VIRTUAL PROOFING IN THE PACKAGING INDUSTRY

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Virtual Proofing in the Packaging Industry

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The purpose of this study is to measure the variation of opacity when overprinting spot colors on film during a typical flexographic press run and to determine how that variability affects the reliability of virtual proofing. This study addresses the packaging industry's current attitude toward virtual proofing and how the adoption of virtual proofing will affect a package printer. It also explains how virtual proofing works and the equipment and processes needed to implement a virtual proofing workflow.

This study explains the process of printing the test targets that were provided by Integrated Color Solutions and the data collected from the targets. The data from this study was supplied to ICS, to be analyzed for the improvement of Remote Director, the company's virtual proofing software.

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Chapter I: Introduction

Packaging is one of the largest print segments in the printing industry and it continues to grow each year. Even with the onset of the economic downturn, which began in 2007, the packaging industry managed to experience increased profit rates. A study conducted in 2009 concluded that, “Package printers reported an average profit as a percentage of sales of 5.03 percent…while the printing industry as a whole saw profits drop from 3.0 percent to 1.5 percent of sales” (Davis 15). Even while the economy was plummeting, the packaging industry managed to keep growing, whereas the rest of the printing industry experienced declining profits. With the problems caused by the downturn in the economy, the printing industry has become increasingly more competitive. In order to remain in business, package printers need to adapt to new technology. One method of expansion is the implementation of virtual proofing.

Traditional proofing refers to the practice of reviewing a printed physical sample of the product to ensure the accuracy of its color before it is sent to production. In doing this, a printer and client are given the chance to grant or deny approval for the final press run. This is an important step because companies pay anywhere from $20 to $200 for inkjet proofs to ensure that their corporate logos and colors are displayed accurately and uniformly across various substrates and media (Hershey 12).

One technology that can help these printers depict these colors accurately on screen is virtual proofing software. “[Virtual] proofing simply refers to the review of a potential print project on a computer monitor instead of on a physical substrate” (Shaffer 40). Virtual proofing is a useful technique because it allows for changes to be made immediately. It is also a less expensive option because the cost of getting a press ready with the correct inks and substrates is substantial, especially when only a handful of samples will be printed and viewed. Once the

inkjet proofs have been printed and approved, they must be archived and stored in a warehouse in case the client comes back with a discrepancy or would like a reprint. Another benefit with virtual proofing is eliminating the time spent shipping proofs. Virtual proofs can be sent instantly and reviewed and approved instantly; time compression is critical here. If press proofs were eliminated from the production workflow, the area used to store these files could be more efficiently used to store current client work or new machinery.

Historically, package printers have been hesitant to employ virtual proofs because they worry that the color on screen will not be comparable to the color coming off the press. But, by using virtual proofing, package printers will have a much more reliable way to review their products and ensure the accuracy of their color. This is particularly important in the packaging industry where an organization is often recognized and defined by their corporate colors, such as Coca-Cola, Raisin Bran cereal, or Tide detergent. These companies use spot colors, rather than process colors, as a crucial and identifiable part of their brand image.

However, virtual proofing is not perfect and does come with a few challenges. Printed pieces absorb and reflect light; in comparison, computer monitors transmit light. Therefore, the colors on the screen would be seen differently than the colors of the final version (Klimchuk). Currently, few press operators are trained on how to view a screen and determine whether those color results will be similar to what is printed. In addition, the equipment to accurately view these images is not yet found in a pressroom. In fact, the technology for these screens is still in development.

This study helps attain accurate spot color readings for the improvement of Integrated Color Solutions' (ICS) virtual proofing software. In doing so, package printers will be more inclined to use virtual proofing. ICS is an organization that develops, "the most complete suite of

color management products on the market. ICS develops innovative products and solutions that allow companies to efficiently create, visualize and consistently produce ‘Precise Color’” (About Us).

Traditional proofs have proven to be extremely accurate, but as technologies advance, the opportunity for virtual proofing becomes more and more realistic. This test will determine whether the measured variability in the overprints will significantly alter the virtual proofs ability to show accurate color. Switching to virtual proofs would be an excellent decision for package printers because it would save them money, time, and materials, while allowing them to make instant changes to color and placement when necessary. Although retraining and new equipment would be necessary and expensive, the savings on print materials and storage space would outweigh these initial costs.

The purpose of this study is to measure the variation of opacity when overprinting spot colors on film during a typical flexographic press run and to determine how that variability affects the reliability of virtual proofing. An experiment was conducted in which spot colors were printed on a polypropylene substrate and the inks’ opacity was measured using an Xrite 361T Tabletop Transmission Densitometer. These measurements were delivered to ICS, so that the organization may develop their color modeling software more accurately.

Chapter II: Literature Review

The implementation of virtual proofing can provide numerous benefits to package printers that are looking for ways to increase profit. Finding a way to decrease the number of hard copy proofs that must be produced and sent to different locations for approval can yield savings on shipping costs, generate faster customer signoffs, as well as reduce the amount of materials and power used (Hershey 12). Larry Moore, the Applications Support Manager for EskoArtwork, states that the, "Shipping and consumable costs of $20 to $200 might not seem too expensive, but when you consider the need to deliver three or four iterations per project, the costs can add up quickly over a year's worth of projects for a given customer" (Hershey 12). Switching from inkjet proofs to virtual proofs would eliminate these costs and expedite the process of approval and production.

Savings gained from switching to virtual proofing also depend on the size of the company and its production level. A company with locations along the East and West Coasts that needs approved proofs sent back and forth will incur larger savings than a printer who produces local products (Cleaveland 28). Because of this, larger printing firms have primarily adopted the method of virtual proofing. Joseph Marin, Senior Analyst of Digital Technologies at Printing Industries of America, says, "Over the past year, however, it [has] started to trickle down to your midsize commercial printers. They [are] adopting the technology because the prices have come down on the software" (Cleaveland 26). Marin then discusses the costs associated with implementing a virtual proofing workflow.

Although virtual proofing can potentially cut costs and improve efficiency, certain conditions must be met in order to have an accurate virtual proofing system. A monitor with a suitable color gamut, proper monitor calibration, and color profiles, color definition and suitable

lighting are all necessities when using a virtual proofing workflow (Hershey 13). Bertin Sorgenfrey, Head of International Marketing for Dalim Software, says, “Clients who take color seriously make sure that every room has the correct lighting conditions, light gray carpets and [gray] paint on the walls to prevent reflection, foil for windows to block out UV light, and regular [monitor] calibration” (Hershey 13). Other conditions must be met when executing virtual proofing for products that use spot colors. Dan Caldwell, President of Integrated Color Solutions notes that proofing systems must use color kitchens to blend inks in order to create accurate proofs that display more than just process colors. If all of these conditions are met, incredibly accurate proofs will be produced. Caldwell explains:

> ICS Remote Director can dynamically switch selected colors and print conditions to show a client its package printed in 4-color or 6-color; offset, gravure, or flexo; #3 sheet versus a #1 sheet. The proof can be cloned to provide side-by-side comparisons of these variables, taking the guesswork out of the quality versus cost decisions. (Hershey 14)

Virtual proofing provides benefits and ways of enhancing the proofing process, but many companies are reluctant to make the transition because they are comfortable with their current workflow, or apprehensive. One organization that has made the switch to virtual proofing is the University of Missouri-Columbia (Wise).

