c(6,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.2, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)

boxplot(cyanDataBootA, main="100% Dot Cyan", notch=TRUE, las=2, col =
hcl(c(rep(200,6))),names=plotLabels, ylim=c(0.75,1.05))
abline(h=c(0.85, 0.90, 0.95), lty=5, col="blue", lwd=2)
boxplot(magentaDataBootA,main="100% Dot Magenta",notch=TRUE, las=2,
col=c(hcl(rep(0,6))),names=plotLabels, ylim=c(0.75,1.05))
abline(h=c(0.85, 0.90, 0.95), lty=5, col="magenta", lwd=2)
boxplot(yellowDataBootA,main="100% Dot Yellow",notch=TRUE,las=2,col =
c(hcl(rep(80,6))), names=plotLabels, ylim=c(0.75,0.90))
abline(h=c(0.80, 0.85, 0.90), lty=5, col="darkgoldenrod2", lwd=2)
boxplot(blackDataBootA, main="100% Dot Black", notch=TRUE, las=2,  col =
"lightgrey", names=plotLabels, ylim=c(0.90,1.20))
abline(h=c(1, 1.05, 1.10), lty=5, col=8, lwd=2)
mtext("Test", side=1, cex = 1.2, col="firebrick",font=2, outer=TRUE)
mtext("Status T Optical Density", side=2, cex=1.2, col="firebrick", font=2,
```

```
outer=TRUE)
mtext("Boxplots of Press A, all Tests, After Re-Sampling",side=3,line=0,cex=1.5,col="firebrick",font=2,outer=TRUE)

##################################
win.graph()
par(mfrow=c(1,4))
par(mar=c(6,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.2, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)

boxplot(cyanDataBootB, main="100% Dot Cyan", notch=TRUE, las=2, col = hcl(c(rep(200,6))),names=plotLabels, ylim=c(0.75,1.05))
abline(h=c(0.85, 0.90, 0.95), lty=5, col="blue", lwd=2)
boxplot(magentaDataBootB,main="100% Dot Magenta",notch=TRUE, las=2, col=c(hcl(rep(0,6))),names=plotLabels, ylim=c(0.75,1.05))
abline(h=c(0.85, 0.90, 0.95), lty=5, col="magenta", lwd=2)
boxplot(yellowDataBootB,main="100% Dot Yellow",notch=TRUE,las=2,col = c(hcl(rep(80,6))), names=plotLabels, ylim=c(0.75,1.05))
abline(h=c(0.80, 0.85, 0.90), lty=5, col="darkgoldenrod2", lwd=2)
boxplot(blackDataBootB, main="100% Dot Black", notch=TRUE, las=2,  col = "lightgrey", names=plotLabels, ylim=c(0.90,1.20))
abline(h=c(1, 1.05, 1.10), lty=5, col=8, lwd=2)
mtext("Test", side=1, cex = 1.2, col="firebrick",font=2, outer=TRUE)
mtext("Status T Optical Density", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Boxplots of Press B, all Tests, After Re-Sampling", side=3, line=0, cex=1.5, col="firebrick", font=2, outer=TRUE)

####################################################################
##################################
######                          Histograms of Bootstrapped   Data
######
####################################################################
##################################
win.graph()
par(mfrow=c(1,6))

par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(cyanDataBootA[[x]], main=paste(x), xlab="", ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2,
```

```
outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press A, 100% Dot Cyan, After Re-Sampling",side=3,line=0,cex=1.5, col="firebrick", font=2, outer=TRUE)
###################################
win.graph()
par(mfrow=c(1,6))
par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 0.8, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(magentaDataBootA[[x]], main=paste(x), xlab="", ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2, outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press A, 100% Dot Magenta, After Re-Sampling", side=3, line=0, cex=1.5, col="firebrick", font=2, outer=TRUE)
###################################
win.graph()
par(mfrow=c(1,6))
par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(yellowDataBootA[[x]], main=paste(x), xlab="", ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2, outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press A, 100% Dot Yellow, After Re-Sampling", side=3,line=0,cex=1.5,col="firebrick", font=2, outer=TRUE)

###################################
win.graph()
par(mfrow=c(1,6))
par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(blackDataBootA[[x]], main=paste(x), xlab="", ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2, outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press A, 100% Dot Black, After Re-Sampling",side=3,line=0, cex=1.5, col="firebrick", font=2, outer=TRUE)
```

