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Generating ICC Output Profiles for Different Substrates: Application too a Shinohara Offset Press & Several Printers

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GENERATING ICC OUTPUT PROFILES FOR DIFFERENT SUBSTRATES: APPLICATION TO A SHINOHARA OFFSET PRESS & SEVERAL PRINTERS

by

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It has been noted that there is similarity between the Master theses of Srinivasa Raju Alluri (Raju) and Kailashnath Pohnerkar (Kailash). The explanation is that they worked together on their experiments, collecting and analyzing the data together. They then correlated the data differently. Raju compared different printing devices on the same papers, while Kailash correlated different papers on the same printing devices. This allowed us to isolate different effects on ICC profiles and color gamuts.

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The International Color Consortium (ICC) was formed to undertake problems in achieving reliable and reproducible color throughout the reproduction process; the ICC Profile Specification offers solutions to color matching and quality. Problems with the ICC Profile relate to tools in the field, output devices, various substrates, profile calculation processes and color accuracy.

A color management system (CMS), developed by International Color Consortium, allows color transformation to be carried out by the operating system in conformity. ICC profiles describe the color range of a device and the way it distorts the color of an image. The profiling software is required to be compatible with ICC profile standards. Output profile creation by setting the RGB and CMYK color parameters forms the basic of CMS.

In this thesis, the main purpose is not only to generate ICC output profiles for different substrates commonly used on Shinohara Offset Press, Tektronix Xerox 8200 Solid Ink Printer and HP Designjet 755 CM Plotter but also to compare the print quality of ICC profiles generated for different substrates.

The color gamut of each of the created output profile is viewed by Chromix ColorThink software. A Profile with low ΔE_{rms} will give better printing results.

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CHAPTER 1

INTRODUCTION

"Why doesn't the color match?" Anyone who has ever worked in color publishing has probably asked this question. Matching color has been a quest since the early days of color reproduction. Before 1970, most printed color was separated using red, green, blue, and visual filters in a camera or enlarger. Skilled operators tried to get a better "match" to, or to improve upon, the original photograph with multiple exposures, color correction masks, and dot etching that chemically ate away at the halftone dots or physically changed their size through contact exposures. With so many adjustments, it was easy to see why the process took a long time and still did not always produce the expected color. In the 1990s, the power of color electronic prepress systems (CEPS) came to the desktop computer. Innovations like a common way of describing output (PostScript), graphical user interfaces from Apple and Microsoft, and publishing programs like Adobe Photoshop and QuarkXPress brought high-end color capability to the desktop. Easy-to-use, low cost systems quickly replaced the more expensive, monolithic systems. Yet still same question is found "Why doesn't the color match?" [1-5].

Color is a complex topic – perhaps more so than the computers that we use to reproduce it. Color management attempts to simplify color reproduction by putting the color expertise and science into software. As desktop computers have changed publishing, color management attempts to make color adjustments automatically so that less technical or experienced users can reproduce color easily, accurately, and without frustration [2-4].

Color management attempts to make color more predictable within the limitations of the devices in use. It translates color between devices using a device-independent profile connection space and standard profiles for each device. A profile characterizes a device's color reproduction capabilities. Color transformation is performed by a color management module, or CMM. By using a profile for each device and a CMM, applications can offer a wide range of features that can reduce the time and cost of reproducing color [2,3]. These include:

- More accurate, consistent reproduction between devices.
- Use of the display as a proofing device, known as soft proofing [3].
- Device simulation, or the ability to simulate one device on another for the purposes of proofing.
- Gamut checking and mapping, which can determine if a particular color can be reproduce on a particular device, and if not, select the closest color that can be reproduced.
- Profile embedding, which allows users to store profiles that contain information about the input device in image and other color files [2,3].

Using a color management program that can characterize printing processes, a color profile can be made of a color printer or printing process and used to get an optimal color reproduction. The printer profile is also needed for a screen-to-print match. To get a proof-to-press match or a print-to-print match, profiles of both devices (proof and press, or both printers) are required [2-5].