The virtual proofing method can vary for each company, here Rick Wise, Director of Printing Services at the University of Missouri-Columbia, explains the process that his clients go through when virtual proofing. He prefers that his customers use a virtual proofing method during the design stage, in the form of a portable document format (PDF). First, a PDF of the work is created by the prepress department, which is then emailed internally to the customer service representative (CSR) working on the job for pre-approval. From there, the PDF of the

work and an electronic proof sheet are sent to the client for their approval. Using PDF files saves the client money because the University of Missouri-Columbia charges $21 per page for their lowest resolution proof; on a document with multiple pages, these costs can accumulate quickly, even more so for a higher resolution or color version of the proof. The client then returns the proof electronically to their CSR either with approval for print or with correction annotations that they have made using Adobe Acrobat Reader. Along with the file, the client sends the electronic proof sheet, which is then treated like a contract proof. In packaging, this would also be beneficial for print jobs that require an ink drawdown, which is actually used to match brand colors on press. (Wise).

In other cases, the client will print the PDF with a desktop printer and mark any necessary changes and fax it back to the university. If the customer does not have design experience, which is usually the case, the graphics department at the university is able to talk with clients individually and solve any issues that are present. This is the least favorable method for corrections, because it is done over the phone and relies heavily on wordy explanations to achieve the desired results. In this case, the client, after receiving and viewing the PDF, calls their CSR and explains over the phone the problems that they see. This is especially difficult because it can easily lead to misinterpretation and there is no signature approving or denying the changes (Wise).

The University of Missouri-Columbia does not recommend virtual proofs for the final stages of a high quality four-color process proof because setting up the calibration of a client's monitor to match the calibration of the monitor in the prepress department is a difficult task. Proper and accurate calibration requires an expensive monitor, calibration software and recalibrating the equipment depending on the equipment. In addition, having a physical example

of what the final product looks like allows press operators to know exactly what their results should be, especially when it comes to getting the color correct (Wise).

However, the university highly recommends virtual proofing for work that includes spot colors, as in the packaging industry. Because spot colors are consistent and do not change depending on the press and inks, they are an excellent candidate for this process. If a job includes just black and a spot color, the color reproduction is less important than the placement and content, both of which are easily viewed from a virtual proof (Wise) In the packaging industry, this would also be true for an approved ink drawdown that is used for matching brand color on press.

If a client is unconcerned with reaching an exact color reproduction, virtual proofing is a good option. This usually indicates that a client is more concerned with content and layout, and trusts the judgment of the university to produce “pleasing color.” Because there is less time spent going between client and university, the printers are able to get the job done more quickly (Wise).

In sum, Rick Wise states that virtual proofing is an important aspect of their design process and, “[virtual] proofing saves our customers money and cuts hours and sometimes even days off the design stage of the production process” (Wise).

One of the most essential steps in virtual proofing is the calibration process. Without proper calibration, the results may vary across a wide range. Accurate calibration starts with the monitor. Here an explanation of the pros and cons of various types of monitors, including cathode ray tube, liquid crystal display, plasma, and gas plasma are discussed (Q&A).

There is an ongoing quality debate between cathode ray tube (CRT) monitors and the newer liquid crystal displays (LCD). Each comes with a series of positives and negatives that must be weighed against each other to determine the best option (Q&A).

Invented in 1897 by Karl Ferdinand Braun, cathode ray tubes display color by beaming an electron stream through a shadow mask onto a screen with red, blue and green phosphorous dots; as the beam hits the phosphorous dots, it causes them to glow, creating an image.

Liquid crystal displays have a grid of liquid crystals, which act “like shutters and allow varying amounts of light to pass through them and on to red, green or blue colored filters” (Q&A). A fluorescent or light-emitting diode supplies the light that passes through the shutters; the current applied to that part of the grid determines how much the shutter will open – a white pixel has an open shutter, a black pixel has a closed shutter (Steele).

Cathode ray tubes are superior in that they are cheaper than liquid crystal displays; however, as LCD technology improves, the cost of LCD screens is likely to come down. CRTs also have a faster response time, making them better for “displaying fast-action games and movies,” because they lack the “comet tails” that result from “rapidly moving objects” across an LCD screen (Q&A).

However, CRT technology comes up short in a variety of ways. CRTs use nearly twice as much power to run, and therefore more heat is generated (Q&A). CRTs also create a strong electrical or magnetic field that has the ability to negatively affect and interfere with nearby equipment. In fact, CRTs can create radiation because of the high radio frequency interference required to run them. Another downside, cathode ray tube screens refresh themselves 72 times per second, which creates a flickering effect that can affect viewing quality (Q&A).

The quality of LCD screens is measured by their “native resolution”: the precise, fine grid of holes filled with liquid crystals. When the screen resolution matches the native resolution, the image will be depicted very clearly; CRT displays are not as crisp and can have obvious distortion and blurring. At the same time, images on CRT screens can be shown at any resolution without significant loss of sharpness. A richer and wider spectrum of colors allows for images on a CRT to be displayed better. LCD screens have trouble generating true blacks and dark grays, which means that images are displayed with less contrast. Liquid crystal displays have to use dithering to offset the pour quality. Dithering is the process of displaying or printing an image without sharp edges so that there appear to be more colors in it than are really available. Although LCD produces pleasing colors, the images are inaccurate and should not be used when color correcting or for image editing (Q&A).

LCDs are advantageous because they are much smaller, thinner and lighter than CRTs, so they can easily be transported and used in the office or on the road. One of the biggest former drawbacks to LCDs, was the viewing-angle restriction: multiple people could not accurately view the same image from different positions; this was particularly problematic for prepress departments, in which multiple people view and approve an image on the same screen, at the same time. As technology advanced, this problem has diminished. Dead pixels are another issue for LCD screens. A dead pixel is one that is stuck as white, black, or colored; “Some are dead on arrival; some appear during use” (Q&A). Luckily, rubbing these spots with a soft cloth can revitalize these dead pixels. Industry standards allow up to seven dead pixels on a 1600x1200 dpi screen. Although not life threatening, dead pixels can be particularly annoying and problematic, depending on their location (Q&A).

CRT displays are more difficult to recycle than LCD, because they contain large amounts metals and other hazardous materials, which must be separated before the recycling process. In fact, many states are charging disposal fees to cover the cost of recycling (Steele). LCDs are more environmentally friendly because their thinner size requires fewer materials and they last longer. CRTs last approximately 20,000 hours without the chance of repair, whereas LCDs can last up to ten years, assuming the backlights are replaced when necessary – backlights last approximately 50,000 hours (Steele).

CRT and LCD screens required a warming period in order to ensure they reach a stable state in which color images are accurately displayed. Once they have reached their own optimal levels, LCD monitors still outshine their competition with brightness levels of 500 nits compared to 200 nits on a cathode ray tube monitor. A nit is a unit of measure based on the candela that measures luminous intensity (Q&A).

One of the biggest drawbacks of a CRT monitor is that it relies on analog technologies that must be maintained more often than the highly stable LCD screen. Analog is a rapidly diminishing practice as the world becomes more and more digitized (Q&A).

Beyond the CRT and LCD debate, there is question of the benefits of and differences between plasma screens and liquid crystal displays. Found most often in television screens, plasma technology creates an image by using a plasma discharge to excite phosphors between two glass panels. Negatively, images that are displayed on a plasma screen for a long period of time have the potential to be “burned” into the screen. But, plasma displays do exceed LCDs in terms of contrast, size capabilities and speed (Steele).

