Gravure Research Agenda
Achieving Repeatable Color in Packaging Printing

Bob Chung, RIT

Keywords: Process, Capability, Quality, Control, Assurance

Abstract
Repeatable color is a fundamental requirement for predictable color. This article identifies and explains key steps—from understanding variation, to process standardization, process capability assessment, process control, and quality assurance—in achieving repeatable color for process color printing.

What Do Brand Owners Want?
When I attended gravure conventions and graphic arts conferences, I wanted to find out technologies of interest and current workflow issues. When I asked converters and suppliers what they wanted out of the conference, many told me they wanted to hear what brand owners have to say.

As I listened to presentations by fast moving consumer goods companies, they wanted to be able to bring new products faster to the market; they wanted their products flying off store shelves. This means that they want consistent color in packaging to build brand recognition; they want to be able to predict how printed packaging graphics would look like, in the design stage. In short, brand owners are looking at their supply chain to help them create added value in merchandizing.

What Can the Supply Chain Do?
Customers’ voices are loud and clear in the fast-moving consumer goods industry. They want repeatable and predictable color from design to printing. Sure, color management is a solution for predictable color. But, the success of color management depends on whether printing process is repeatable. How do you enable today’s press operators to achieve consistent color? What is the relevance of material control and process control? How do you realize consistent packaging graphics with high visual impact? As a packaging printer and converter, do you have a sound approach in achieving repeatable and predictable color?

Achieving Repeatable Color
Rochester Institute of Technology, partnering with the Films Division of ExxonMobil Corp., developed a methodology for repeatable color in packaging printing that has been tested and validated in a number of printing platforms. This article explains major principles and key steps involved.

There are five key steps in the repeatable color methodology: (1) understand variation in color printing, (2) standardize the printing process platform, (3) conduct a process
capability study, (4) determine the process control measures that can effectively bring the process back in control, and (5) document color conformance to specifications. Below are elaborations of each of these points.

**Understanding and Measuring Color Variation**

We all experience variation in our daily life. An obvious example of variation is springtime temperature fluctuations. The temperature in upstate New York could be freezing one day and climb to 60°F the next day. The range of temperature variation can vary by 30°F within a day. A subtle example of variation is the difference between snowflakes. Because snowflakes are small, we may think that they are the same in size and shape. In fact, they are quite different from one another as evidenced in the photomicrograph (Figure 1).

![Figure 1. Photomicrograph of three snowflakes](image)

In other words, all things vary. The major issues are (a) if we can measure the variation, and (b) if the variation is within the limits of acceptability. Color variation in printing is no different. Traditionally, the eye is the only tool for detecting color variation in the pressroom. While pressmen control ink film thickness, the lighting influences the printed color, and the visual sensation is subjective and difficult to document.

In the methodology developed by RIT, we measure color patches of known device values with a color measurement device. These patches include solids and tints of CMYK, as well as solids of spot color. Both Status T densities and CIE colorimetric values (CIELAB and CIELCH) are collected from these patches. For process color printing, we measure solid ink density and dot gain as process responses. This is because that complementary filter densities of process color inks are sensitive to ink film thickness changes (Chung, 2006). For spot color printing, we measure CIELAB values, ∆L*, ∆h, and ∆C* as process responses.

In short, we need to (a) acknowledge that there are variations in printing, (b) use appropriate color measurement devices to detect color variation by measuring multiple samples, and (c) perform data analysis to derive descriptive statistics, e.g., central tendency and standard deviation, to ascertain the variations in the printing process.

**Standardizing the Printing Platform**

Color variations come from many sources, e.g., materials, machines, measurement, and workflows. Similar to all printing processes, sources of variation in material include ink and substrates. Sources of variation in a rotogravure press include cylinder, doctor blade, and the press settings. Sources of variation in color measurement include the instrument itself, its calibration, measurement conditions, etc.
Managing color variation in a pressroom is about minimizing the risk of receiving non-conforming materials and maximizing the best practices in the pressroom. We minimize the risk by (a) specifying critical parameters in materials and components used in the process, (b) communicating these parameters as requirements to vendors, and (c) holding vendors accountable for delivering only acceptable materials via certificate of analysis (COA) for every shipment of materials or components.