Matching the proof to the press and the various factors affecting it to be analyzed. The color gamut of the proofing devices requires a profile or color adjustment to match the conditions of the process, and the contract proof should match the press conditions. The modifications to the printing parameters should be recharacterized and a new profile should be created. The proof can be matched to the press by the application of international color consortium (ICC) profiling [6].

The color of a print depends on the equipment used to produce that print. If equipment is changed, the color has to be converted into the color space of the new device. The International Color Consortium (ICC) offers a way to do this conversion. Part of the process involves a CMM, i.e., a color management module or a color matching method. ICC has persuaded all CMM vendors to use the same device profiles, making it possible to input an image on one device and output it on another with predictable results [7-8].

The goal of the International Color Consortium (ICC) is to create, promote, and encourage the standardization of cross-platform color-management architecture for imagesetters, color monitors, and presses. The ICC standard data profile format translates computer language into a device-independent color space arrays to enable production equipment to communicate. The International Color Consortium (ICC) was created to solve color management problems [9-10].

CHAPTER 2

WHY COLOR MANAGEMENT?

Color management is defined as achieving a planned, realistic color that can be repeated. Color management allows using software to automatically determine the color reproduction characteristics of scanners, monitors, and output devices, and then to automatically make image settings necessary for optimal color reproduction. Color management is defined as achieving a planned, realistic color that can be repeated. The proliferation of lower cost color printers has created a need for the management of processes used to print color images. The images produced by these printers are being compared to photographs, which are continuous tone images. Continuous tone images are produced with a virtually unlimited range of color or shades of grays. Most printers use a digital process that cannot reproduce continuous tones images. A digital process can represent only a limited number of colors or gray levels. [11-12].

The Need For Open Color Management

Before desktop publishing, high-end prepress operators used proprietary or closed-loop systems, where all devices were integrated and calibrated to known values in order to work together. Color specialists were highly trained professionals who could work these systems to make a wide variety of adjustments to the color in a scanned image and predict, with reasonable accuracy, what the final printed piece would look like based on their manipulations [13-14]. Desktop publishing has brought about the increase of open production systems. The design and production workflow is no longer confined to a closed system, but may be distributed across many different systems made up of devices from different vendors [15].

Because each device reproduces color differently, the color you see at one stage of design and production rarely matches what you see at another. In other words, color is device-dependent – the color you see depends on the device producing it. A scanner interprets an image as certain RGB (red, green, blue) values according to its particular specifications; a particular monitor displays RGB colors according to the specifications of its phosphors; a color desktop printer outputs in RGB or CMYK according to its own specifications, and each press produces printed output according to the specifications followed (e.g., SWOP, TOYO, DIC, etc.) and the type of inks used [15]. Thus, the need for an open color management system to communicate color reliably between different devices and operating systems. Open color management lets one compensate for the differences in these devices and communicate color in a device-independent manner [16-18].

Perhaps the most frustrating aspect of working with digital files for color output is that WYSIWYG (what you see is what you get) doesn't always apply. The color you work so hard to get "just right" on your monitor doesn't look nearly as right when you print it. The reason is simple. By their very natures, a monitor and a printing press reproduce color in completely different ways. A monitor uses the RGB color model. This is an additive color model where red, green, and blue light is combined to create colors, and combining full intensities of all three make white [19].

A printing press, by contrast, uses the CMYK color model, in which three colors of transparent ink (cyan, magenta, and yellow), are combined along with black (noted as K), in varying amounts to create colors. CMYK is a subtractive color model where the inks filter the white light that reflects back from the paper and subtract some of the red, green, and blue light from the spectrum. The color we see is what's left in the spectrum. Subtracting all colors by combining the CMY inks at full saturation should, in theory, render black [20].

However, impurities in the existing CMY inks make full and equal saturation impossible; some RGB light does filter through rendering a muddy brown color. Hence, the addition of black ink to CMY [15]. Moreover, RGB and CMYK have different color gamuts, or ranges of reproducible colors. RGB monitors can display more colors than can be matched in print. Conversely, some CMYK colors cannot be matched on-screen. Moreover, RGB gamuts vary widely between devices with some gamut's being considerably wider than others. While this may seem beneficial, wider RGB gamut's can be problematic when outputting to a press. The colors in the RGB gamut that are outside the CMYK gamut must be compressed (i.e., mapped to a space within the CMYK gamut). This always entails a loss to the quality of the original design and underscores the feeling that what you see is not what you get [21-22].