Beyond traditional plasma screens, a new gas plasma monitor is emerging in the market. Gas plasma screens are incredibly expensive. In 1996 a screen cost $20,000; by late 1998, it

dropped to below $10,000; and by 1999 is slipped to below $5,000 (Hill). The price continues to plummet and the resolution soars as the technology improves. Gas plasma screens are similar to CRTs in that they illuminate phosphor, however the curved CRT surface is now replaced with a slimmer flat screen. Gas plasma uses a matrix of glass bubbles, "every glass bubble within the matrix is filled with neon and xenon gases and surrounded by a phosphorescent coating" (Hill). As electricity runs through the matrix, the gases create ultraviolet rays than glow and make an image. The image is unique in that it has more depth, texture and warmth than typical monitors.

Gas plasma screens are very thin, usually only four inches deep, which makes them easy to place on a wall. Additionally, they have spectacular viewing angles. Most CRTs have a 120-degree viewing angle – meaning that the image will remain undistorted 60 degrees from the center. LCDs have to be viewed from straight on. Gas plasmas have a viewing angle, without distortion, of 160 degrees (Hill). They are also able to display rich, color-saturated images like "landscapes… close-ups of flowers, birds, [and] charts" which is useful in the printing industry (Hill).

Gas plasmas are rich with contrast and color saturation, but tend to be less bright than their counterparts. Despite this drawback, in a 1999 study it was noted that gas plasma screens have a long lifespan, however it received an estimated half-life of only 30,000 hours (Hill).

Choosing the right monitor is an important step in making the switch to virtual proofing. The size of the screen, the amount of space it will take up, the cost, the image resolution, and the accuracy of color are all things that must be accounted for when deciding on a monitor. Once a person has chosen the right monitor for him or herself, the process of calibration occurs (Q&A).

Calibration is the process of altering a screen's settings to, "ensure that [one's] editing decisions are based on the right information" (Story). Calibration can be quite straightforward; it

is simply the act of altering the brightness, contrast and tint of one's screen. Some operating systems, such as Mac OS X, offer basic tools to calibrate. Another option is a device known as a colorimeter. The tools of OS X are great for a casual color corrector, but production companies should use colorimeter devices (Story).

The settings within an operating system are changed manually and therefore can be skewed. Colorimeters are more accurate because, unlike the control settings in the OS X system, colorimeters do not rely on human perception of color and therefore eliminate the subjectivity of the other process. Instead colorimeters take, "precise light measurements directly off [one's] monitor and feeds them into dedicated software that creates the profile" automatically (Story). The profile takes approximately half an hour to create based on the colorimeter's readings (Story).

Calibration should only be done after the screen has had time to warm up, approximately one hour after turning it on, to ensure that the colors will be displayed accurately. Ambient light during calibration should be similar to the light conditions during working hours (Story).

Recalibration should occur often, at least once a month, to ensure that the monitor is accurately displaying what it should. As time goes by, monitors go thorough subtle color shifts that may change one's original calibration; at which point, the process should be done again. In the virtual proofing world, where color may be crucial, the act of recalibrating should be done more often, from every week to every day. Once calibration is complete, a color profile must also be implemented for accurate virtual proofing (Story).

A color profile is the range of colors that a reproduction system, such as a monitor or a printer, can display from the entire range of possible colors (Gibbs 40). Ken Elsman, of Global Graphics Software, notes that in order for virtual proofing to be successful, "There has to be a

relationship between the designer, the people developing the work, and the printer so that everyone involved agrees on paper and standard ink sets, and all of the components that affect color. Everyone has to agree to one profile, and stick with it" (Core 33).

The International Color Consortium (ICC) developed the industry standard color profile format. When managing color, software applications including: Adobe Photoshop, Illustrator, InDesign, and QuarkXPress save color files with embedded ICC color profiles and read ICC profiles when they open a color file. These applications support color management to ensure consistency in color as the files move between applications and various proofing and printing devices (Lawler 60).

Commercial printing companies usually have color profiles that define the color space their printing presses can print from. These profiles can be provided upon request and it is advisable to create documents using color profiles to guarantee consistent color during the virtual proofing stage of production (Lawler 62). Some printers may prefer documents that only use cyan, magenta, yellow and black (CMYK) color. If that is the case, CMYK press profiles should be obtained from the printer for consistent color. If the printer cannot send the profile, it may be necessary to ask what type of profile is recommended. The Adobe Creative Suite ships with predefined CMYK profiles that may provide a close representation to the printer's color space (Lawler 62). Matching the printers profile to that of the monitor will help to ensure accurate color is displayed on screen during the virtual proofing process. Color profiles used in the design stage should be set to match the color gamut of the output device so as to eliminate, or reduce, the chance of surprises on the press (Lawler 62). Often times the color available for display on the monitor does not match what can be done on a press. In this case, out-of-gamut colors can be

displayed using a program, like CHROMiX's ColorThink Pro, to indicate to a customer what will and will not be possible on press.

Color proofing should be done based on the LAB Color model. LAB Color independently caries color and tonality on three separate channels: luminance (L) and color (A and B). Any changes to contrast on the L channel, will not affect the color channels. Unlike RGB or CMYK color systems, LAB is designed to approximate human vision. The LAB Color space is both mathematically efficient and perceptually uniform (Drury).

Chapter III: Research Methods and Procedures

The purpose of this study is to measure the variation of opacity when overprinting spot colors on film during a typical flexographic press run and to determine how that variability affects the reliability of virtual proofing. The data from this study was supplied to ICS, in order for them to improve their virtual proofing software. In doing so, package printers will be more inclined to use virtual proofing. The Scientific Method and Elite and Specialized Interviewing were used to gather and analyze data in this study.

The Scientific Method was used to conduct the research for this study. The Scientific Method is one of the most well known research methods today. It involves using five steps to reach a solution, one must: (1) identify and define a problem, (2) formulate a hypothesis, (3) collect, organize and analyze data, (4) formulate conclusions, (5) repeat, verify and modify the research. The verification step is the most crucial to this method, "the repeatability and verification of research is only achievable when variables are completely controllable by the researcher" (Levenson 19).

The lack of reliable and accurate data for spot colors in the world of virtual proofing is a current problem for package printers. Because of this, many package printers, who use spot colors often, have not made the switch to virtual proofing. It is assumed that improving the virtual proofing software to include spot colors will increase the number of package printers who use this type of software.

The research portion of this project began by acquiring a test target developed by ICS that measured six inches in width and eleven and three fourths inches in height (*Appendix A*). These test targets were comprised of patches of spot colors including: Pantone Goe Medium Yellow C, Pantone Goe Bright Red C and Pantone Goe Dark Blue C, which were printed over

opaque white ink. Though the hue was not of significance for the test results to be valid, ICS only wanted high chroma colors, so as to print a simulation of a four-color process. These targets had patches of color consisting of various halftone dot frequencies arranged as a ramp that increased in increments of ten percent, from zero to 100 percent. The test target also had patches of the spot colors printed over each other on top of white color patches. Three patches were measured to collect data: white (one color), blue over white (two colors), and red and yellow over white, or orange (three colors). (*Appendix A)*

A total of eleven inks were needed: three spot colors, opaque white and black. Each of the three spot colors had three opacities: low opacity, mid opacity, and high opacity. The low opacity inks had normal Pantone ink with a 5 percent extender added to reduce opacity and decrease color strength. The mid opacity inks received no change. The high opacity inks had normal Pantone ink with a 5 percent addition of opaque white to increase opacity. The inks pH and viscosity were measured before going on to press, the goal was to have a pH of approximately 9 and a viscosity reading of approximately 25 seconds with a #2 Zahn cup. The pH for each ink was within the correct range of 9; however, the viscosity was well above the target of 25 seconds. As a result, the researchers altered the low-opacity inks by adding water, thus reducing the viscosity to fit the parameters; however, this caused a wetting problem so the researchers decided to use the unaltered ink straight from the bottle.