Figure 2 is an example of the COA from an ink supplier. Spectral reflectance curves of the sample and the reference are plotted at left. The color difference between the sample and the reference, under different illuminant/observer combinations, are shown at right. The conformance is indicated by the location of the sample plots in relation to pre-established color tolerances.

To maximize color repeatability, adherence to standard operating procedures includes the procedure for preparing press-ready inks, cylinder and doctor blade mounting, press make-ready, and on-site color measurement set-up. Table 1 is a summary of critical parameters in ink, image carrier, and press settings to be standardized and controlled for a gravure printing platform using solvent-based inks. An example of how a specific fingerprinting press run is organized is shown in Appendix 1.

Table 1. Process parameters in a gravure printing system

<table>
<thead>
<tr>
<th>Solvent-based ink</th>
<th>Cylinder</th>
<th>Press settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color formulation</td>
<td>Engraving mechanism</td>
<td>Doctor blade (angle &amp; pressure)</td>
</tr>
<tr>
<td>Concentrate</td>
<td>Engraving curves</td>
<td>Cylinder pressure</td>
</tr>
<tr>
<td>Vehicle</td>
<td>Color management</td>
<td></td>
</tr>
<tr>
<td>Solvent</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conducting a Process Capability Study

RIT’s methodology recognized that quality process drives quality products. Assessing capability of the printing process is essential to ensure quality of the process. Process capability assessment, often referred to as press fingerprinting, can be divided into two categories: process color and spot color. Process color printing uses the standard four
Achieving Repeatable Color in Packaging Printing / Chung

inks, CMYK. We use densitometry to measure process responses such as solid ink density and dot gain. Spot color printing uses any number of specially formulated inks. We use colorimetry to measure spot color responses.

Assessing Capability of Process Color Printing

Color variation exists spatially as well as temporally. Spatial variation should be investigated first. Once detected, it should be fixed so that special-caused variations are removed. We need to acknowledge the magnitude of random or chance-caused variations.

There are two approaches in assessing spatial uniformity of process color printing. Depending on the real estate of the test form, we can use two identical color charts or a long gray bar. When there is plenty real estate in the test form (Figure 3), we can place two color charts, e.g., IT8.7/3 basic (182 patches), at different locations of the press sheet, in this case, upper left and lower right. When there is little real estate in the test form, we can place a long 3C gray bar, shown as the second row from top of Figure 3, across the press sheet. The 3C gray patch should contain some amounts of cyan, magenta, and yellow, e.g., 50C/40M/40Y, which appears neutral, and would match an adjacent black tint patch.

Figure 3. Test form containing color charts and 3C gray patches

The question we want to answer is, “What are the color differences of the same color patches located at different locations of a press sheet?” In the first case, spatial uniformity is a measure of color differences between corresponding color patches from the two identical color charts. In the second case, spatial uniformity is a measure of color differences between individual 3C gray patches and their average.
We use a color measurement instrument, interfaced to a laptop computer, and Excel templates to capture color measurement data and to perform associated data analyses. Both methods end up with a ΔE distribution. We choose cumulative relative frequency of ΔE (or CRF curve) to depict spatial uniformity of the printing process. Figure 4 shows spatial uniformity of a digital press using two-chart and 3C gray methods. To interpret the (solid) curve, generated from two color charts, the maximum ΔE of 6 is found at the end of the CRF curve, the midpoint ΔEs is 1.5, etc.

![Figure 4. Spatial uniformity of a digital press](image)

By observing the ΔE distributions or CRF curves in Figure 4, we can tell that the two approaches produce different results. Variations from the two IT8.7/3 basic charts are derived from a larger area of the press sheet and from CMYK combinations. Thus, it is more comprehensive in depicting spatial variation than using the 3C gray patches where only one level of CMY combination is sampled, and variation of the black printer is not accounted for, across the press sheet.