```
##################################################################
Press B
win.graph()
par(mfrow=c(1,6))

par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(cyanDataBootB[[x]], main=paste(x), xlab="",
ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2,
outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press B, 100% Dot Cyan, After Re-Sampling",side=3,
line=0, cex=1.5, col="firebrick", font=2, outer=TRUE)
#################################
win.graph()
par(mfrow=c(1,6))
par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(magentaDataBootB[[x]], main=paste(x),
xlab="", ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2,
outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press B, 100% Dot Magenta, After Re-
Sampling",side=3,line=0,cex=1.5,col="firebrick", font=2, outer=TRUE)
#################################
win.graph()
par(mfrow=c(1,6))
par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(yellowDataBootB[[x]], main=paste(x),
xlab="", ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2,
outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press B, 100% Dot Yellow, After Re-
Sampling",side=3,line=0,cex=1.5, col="firebrick", font=2, outer=TRUE)
#################################
win.graph()
par(mfrow=c(1,6))
```

```
par(mar=c(5,5,3,2), oma=c(3,3,3,3), col.main="blue", col.sub=1,
   col.axis= "green4", col.lab="firebrick", cex.main=1.6, cex.sub=1,
   cex.axis= 1, cex.lab= 1.4, font.main=2, font.axis=2, font.lab=2)
lapply(plotLabels, function(x) hist(blackDataBootB[[x]], main=paste(x), xlab="",
ylab="",breaks="Scott"))
mtext("Status T Optical Density", side=1, cex = 1.2, col="firebrick",font=2,
outer=TRUE)
mtext("Frequency", side=2, cex=1.2, col="firebrick", font=2, outer=TRUE)
mtext("Histograms of Press B, 100% Dot Black, After Re-
Sampling",side=3,line=0, cex=1.5, col="firebrick", font=2, outer=TRUE)

######################################################################
##################################
######################################################################
##################################

testComined <- gsub("[0-9]", "", data$Test)
testComined <- gsub("B", "A", testComined)
testComined <- gsub("D", "C", testComined)
testComined <- gsub("F", "E", testComined)
dataCombined <- cbind(data,testComined)

dataCombinedSplit <- split(dataCombined, list(dataCombined$testComined,
dataCombined$Color, dataCombined$Press))
dataMatrixCombined <- lapply(dataCombinedSplit, "[[", 4)
MeansComined <- lapply(1:24, function(x)
                                                          (replicate(2000,
mean(sample(dataMatrixCombined[[x]],length(dataMatrixCombined[[x]]),
replace=TRUE)))))

names(MeansComined) <- names(dataMatrixCombined)
head(MeansComined)

standardErrorBootCombined <- do.call(rbind, lapply(MeansComined,sd))
rownames(standardErrorBootCombined) <-
    names(dataMatrixCombined); colnames(standardErrorBootCombined) <-
"seBoot"; standardErrorBootCombined

meansBootCombined <- do.call(rbind, lapply(MeansComined, mean))
rownames(meansBootCombined) <-
  names(dataMatrixCombined); colnames(meansBootCombined) <- "meansBoot";
meansBootCombined
```

4. Sample Data

Press	Color	Test	Density
A	C	A MkRdy1	0.84
A	C	A MkRdy1	0.84
A	C	A MkRdy1	0.84
A	C	A MkRdy1	0.84
A	C	A MkRdy1	0.85
A	C	A MkRdy1	0.85
A	C	A MkRdy1	0.85
A	C	A MkRdy1	0.85
A	C	A MkRdy1	0.85
A	C	A MkRdy1	0.85
.	.	.	.
.	.	.	.
.	.	.	.
A	M	C MdSpd1	0.82
A	M	C MdSpd1	0.82
A	M	C MdSpd1	0.82
A	M	C MdSpd1	0.82
A	M	C MdSpd1	0.83
A	M	C MdSpd1	0.84
A	M	C MdSpd1	0.84
A	M	C MdSpd1	0.84
A	M	C MdSpd1	0.84
A	M	C MdSpd1	0.84
.	.	.	.
.	.	.	.
.	.	.	.
B	Y	D MdSpd2	0.84
B	Y	D MdSpd2	0.8
B	Y	D MdSpd2	0.79
B	Y	D MdSpd2	0.8
B	Y	D MdSpd2	0.82
B	Y	D MdSpd2	0.83
B	Y	D MdSpd2	0.84
B	Y	D MdSpd2	0.8
B	Y	D MdSpd2	0.78
B	Y	D MdSpd2	0.79
B	Y	D MdSpd2	0.81
B	Y	D MdSpd2	0.82
.	.	.	.
.	.	.	.
.	.	.	.
B	K	F PrdSpd2	1.07
B	K	F PrdSpd2	1.03
B	K	F PrdSpd2	0.98
B	K	F PrdSpd2	0.97
B	K	F PrdSpd2	0.96
B	K	F PrdSpd2	0.97
B	K	F PrdSpd2	1.07
B	K	F PrdSpd2	1.03
B	K	F PrdSpd2	0.98
B	K	F PrdSpd2	0.97
B	K	F PrdSpd2	0.95
B	K	F PrdSpd2	0.97