These ink lay-downs were printed on a transparent plastic film. The plastic material used was a polypropylene substrate from Multi-Plastics Inc., used for narrow web. The film was a 5000 clear polypropylene of two mil gauge or 0.0127mm in thickness. The opaque white ink was printed on the transparent plastic before the spot colors to ensure a proper color reading from the

transmission densitometer. After white had been lain down, the print sequence was yellow, red, blue and black.

Five different anilox rolls were used as is depicted in the chart below:

Color	#	Line Screen (in lines per inch)	Volume (in billions of cubic microns)
White	4	800	1.99
Yellow	14	800	1.65
Red	3	800	1.62
Blue	2	800	1.95
Black	7	360	6.95

Table 1 – Anilox rolls

For each of the nine targets that were printed, 200 sheets were printed with five sheets pulled for measurement from the beginning, middle and end of the run. Sample data was collected and the mean measurement was used to record the final measurement to be sent to ICS. An X-rite transmission densitometer was used to measure opacity.

The ink lay-downs were printed on the Mark Andy 2200 flexographic press; a narrow web press, with a seven-inch diameter. The Mark Andy press features eight units, with a drying unit between each one. Because the researchers printed on a film substrate, a flexographic printing process was determined to be ideal. The Mark Andy was chosen because it has a drying unit that uses forced air between each printing unit, which helped ensure that the ink adhered to the plastic film.

The plate material used for the testing is a DuPont™ Packaging Graphics Cyrel® DFQ (digital fast durometer) plate material. The exposures were: a plate back exposure of 61 seconds,

then the plate material was imaged on a CDI Spark (Cyrel® Digital Imager), followed by a main exposure of eight minutes, and processed by Dupont™ Cyrel® Fast 1000 EC/LF processor. After processing, a post exposure for four minutes and a tack exposure of three minutes completed the curing of the plate. The plates had a line screen of 150 lines per inch.

The press operators looked for contrast between highlight and shadow areas, targeting a midtone dot of 67 percent; once this level was achieved, all pressures and settings were left unmodified. The low opacity inks were printed first, followed by the mid opacity inks, and finally the high opacity inks.

Once all of the data had been collected, the researchers determined whether the results could be used to develop the software for ICS. Further tests with more colors, more substrates or overprints would help improve the software as well and are an opportunity for further testing.

According to Dr. Harvey Levenson, Graphic Communication Department Chair at Cal Poly San Luis Obispo, Elite and Specialized interviewing is a research method that focuses on obtaining high quality information from professionals and executives. The process was developed by Lewis A. Dexter, who believed that people who see themselves as important individuals require a different approach than the “average person” when conducting an interview. An Elite and Specialized interview differs from a standard interview in that a set of questions should not be developed because it may limit the amount and quality of information that the interviewee provides. During an Elite and Specialized interview, questions should be formulated so that they are precise and open-ended (Levenson 22).

An interview with Dan Caldwell, President of Integrated Color Solutions, was conducted for this research. The researchers asked questions about the specifics of the color testing experiment along with general questions about virtual proofing in the printing industry. The

researchers also asked questions about what makes many package printers hesitant to switch to a virtual proofing workflow and what it would take to convince package printers that virtual proofing would benefit their businesses. Further questions were asked concerning any issues that ICS had come across while developing and testing the software. The researchers asked additional questions, such as: Where do you see this technology going in the future? Do you think press proofs will ever be eliminated from the production process completely?

Chapter IV: Results

The researchers conducted the experiment as defined in Chapter Three with a few slight modifications. As was defined, viscosity, pH, anilox, and impression were controlled, whereas density, spectral data, and dot area were left alone.

The inks pH and viscosity were measured before going on to press. The pH for each ink was within the correct range of 9. However the viscosity was well above the target of 25 seconds in a #2 Zahn cup. As a result, the researchers altered the low-opacity inks by adding water, thus reducing the viscosity to fit the parameters.

When the low-opacity inks were put into the press, they created a wetting problem. Wetting issues are caused because the surface energy of the substrate is too high and the ink is not able to lay flat upon the surface. It tends to bead up, making it difficult to dry.

The researchers decided that proper wetting was more important than the ink viscosity, so the ink stations were refilled with ink, straight from the jug. When the press began again, the wetting issue had disappeared and a good impression was made.

The viscosity measurements for the inks were as follows:

Ink	Viscosity (s)	pH
White	43.28	9.03
Black	50.95	10.15
Low Yellow	56.42	9.84
Low Red	49.85	9.44
Low Blue	60.64	9.45
Med Yellow	115.65	9.69
Med Red	48.31	9.60
Med Blue	81.38	9.25
High Yellow	112.2	9.70
High Red	56.59	9.69
High Blue	64.34	9.44

Table 2 – Viscosity of Inks

As is the case with all print runs, impression is a variable without very much control. As was outlined in the set-up, once impression was set and found to be adequate, it was left alone for the rest of the run. However, impression did need to be tweaked because a second substrate was tested at the same time as the polypropylene. Subsequently, impression varied slightly throughout the course of the press runs. Based on a visual analysis, the impression did improve throughout the press run; the high opacity inks had a better impression than the low opacity inks.

The researchers conducted an elite and specialized interview with Dan Caldwell, President of Integrated Color Solutions.

When asked, “Where do you see this technology [virtual proofing] going in the future?” Caldwell explained that he predicted virtual proofs would replace press proofs in two years, six years ago. Although his prediction has not come true yet, Caldwell expressed his belief that press proofs would eventually be eliminated completely. He stated that virtual proofs have surpassed press proofs, and have become a better alternative.

The researchers then asked, “Is there hesitation in the industry to initiate virtual proofs?” Caldwell stated that the industry is hesitant because virtual proofs need to be viewed in the right setting and require an investment in calibrated equipment. He said that there are objections to virtual proofing because it is “not paper,” and requires a paradigm shift from the usual workflow. The end users are cautious to make the investment, even though it would eventually save money for them and their customers.

When asked, “What needs to be in control during print in order for soft proofs to be valid or accurate?” Caldwell responded by saying that opacity is the most crucial factor that will be used to develop ICS’s spectral prediction model. The linearity from 0 to solid will be analyzed to predict how colors will blend.

The final question, “What are some of the challenges to virtual proofing with white ink?” He answered by saying that they assumed printing spot colors over white ink was the same as printing them directly on paper. He stated that the results were promising but not precise.

Chapter V: Conclusions

The purpose of this study is to measure the variation of opacity when overprinting spot colors on film during a typical flexographic press run and to determine how that variability affects the reliability of virtual proofing. The data shows that the ink's opacity is not in control for this pressrun, therefore, the virtual proofs cannot be considered a reliable way to proof spot colors, where opacity is such a critical variable. (*Appendix D*)

In order to determine whether or not the process was valid, a series of control charts were drawn based on the data that was collected after the print run. Control charts show variation in a process over time and can help identify whether the variation is due to common cause – changes that are due to chance – or special cause – changes that are unnatural and can be assigned to a cause.