Our recommendation is to use the two IT8.7/3 charts for spatial uniformity assessment whenever the real estate is available in the test form. The 3C gray bar can be used as an alternative test target recognizing that the spatial variation, estimated from the 3C gray bar, is conservative.

Spatial uniformity of a printing process should not be assumed, but assessed because the color matching performance of the process can only be as good as its inherent variation. In other words, the larger spatial variation is, the less uniform the printed color will be. This, in turn, impacts the color matching performance of the device. While gravure is known for uniform inking, the spatial uniformity assessment, as prescribed, provides documented evidence as such. Spatial uniformity of flexo printing depends on the evenness of the pressure settings on both sides of the impression cylinders. Spatial uniformity of offset printing depends on both ink demand within an ink zone and ink key settings across the width of the press.

Now, let’s address temporal consistency of the printing process.

The assessment of temporal consistency of process color printing requires that the press is running at steady state. Multiple press sheets are pulled either during printing or
afterwards. In order to study variation over time, a sample size of 30 is recommended over the length of the press run. For example, if it’s a sheetfed offset press run at 9,000 impressions per hour and there are 9,000 sheets available, we would pull samples at every two minutes or every 300 impressions. If we print roll-to-roll with a packaging gravure press and the substrate is 9,000 meters in length, we would tag the roll at every 300 meters and fetch the tagged samples afterward with the use of a roll re-winder.

For process color printing, we use densitometry to assess temporal consistency of the printing process. By measuring solid and tint patches of CMYK from 30 press sheets, we can plot the time chart on dot gain variation, shown in Figure 5.

![Figure 5. Dot gain capability of a digital press](image)

The fact that the complementary filter density is sensitive to ink film thickness change and is one dimensional, we use indices, CP and CpK, to describe the capability of process color printing. CP is a measure of the spread of the process in relation to the tolerance; CpK is a measure of both the centeredness and the spread of the process in relation to specifications (Chung and Shimamura, 2001). Table 2 provides a statistical summary, including CP and CpK, of the digital press.

<table>
<thead>
<tr>
<th>50% DG</th>
<th>K</th>
<th>C</th>
<th>M</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aim point</td>
<td>22.0</td>
<td>20.0</td>
<td>20.0</td>
<td>18.0</td>
</tr>
<tr>
<td>Average</td>
<td>21.58</td>
<td>21.87</td>
<td>19.83</td>
<td>17.62</td>
</tr>
<tr>
<td>Max</td>
<td>23.18</td>
<td>23.22</td>
<td>21.56</td>
<td>19.42</td>
</tr>
<tr>
<td>Min</td>
<td>19.75</td>
<td>19.80</td>
<td>17.90</td>
<td>16.19</td>
</tr>
<tr>
<td>Range</td>
<td>3.43</td>
<td>3.43</td>
<td>3.66</td>
<td>3.23</td>
</tr>
<tr>
<td>σ</td>
<td>0.86</td>
<td>0.90</td>
<td>1.03</td>
<td>0.98</td>
</tr>
<tr>
<td>CP</td>
<td>1.73</td>
<td>1.66</td>
<td>1.45</td>
<td>1.53</td>
</tr>
<tr>
<td>CpK</td>
<td>0.99</td>
<td>1.53</td>
<td>0.91</td>
<td>0.89</td>
</tr>
</tbody>
</table>

It’s important to know that CpK index cannot be greater than the CP index, but CpK can approach or equal to CP if the process is centered. In addition, the higher the indices are, the more capable is the process. As a rule of thumb, the process is capable in meeting
specifications when CpK is greater than 1.33; the process is acceptable when CpK is between 1.0 and 1.33; the process is not capable in meeting specifications thus needs improvement, when CpK is less than 1.0. When the printing process is both accurate and capable, it provides the foundation for achieving predictable color in color-managed workflows.

Assessing Capability of Spot Color Printing

A densitometer uses built-in red, green, and blue filters to detect changes in cyan, magenta, and yellow ink film thickness. A densitometer does not provide the same level of sensitivities when printing non-process color inks. A colorimeter is more suited for measuring variations of spot color inks.