Device-Independent Color

Color varies depending on the device, that produces it. In a sense, each device speaks its own color language that it can't communicate well to another device. What's needed is an interpreter [23].

To illustrate this, imagine four people in a room. Each person is assigned a task that requires agreement among them all. One speaks English, one speaks French, one speaks German, and one uses sign language. For our group to communicate, they need an interpreter who knows all four languages, as well as an agreed-upon neutral language. All discussion must first go through the interpreter who then translates it to the neutral language that all can understand. Each will continue to use his or her own native language, but will communicate which each other by using the neutral language [24-27]

A color management system works in much the same way, using a device-independent color model as its neutral color language by which all color information is referenced. The particular color model used is CIELAB, developed in 1976 by the Commission Internationale de l'Eclairage (International Committee on Illumination, or CIE). CIE's standard for measuring color is based on L, a, b values [15]. A color-management system is a method of defining the color of an image using a universal color space, a device independent color transform engine, and a series of device-specific profiles [28].

CHAPTER 3

COLOR THEORY

Color Overview

The perception of color by humans is a function of three receptors in the eye, referred to as red, green, and blue cones. Because of this, color systems are generally based on three components called tristimulus values. The representation of color in imaging systems has its foundation on numerous color spaces based on tristimulus values, but we will explore only the Red, Green, and Blue (RGB) and Cyan, Magenta, and Yellow (CMY) color spaces. Color Cathode Ray Tube (CRT) monitors and most computer graphics systems use the RGB color space and the color picture publishing industry uses the CMY color space [28,29].

Additive Colors

The RGB color space consists of the three additive primary colors red, green and blue. The components of these primaries are combined additively to produce the desired color. Combining the maximum value of each component results in the color white [28-29].

Additive colors are created by mixing spectral light in varying combinations. The most common examples of this are television screens and computer monitors, which produce colored pixels by firing red, green, and blue electron guns at phosphors on the television or monitor screen [28-29].

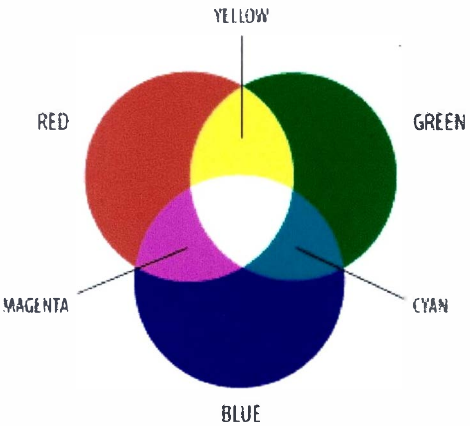

Figure 1. Additive Color Theory

Subtractive Colors

The CMY color space consists of the complement of the additive primary colors. These are known as subtractive colors, because the primary colors absorb their complement. Cyan will absorb Red, Magenta will absorb Green, and Yellow will absorb Blue. Therefore, combining the maximum value of each component results in the color black [28-29].

Subtractive colors are seen when pigments in an object absorb certain wavelengths of white light while reflecting the rest. This is the nature of color print production and cyan, magenta, and yellow, as used in four-color process printing, are considered to be the subtractive primaries. The subtractive color model in printing operates not only with CMY (K), but also with spot colors, that are, pre-mixed inks [29].

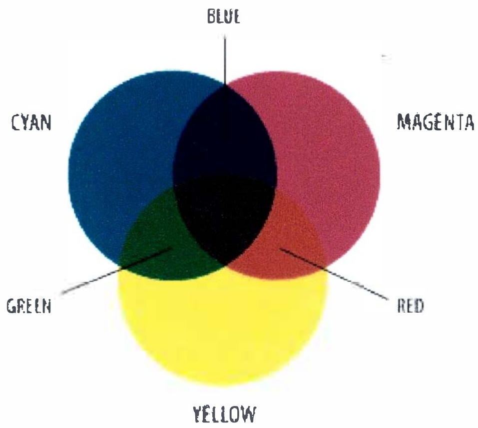

Figure 2. Subtractive Color Theory

CHAPTER 4

COLOR GAMUT

What is Color Gamut?