Due to the small data size, an individuals control chart (I-chart) was used because it displays individual data points, as opposed to the averages used in other control charts.

To build a control chart, the first step is selecting an attribute to monitor, in this case, opacity over the print run. Data is collected. A centerline is calculated by determining the average of the data. The Upper Control Limit (UCL) and Lower Control Limit (LCL) are calculated to be three standard deviations away from the centerline. Data that falls between the UCL and LCL is considered to be in control. Seven charts were built based on the ink color and opacities: low-opacity blue, medium-opacity blue, high-opacity blue, low-opacity orange, medium-opacity orange, high-opacity orange, and white.

Generally, when analyzing a control chart, one should look to see that: no points are outside the control limits; the number of points above and below the center line are approximately equal; the points fall randomly above and below the center line; most points, but

not all, are near the centerline and only a few are close to the control limits. With these parameters, the researchers analyzed the control charts.

Of the seven charts, all seven of them were considered to be out of control. The white, medium-opacity blue, high-opacity blue, low-opacity orange, medium-opacity orange and high-opacity orange all had data points outside the control limits. The following chart indicates the number of points that fall outside the control limits:

Ink Color	# of Dots above UCL	# of Dots below LCL	Total Beyond Control Limits
Blue MO	2	1	**3**
Blue HO	0	3	**3**
Orange LO	6	5	**11**
Orange MO	1	0	**1**
Orange HO	5	0	**5**
White	1	8	**9**

Table 3 – Data Points Beyond the Control Limits

Within each of the charts there were other problems that would make the data out of control. Each chart had several points in a row; there was very little variability above and below the centerline.

With the exception of the high-opacity orange chart, all of the other charts indicate a general upward trend, with the points at the end of the pressrun higher than those at the start of the pressrun. This is also an indicator of a process being out of control.

Low-opacity blue was the only chart with all data points between the control limits, however it had several data points in a row with the same value, thus making it out of control as well.

Because each of the charts had one or more indicator of an out of control process, the overall process was determined to be out of control; thus making the virtual proofs an unreliable way to proof color at this point in time.

During an interview with Dan Caldwell, President of ICS, he confessed that he predicted virtual proofs would eliminate press proofs in two years, six years ago. With any new technology, there is an introductory term during which the industry slowly becomes more accepting to the new alternative as the glitches are being solved. When industry members do accept the new technology, an investment in high quality monitors and calibration systems must be made as well. And Caldwell does see this change occurring soon. The hesitation within the packaging industry to initiate virtual proofs stems from the radical paradigm shift. Most of the objections to virtual proofing come from the fact that it is "not paper." Caldwell further explained that printers do not want to switch because their customers are not asking for it; however, customers complain that their printers are not offering virtual proofs as part of their services.

Caldwell also revealed that opacity is the most important variable considered when Integrated Color Solutions develops the algorithms for their spectral prediction model—which is used by the Remote Director software to create a virtual proof. The test results from the printed spot color targets show that opacity does tend to vary slightly throughout a print run. This can affect the reliability of the virtual proof because some prints will look slightly different than others. Imaging opaque white on a screen and displaying overprinted spot colors on top of the opaque white also presents additional challenges. Although the data indicates that the process is out of control and unreliable, ICS can still use the information. The software that ICS develops will have to predict this variation and display the most accurate rendition of what can be

expected to print. It will have to calculate the expected average opacity for every element in the file and render it on screen.

With so many variables associated with virtual proofs, it is safe to say that press proofs still have quite some time before they become completely obsolete.

Appendix A: ICS Test Target

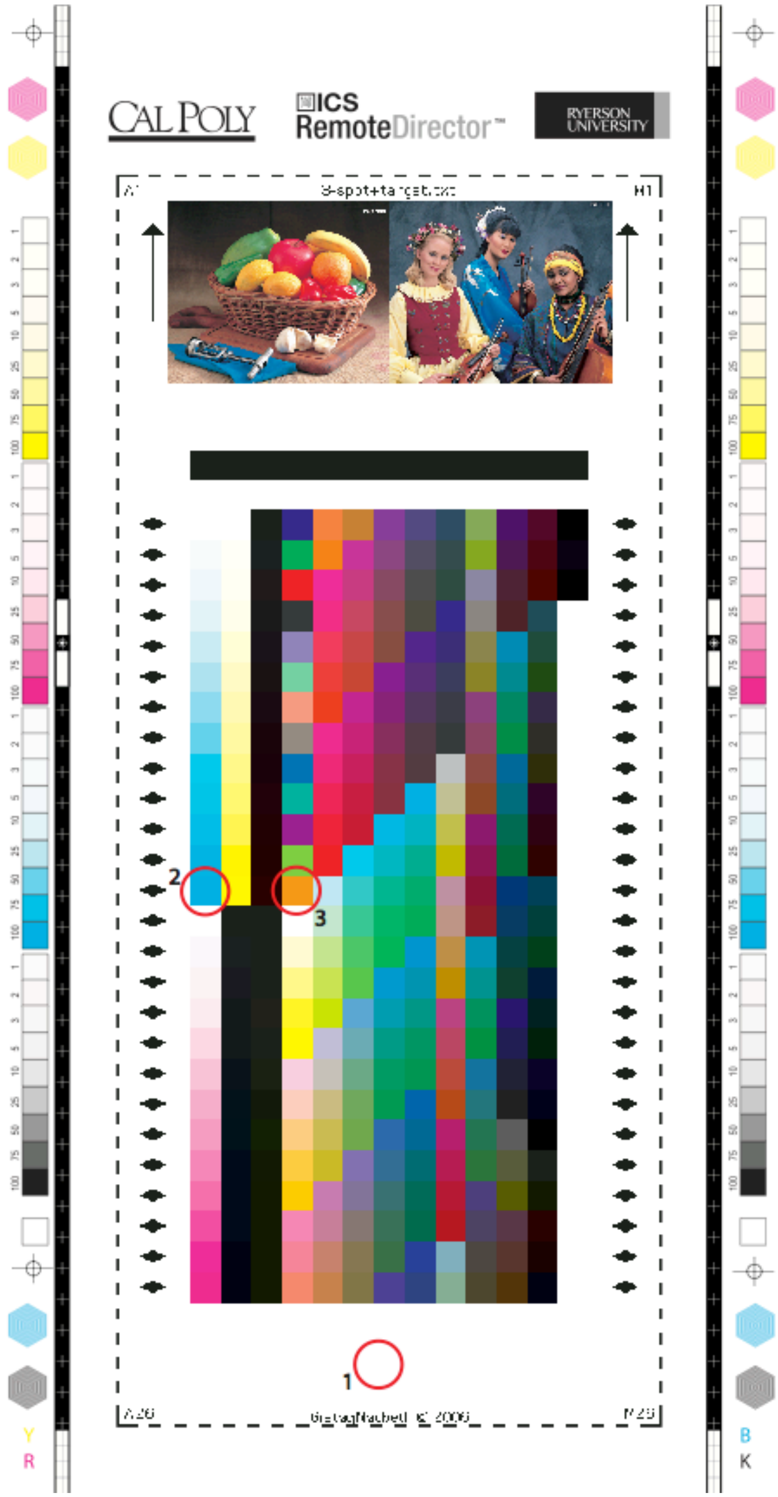

Figure 1 – ICS Test Target

Appendix B: Opacity Charts

Low Opacity Inks

	Sample	White	Blue	Orange
Beginning	1	.18	.72	.71
	2	.18	.73	.71
	3	.17	.73	.71
	4	.18	.73	.71
	5	.18	.73	.71
Middle	1	.19	.72	.73
	2	.18	.72	.72
	3	.19	.72	.72
	4	.18	.73	.72
	5	.18	.74	.72
End	1	.19	.72	.73
	2	.19	.73	.73
	3	.19	.73	.73
	4	.19	.72	.73
	5	.19	.73	.73