Similar to process color printing, there are two aspects of color repeatability in spot color printing: spatial uniformity and temporal consistency. Spatial uniformity of a spot color is estimated by colorimetric measurements collected from across a printed sheet. No special test target is necessary for collecting color measurement data if the spot color is printed everywhere. Measurements across the printing direction (widthwise) and in the printing direction (lengthwise) are collected.

Our experiences indicate that width (side-to-side) variation is more significant than circumferential (gripper-to-tail) variation. To keep the process simple and effective, the RIT methodology assesses spatial variation of spot color by measuring a total of 30 CIELAB values across the press sheet. A CRF curve can be constructed based on color differences between individual CIELAB data and their average.

Temporal consistency is a measure of inking repeatability over time. It measures time-dependent variation at a fixed location on the printed sheet. Operationally, the measurement location should be representative of the spot color in question, and is free from flaws such as surface scratches or coffee stains. Temporal consistency is estimated by the CRF curve of all ΔE's between individual ΔE's and its average. Figure 6 illustrates the temporal variation of a dark blue spot color as a CRF curve (Chung, 2005).

The median ΔE is 1 with a maximum ΔE at 2.5. High chroma colors, as seen in many brands, with a median ΔE of 1 and maximum ΔE of 2.5 are visually uniform. Spatial uniformity criteria for pastel colors are tighter than that of high chroma colors.

![Figure 6. The CRF curves of temporal variation of a spot color](image-url)
Implementing Process Control

“If you do not measure, you cannot control,” is an adage. While the statement is true, it does not tell the rest of the story. For example, if you measure the press sheet only once, you know nothing about variation of the process. If you measure press sheets and do not use the data to regulate the process, you’re not getting the benefit of process control.

Process control in packaging printing is about (a) regulating the press to verify its conformance to specifications and (b) taking corrective action as required. As shown in Figure 7, regulating activities begin with printing a live job with a color control bar and press sheet sampling. This is followed by visual inspection and color measurement. The measurement data are compared to pre-established aim points and tolerances. If the process is capable of meeting specifications, as verified by process capability assessment, then correction actions can be introduced based on process know-how by pressmen.

Figure 7. A generic process control diagram

Below is an example of how press site color control is implemented with the use of a test target, an on-site color measurement system, and a decision-making table for process color printing. A pressman is an important part of the process control loop. Thus, the measurement system must be easy to use and it must provide clear signals for what to do with the signal. Table 3 is a screen capture of a section of the Excel template for on-site color measurement and process control. The yellow highlighted area captures the information about a press sheet.