A color gamut is simply a range of colors. For an output device like a printer or monitor, it's the entire range of colors that the device can produce. For an input device like a camera or scanner, it's the entire range of colors that the device can sense. [30].

Output devices actually work with only a limited number of colors. Monitors, for example, use only red, green, and blue; the particular choices of red, green, and blue are determined by the phosphors in a CRT-based monitor or the color filters in an LCD-based monitor. All the other colors you see on the screen don't really exist in soft return [30].

To define the entire gamut for a monitor, you only need mark the points on the diagram that represent the colors the monitor actually produces. You can measure these colors with either a colorimeter or a spectrophotometer along with software that ensures the monitor is showing 100 percent red for the red measurement, 100 percent green for the green measurement, and 100 percent blue for the blue measurement [30].

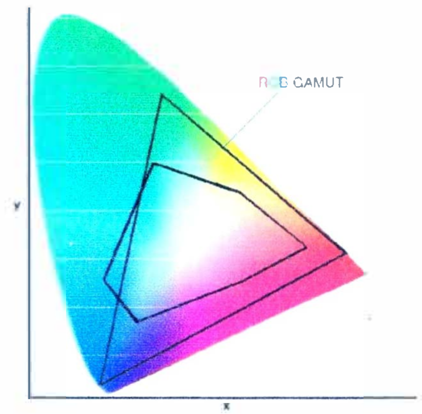

Figure 3. RGB Gamut

One thing you'll notice immediately about any of these color gamuts is that they are much smaller than the entire range of colors the human eye can see. This is a function of the phosphors that monitors use in the real world. The gamut's for monitors vary a bit from one to another, but any monitor gamut is much more like any other monitor gamut than it is like any printer gamut [30].

Determining a printer gamut is similar to determining a monitor gamut, but differs in detail. As with monitors, you can generate entire range of colors with just three colors. With printers, the colors come from ink or dye rather than phosphors, and are cyan, yellow, magenta and black. [30].

Unlike monitors, printers can mix colors, one on top of another, rather than having fixed phosphor dots or LCD cells on a screen. For most (but not all) printers, the mixing of inks or dyes is limited to either a full portion of color or no color, with no intermediate steps. So most printers can create dots in a total of seven colors: [30]

-- Cyan, yellow, magenta,

-- Red (which combines yellow and magenta)

-- Green (yellow plus cyan)

-- Blue (cyan plus magenta)

-- Black (which combines yellow, magenta and cyan)

Most printers, in short, offer seven colors to define their gamut, rather than the three colors for monitors. So to visualize a printer gamut, you print blocks of each color, take measurements of each block using a colorimeter or spectrophotometer, plot each of the seven colors on the diagram, then draw lines from point to point, to create a lopsided hexagon. The gamuts for printers vary more than the gamut's for monitors, but here again, any printer gamut will be much more like any other printer gamut than it will be like any monitor gamut. The diagram below shows a typical printer gamut [30].

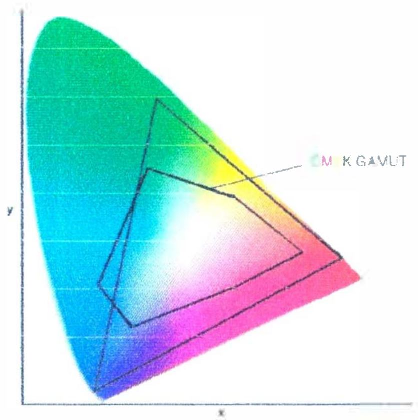

Figure 4. CMYK Gamut

Here again, the gamut is much smaller than the entire range of colors the human eye can see. You'll also note that it's a different shape than the gamut for a monitor. That means there's no way for a printer gamut to exactly match a monitor gamut. The diagram below shows the two gamuts together [30].