Table 4 – Low-Opacity Ink Data

Medium Opacity Inks

	Sample	White	Blue	Orange
	1	.19	.77	.71
	2	.19	.76	.71
Beginning	3	.19	.74	.71
	4	.19	.76	.71
	5	.19	.76	.71
	1	.19	.78	.72
	2	.19	.78	.72
Middle	3	.19	.76	.71
	4	.19	.76	.72
	5	.19	.76	.72
	1	.19	.80	.72
	2	.19	.80	.72
End	3	.19	.80	.72
	4	.19	.81	.73
	5	.19	.82	.72

Table 5 – Medium-Opacity Ink Data

High Opacity Inks

	Sample	White	Blue	Orange
	1	.19	.77	.71
	2	.19	.77	.71
Beginning	3	.19	.76	.71
	4	.19	.75	.71
	5	.19	.76	.71
	1	.19	.80	.73
	2	.19	.80	.73
Middle	3	.19	.80	.73
	4	.19	.80	.73
	5	.19	.78	.73
	1	.19	.79	.72
	2	.19	.81	.72
End	3	.19	.81	.71
	4	.19	.80	.71
	5	.19	.81	.72

Table 6 – High-Opacity Ink Data

Appendix C: Control Charts

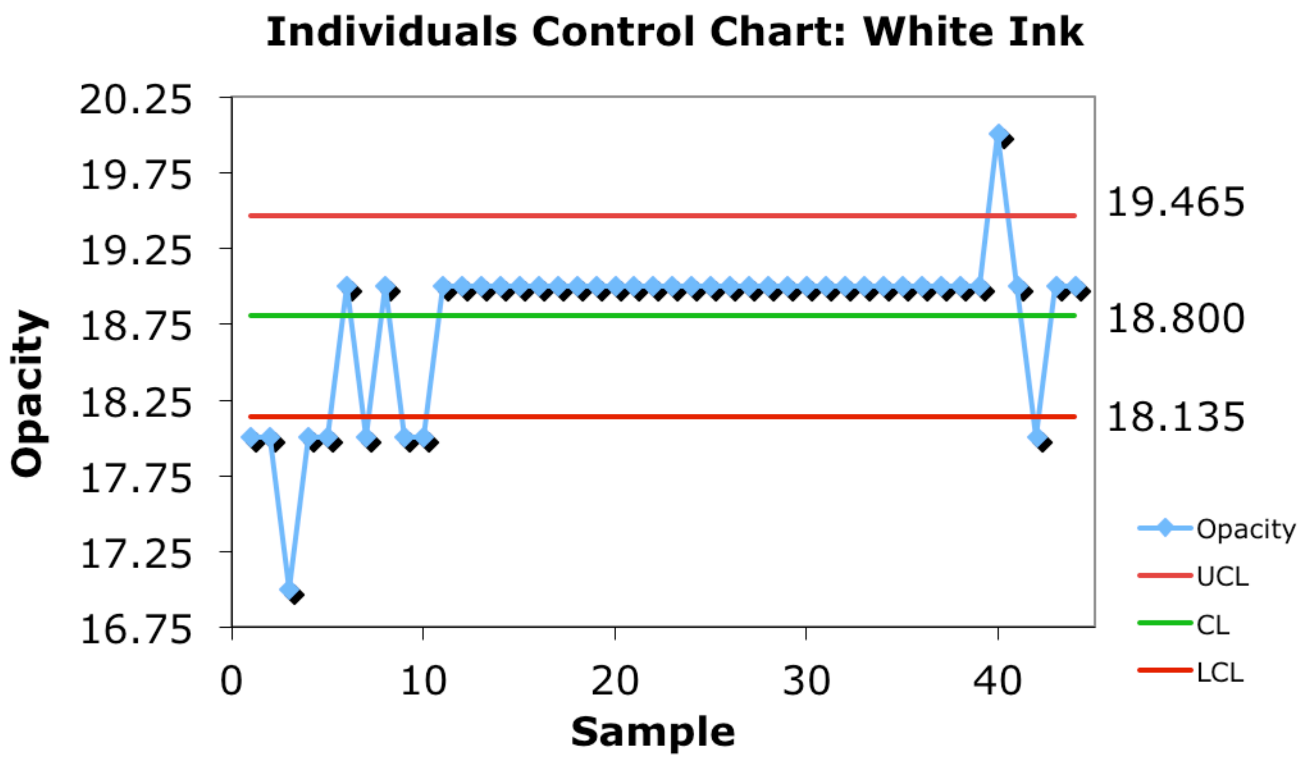

Figure 2 – Individuals Control Chart: White Ink

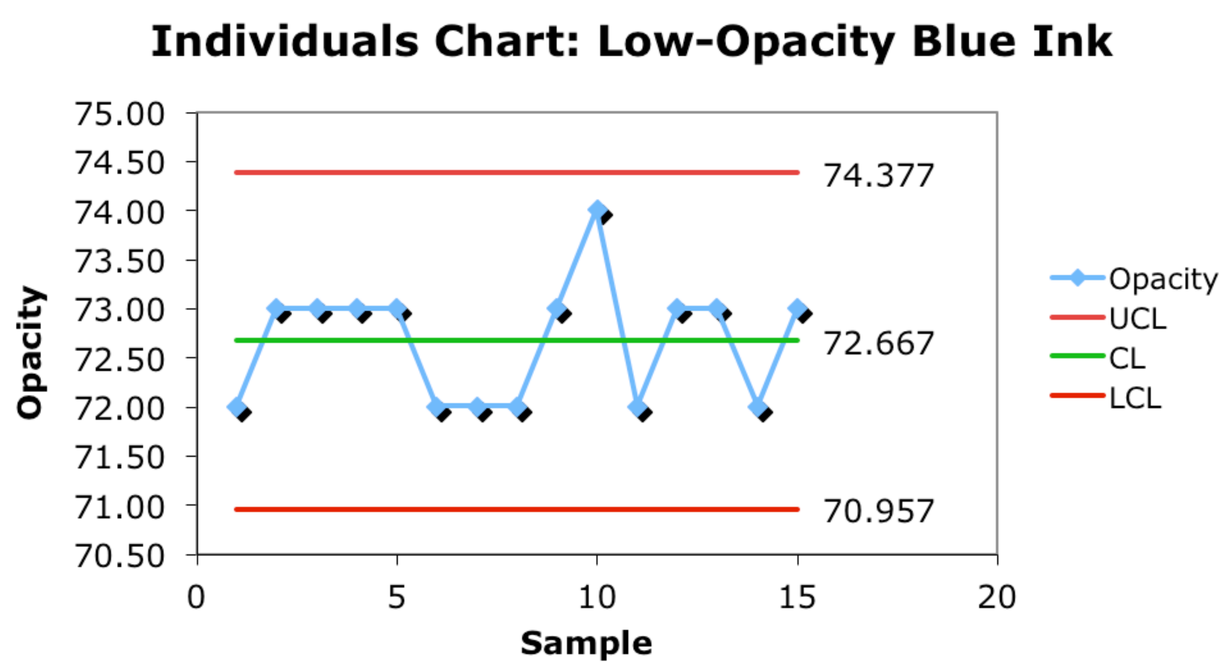

Figure 3 – Individuals Control Chart: Low-Opacity Blue Ink

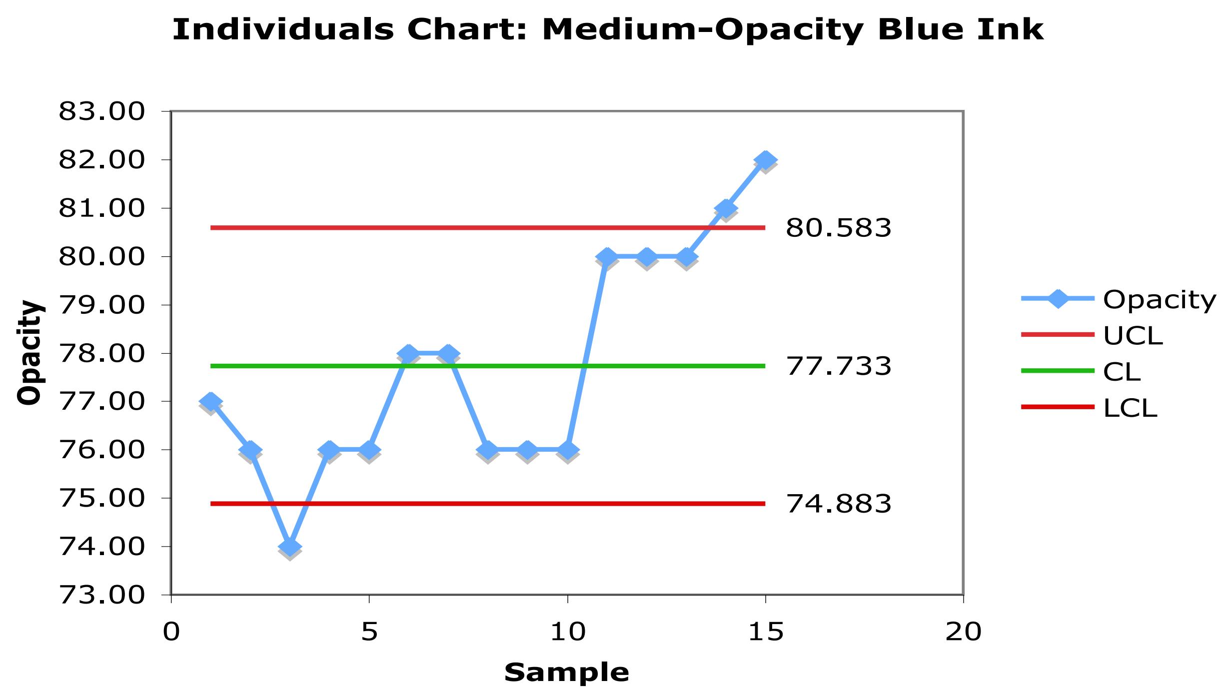

Figure 4 – Individuals Control Chart: Medium Opacity Blue Ink