Table 3. On-site color measurement and feedback

<table>
<thead>
<tr>
<th>Sample</th>
<th>Patch ID</th>
<th>Dv</th>
<th>Dr</th>
<th>Dg</th>
<th>Db</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zero</td>
<td>0.06</td>
<td>0.06</td>
<td>0.05</td>
<td>0.05</td>
<td>95.21</td>
<td>-0.57</td>
<td>-0.13</td>
<td></td>
</tr>
<tr>
<td>Time: 2:50 pm</td>
<td>100% K</td>
<td>1.54</td>
<td>1.53</td>
<td>1.56</td>
<td>1.62</td>
<td>19.35</td>
<td>0.71</td>
<td>3.22</td>
<td>0.03</td>
</tr>
<tr>
<td>Temp: 29.3</td>
<td>50% K</td>
<td>0.51</td>
<td>0.51</td>
<td>0.52</td>
<td>0.54</td>
<td>62.12</td>
<td>0.30</td>
<td>3.06</td>
<td>0.00</td>
</tr>
<tr>
<td>Humid: 36.0</td>
<td>50% C</td>
<td>0.61</td>
<td>0.52</td>
<td>0.60</td>
<td>0.60</td>
<td>56.49</td>
<td>6.39</td>
<td>-0.79</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>7% K</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>91.25</td>
<td>-0.45</td>
<td>0.25</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>100% C</td>
<td>0.64</td>
<td>1.31</td>
<td>0.33</td>
<td>0.15</td>
<td>60.99</td>
<td>-41.46</td>
<td>-46.24</td>
<td>7.85</td>
</tr>
<tr>
<td></td>
<td>50% C</td>
<td>0.28</td>
<td>0.44</td>
<td>0.15</td>
<td>0.08</td>
<td>79.90</td>
<td>-21.57</td>
<td>-22.20</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td>7% C</td>
<td>0.09</td>
<td>0.11</td>
<td>0.07</td>
<td>0.06</td>
<td>92.81</td>
<td>-4.59</td>
<td>-3.77</td>
<td>5.49</td>
</tr>
<tr>
<td></td>
<td>100% M</td>
<td>0.64</td>
<td>0.28</td>
<td>1.34</td>
<td>0.72</td>
<td>48.90</td>
<td>75.83</td>
<td>-5.80</td>
<td>2.47</td>
</tr>
<tr>
<td></td>
<td>50% M</td>
<td>0.36</td>
<td>0.14</td>
<td>0.53</td>
<td>0.31</td>
<td>69.42</td>
<td>41.50</td>
<td>-11.30</td>
<td>10.21</td>
</tr>
<tr>
<td></td>
<td>7% M</td>
<td>0.10</td>
<td>0.07</td>
<td>0.12</td>
<td>0.09</td>
<td>90.72</td>
<td>6.40</td>
<td>-2.72</td>
<td>2.19</td>
</tr>
<tr>
<td></td>
<td>100% Y</td>
<td>0.08</td>
<td>0.06</td>
<td>0.11</td>
<td>0.90</td>
<td>91.51</td>
<td>-7.32</td>
<td>88.23</td>
<td>2.21</td>
</tr>
<tr>
<td></td>
<td>50% Y</td>
<td>0.07</td>
<td>0.06</td>
<td>0.08</td>
<td>0.42</td>
<td>93.28</td>
<td>-7.43</td>
<td>44.94</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>7% Y</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.11</td>
<td>94.74</td>
<td>-2.03</td>
<td>6.82</td>
<td>0.36</td>
</tr>
</tbody>
</table>

The first column records time, temperature, and humidity when it was sampled. The second column shows the layout of the test target, beginning with the substrate white,
followed by solids and tints of black, etc. The rest of yellow highlighted columns are color measurement data, status T densities and CIELAB, sent from GretagMacbeth’s Spectrolino. For process color printing, solid ink densities and dot gain values of the sample are compared with the specifications, and the deviations are shown at the right-hand column. When deviations exceed the pre-established tolerances, they are displayed in red through conditional formatting feature of the Excel.

As mentioned earlier, the process must be capable of meeting specifications and pressmen must know what to adjust in the pressroom in order to bring the process in control. Table 4 summarizes decision-making rules between process parameters and adjustments for a solvent-based gravure printing process. By inspecting solid ink density data in Table 3, all four printing stations conform to specifications. By inspecting the dot gain data, the midtone dot gain of the black printer is too low (-7.05%). Pressmen need to decrease the black ink viscosity by adding the right amount of solvent. The midtone dot gain of the magenta printer is too high (5.49%). Pressmen need to increase the magenta ink viscosity by adding the right amount of concentrate and vehicle.

<table>
<thead>
<tr>
<th>Process parameter</th>
<th>What</th>
<th>Ink adjustment</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid ink density</td>
<td>Too high</td>
<td>Add vehicle</td>
<td>Reduce concentration</td>
</tr>
<tr>
<td></td>
<td>Too low</td>
<td>Add concentrate</td>
<td>Increase concentration</td>
</tr>
<tr>
<td>Dot gain</td>
<td>Too high</td>
<td>Add vehicle and concentrate</td>
<td>Increase viscosity</td>
</tr>
<tr>
<td></td>
<td>Too low</td>
<td>Add solvent</td>
<td>Decrease viscosity</td>
</tr>
</tbody>
</table>

Documenting Quality Assurance

The goal of quality control in packaging printing is to exercise real-time control to produce acceptable products. Quality assurance, on the other hand, is to make sure that acceptable products have been produced. This way, the print buyer has documented evidence of product conformance.