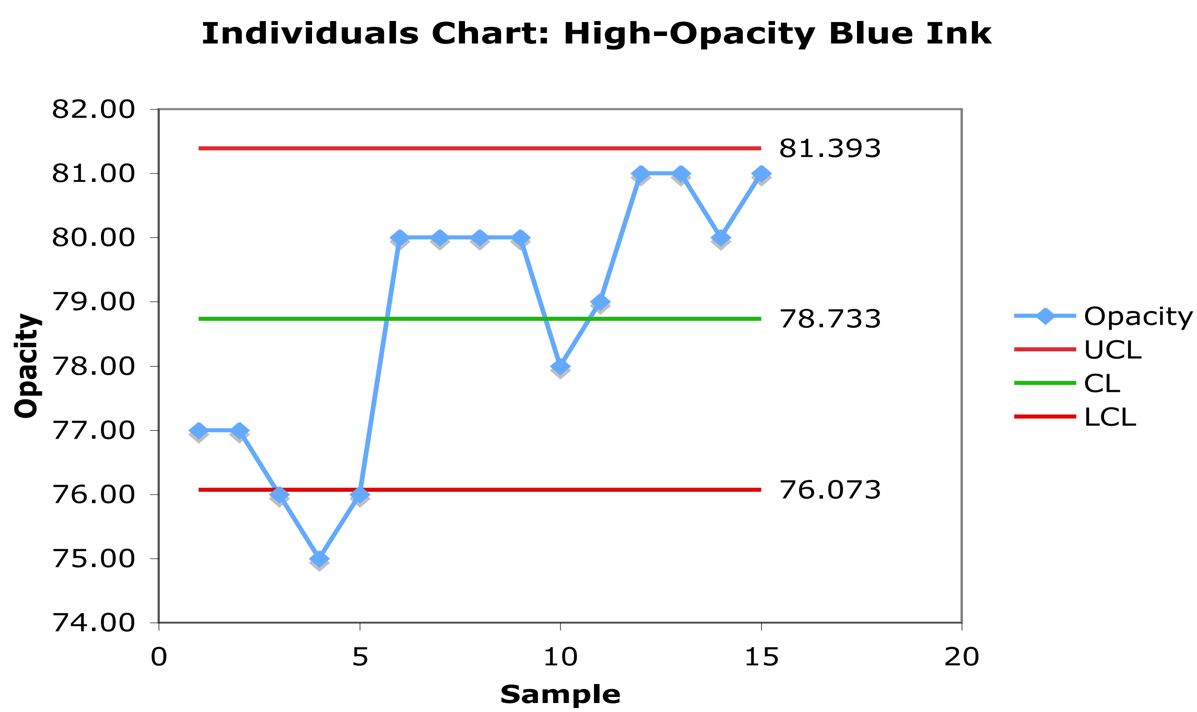

Figure 5 – Individuals Control Chart: High-Opacity Blue Ink

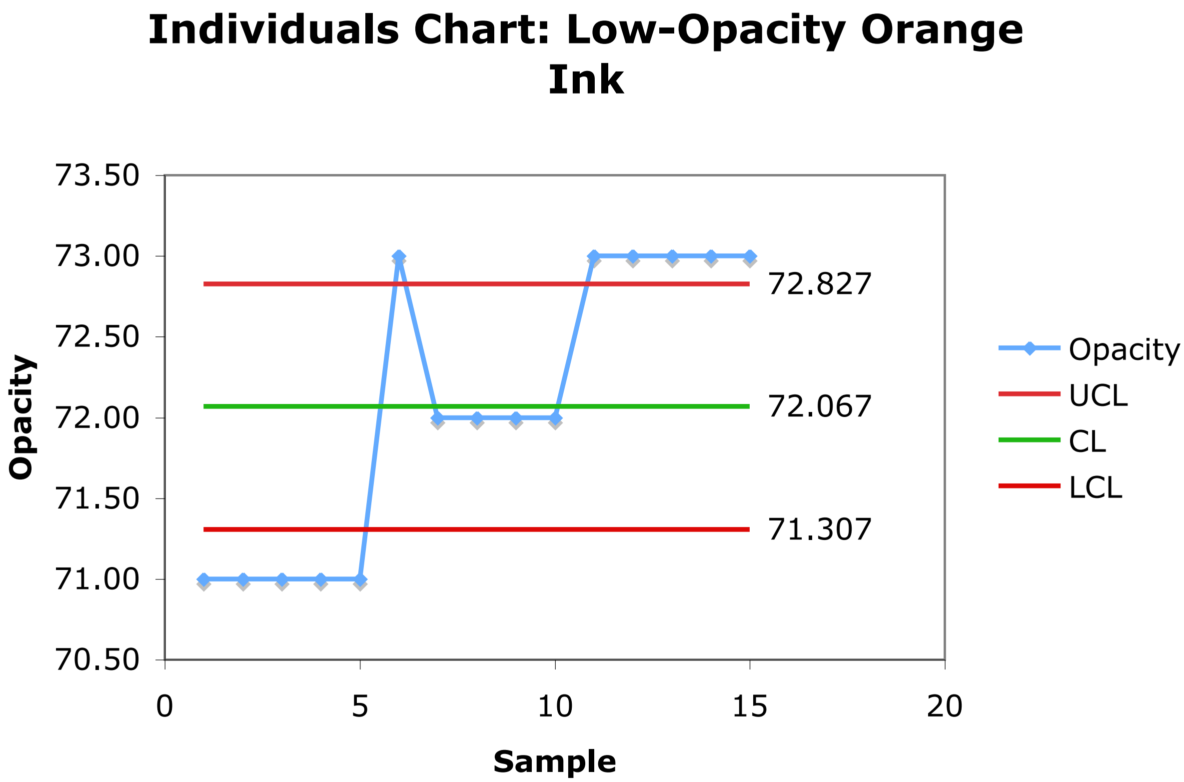

Figure 6 – Individuals Control Chart: Low-Opacity Orange Ink

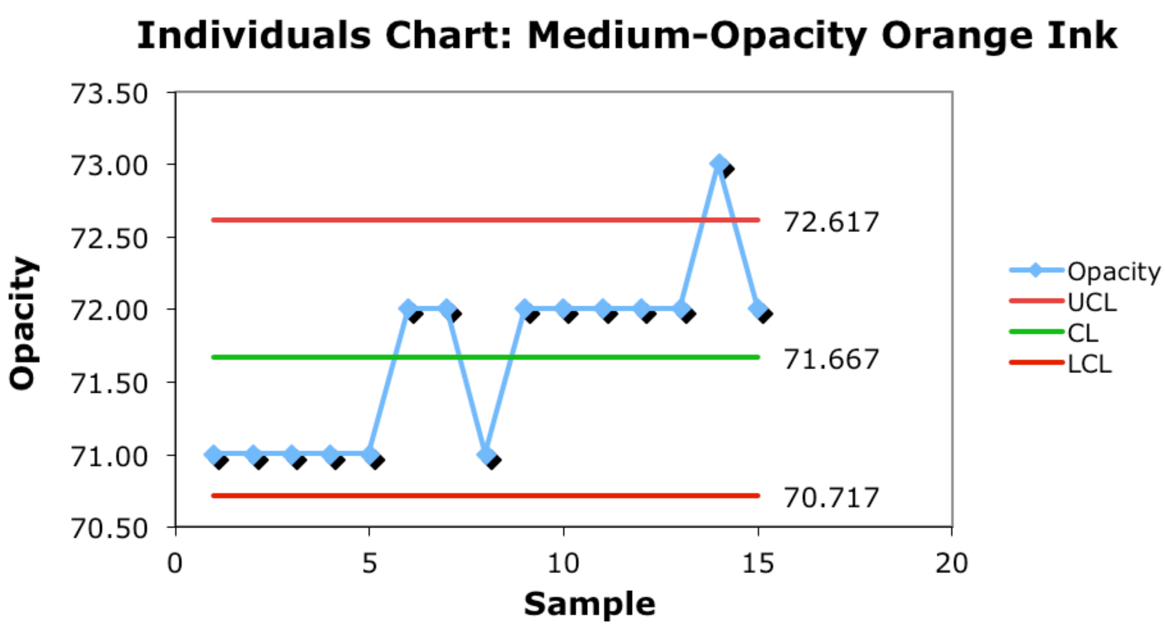

Figure 7 – Individuals Control Chart: Medium-Opacity Orange Ink

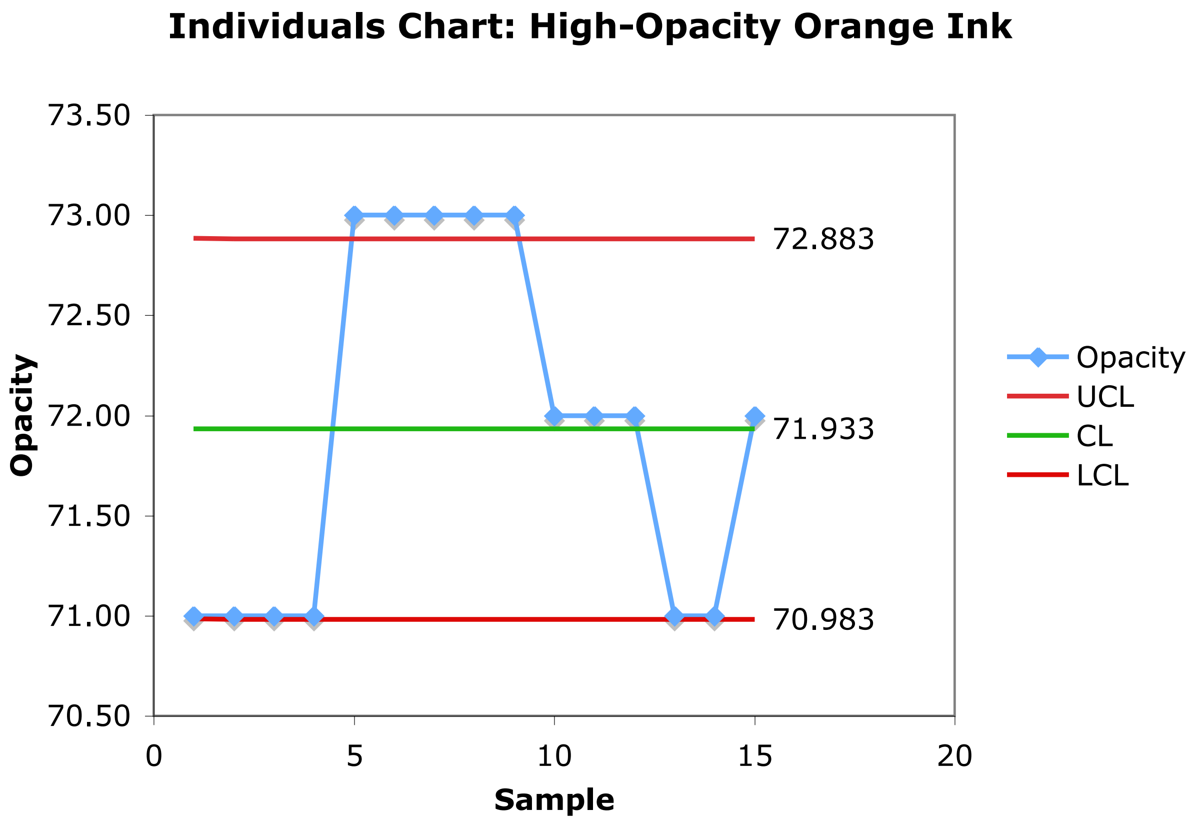

Figure 8 – Individuals Control Chart: High-Opacity Orange Ink

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