The certificate of analysis of printed products is the result of the on-site color measurement and process control record. Figure 8 shows the solid ink density conformance of a press run. Initially, we see color adjustments at the press make-ready stage. Once solid ink densities are in control, they tend to stay in conformance.

![Figure 8. Solid ink density conformance of process color printing](image-url)
Figure 9 shows the dot gain conformance record of a process color printing. In this instance, getting dot gain values of CMYK in conformance took longer than getting solid ink densities in conformance. It is possible to express both densitometric plots in terms of CP and CpK values.

![Figure 9. Dot gain conformance of process color printing](image)

Similarly, quality assurance of spot color conformance can be documented with the performance chart, as shown in Figure 10. The x-axis is the sample and the y-axis is the color difference, ΔE(ab). In this instance, there are two spot colors, orange and green, with a color tolerance of 2 ΔE. In order to reduce ΔE for spot color printing, the primary factors are ink suppliers and quality control of incoming inks.

![Figure 10. Color conformance of spot color printing](image)

The RIT methodology offers two ΔE formulas, ΔE(ab) and ΔE(2000). ΔE(2000) is a bigger color difference ruler and it tends to compress color differences in high chroma color. Using the Figure 9 spot color as an example, 2 ΔE(ab) in the 1976 color difference formula is only 1 ΔE(00) in the 2000 color difference formula (Figure 11).
Figure 11. CRF curve as a function of color difference formula

**Summary**

Packaging printing is an industry in itself. It is also a part of a supply chain that helps fast-moving consumer goods companies thrive. As brand owners demand greater color consistency, packaging printers and converters need to acknowledge print buyer’s needs and do something about it.

This article described the RIT methodology for achieving repeatable color in packaging printing. Beginning with a discussion that variation exists everywhere, it described how color variations in printing are measured and assessed in terms of process capability for both process color and spot color. Using a solvent-based gravure packaging printing as an example, this article pointed out the process control measures that pressmen can implement with ease. Finally, it shows how quality of printed products can be documented and assured.

The methodology provides a sound approach to managing repeatable color in printing. Yet, each printing process is like a unique snowflake that is different and requires special attention. We faced the challenges in articulating goals and developing standard operating procedures that are easy to understand by pressroom managers. We also faced the challenges in developing measurement tools and analysis procedures for process capability assessment and color control that are easy to use by press operators. The competitive advantage can only be fully realized when we accept the mindset of sample-measure-control-assure cycle as the right thing to do in achieving repeatable color in packaging printing.

**Acknowledgment**

The author wishes to recognize the Films Business Division of the ExxonMobil Chemical Company for sponsoring the repeatable color project. He also wants to thank his colleagues, Frank Cost, Bill Garno, Bill Pope, and Fred Hsu at RIT for their collaboration and continuing support of the project.
Literature Cited


About the Author

Bob Chung is a professor in the School of Print Media, Rochester Institute of Technology. Bob was named the RIT Gravure Research Professor in 2004 with the mandate to develop a gravure research agenda and curriculum to help students understand the gravure process and explore career opportunities in the gravure industry. Bob was the recipient of the Michael H. Bruno Award, given by the Technical Association of the Graphic Arts in 2006. He is interested in your comment regarding this article and any suggestion that you may have to further gravure research and scholarship. Visit his web site at www.rit.edu/~gravure or email him at rycppr@rit.edu.
### Appendix 1. Press Run Organizer

<table>
<thead>
<tr>
<th>Press date:</th>
<th>May 19-20, 2004</th>
<th>Objectives: (1) Conduct run_20 on May 19th using new cylinders to demonstrate press-to-proof match via printing on white OPP by numbers &amp; color management. (2) Conduct run_21 on May 20th to demonstrate shortened time to color OK via on-site color measurement &amp; process control techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project description:</td>
<td>Gravure Color Consistency</td>
<td></td>
</tr>
<tr>
<td>Project coordinator:</td>
<td>Robert Chung; <a href="mailto:rycppr@rit.edu">rycppr@rit.edu</a></td>
<td></td>
</tr>
<tr>
<td>Telephone No:</td>
<td>1-585-475-2722</td>
<td></td>
</tr>
<tr>
<td>Today's date:</td>
<td>Mon., April 29, 2004</td>
<td></td>
</tr>
<tr>
<td>Industry partners:</td>
<td>ExxonMobil, etc.</td>
<td></td>
</tr>
</tbody>
</table>

#### Job Specifications

<table>
<thead>
<tr>
<th><strong>PREPRESS</strong></th>
<th>Notes on layout and FTP: Layout size: 700 mm x 1,320 mm (27.5&quot; x 52&quot;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signature contents:</td>
<td>Test block, reference CMYK images, color managed images, and color control bar</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>PROOF</strong></th>
<th>Digital color proof: 1. Kodak Approval (supplied)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>Cylinder-based proof</td>
</tr>
<tr>
<td>Note:</td>
<td>COA of the above</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>CYLINDER</strong></th>
<th>Notes on engraving:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>Electromechanical engraving</td>
</tr>
<tr>
<td>Brand:</td>
<td>Hell</td>
</tr>
<tr>
<td>Notes on engraved cylinders:</td>
<td>QA on engraved cylinders; Photomicrographs of cells at 5%, 50%, and 100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>PRESS</strong></th>
<th>Notes on press:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer:</td>
<td>Schiavi Patriot</td>
</tr>
<tr>
<td>Description:</td>
<td>8 units</td>
</tr>
<tr>
<td>Size:</td>
<td>Width: 1,320 mm, Cir: 700 mm</td>
</tr>
<tr>
<td>Doctor Blade</td>
<td>Notes on doctor blade: New doctor blade assembly for each of the two press runs</td>
</tr>
<tr>
<td>Manufacturer:</td>
<td>ROTOSTRAT</td>
</tr>
<tr>
<td>Brand:</td>
<td>Racal Stabile</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>INK</strong></th>
<th>Certificate of analysis on process and spot color inks on both ink batches, document in English using D50, 2 deg, 0/45 geometry, must be made available before the press run.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer:</td>
<td>BASF</td>
</tr>
<tr>
<td>Description:</td>
<td>Process colors and spot colors</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>SUBSTRATE</strong></th>
<th>Certificate of analysis (COA) on supplied substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brand:</td>
<td>ExxonMobil White Coated</td>
</tr>
<tr>
<td>Description:</td>
<td>Type 42 MH 648</td>
</tr>
<tr>
<td>Size:</td>
<td>1265 mm (OD 769/ Core 152)</td>
</tr>
<tr>
<td>Quantity:</td>
<td>30,000 meters</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>PRINTING</strong></th>
<th>Notes: Certificate of analysis (COA) on supplied substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhere to the printing direction</td>
<td></td>
</tr>
<tr>
<td>*Spot color spec. (CIEXYZ, D50, 2 deg.)***Tol.</td>
<td>Orange: 59 L*, 72 a*, 71 b*</td>
</tr>
<tr>
<td>(**Tol. ±0.10) C: 1.31</td>
<td>1 AE</td>
</tr>
<tr>
<td>**Tol. ±0.10) Y: 0.99</td>
<td></td>
</tr>
<tr>
<td>Dot gain:</td>
<td></td>
</tr>
<tr>
<td>K: 23.8</td>
<td>15.0</td>
</tr>
<tr>
<td>**Tol. ±3%)</td>
<td>9.8</td>
</tr>
<tr>
<td>(**Tol. ±%)</td>
<td>19.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>On-site Measurement</th>
<th>Zahn #2 and Frikmar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity</td>
<td>RIT will set up portable systems by the press site.</td>
</tr>
<tr>
<td>Color (density and CIEXYZ)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>SAMPLING</strong></th>
<th>1) Splice the printed roll every 20 minutes to allow on-site color measurement for process control.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2) Collect 30 press sheets at 1,000 meters (5 min.) intervals after color OK</td>
<td></td>
</tr>
<tr>
<td>3) Ship one set of samples (clearly labeled) to RIT from both press runs for analysis and documentation.</td>
<td></td>
</tr>
</tbody>
</table>