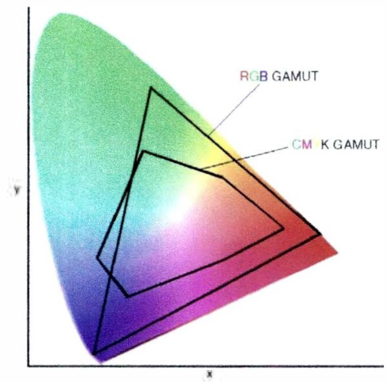

Figure 5. RGB & CMYK Gamut

The key point of this diagram is not just that the gamuts don't match, but that each includes some colors that the other lacks. That means there are certain colors, which monitor can show but can't be printed on a printer and there are colors a printer can print but monitor can't show [9-11].

The problem gets worse if one needs to translate between one kind of device-dependent color model and another. Scanners, for example, use red, green, and blue sensors, and most report colors using an RGB color model. So if one can scan an image and open it in a paint program, the image's color information is defined by an

RGB model. If you want to print the image on a printer that uses a CMYK model, one has to translate the color information somewhere along the line [30].

To do the translation, one's software has to make assumptions both about the RGB color model the information starts in and the CMYK model one moving it to. If either or both sets of assumptions are wrong--and they often will be--the colors can shift even more dramatically than when you move color information from one RGB model to another or one CMYK model to another without trying to redefine the color information in the process [30].

Gamut Constraints

The representation of the whole range, or gamut, of human color perception is quite large. However, when we look at the RGB and CMY color models—which are essentially models of color production—we see that the gamut of colors we can reproduce is far less than what we can actually see [29-30].

Figure 3 clearly shows this problem by superimposing representative RGB and CMY gamut's over the 1931 CIE Chromaticity Diagram [29-30].

Figure 3 shows, the colors created by the subtractive model of CMY don't look exactly like the colors created in the additive model of RGB. Particularly, CMY cannot reproduce the brightness of RGB colors. In addition, the CMY gamut is much smaller than the RGB gamut. [29-30]

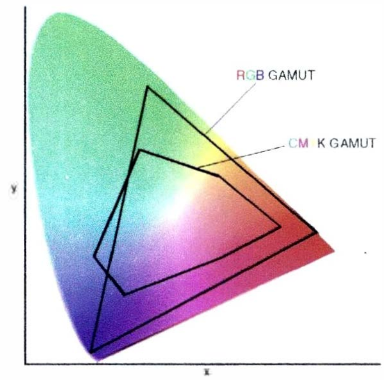

Figure 6. Showing the Differences in RGB & CMYK Gamut's

Both models fall short of reproducing all the colors we can see. Furthermore, they differ to such an extent that there are many RGB colors that cannot be produced using CMY (K), and similarly, there are some CMY colors that cannot be produced using soft return RGB [30].

The exact RGB or CMY gamut depends on other factors as well. Every RGB device, whether a display monitor, color printer, color scanner, etc., has it's own unique gamut. Although the print industry has set standards for color production (e.g., SWOP—Specifications for Web Offset Publications), variances in presses, inks, and paper, as well as differences in environmental conditions within any given print house, affect the gamut of CMY (K) output. These differences in gamut can create problems in the color production of computer-generated graphics and pages and inconsistent color is a problem inherent in all computer-generated color output [30].

CHAPTER 5

COLOR MODELS

CIELAB

CIE stands for *Comission Internationale de l'Eclairage* (International Commission on Illumination). The commission was founded in 1931 as an autonomous international board to provide a forum for the exchange of ideas and information and to set standards for all things related to lighting [31].

CIELAB is the second of two systems adopted by CIE in 1976, [31] as models that better showed uniform color spacing in their values. CIELAB is an opponent color system based on the earlier (1942) system of Richard Hunter called L, a, b [32]. Color opposition correlates with discoveries in the mid-1960s that somewhere between the optical nerve and the brain, retinal color stimuli are translated into distinctions between light and dark, red and green, and blue and yellow. CIELAB indicates these values with three axes: L*, a*, and b*. [31]

The central vertical axis represents lightness (signified as L*) whose values run from 0 (black) to 100 (white). [31] The color axes are based on the fact that a color can't be both red and green, or both blue and yellow, because these colors oppose each other. On each axis the values run from positive to negative. On the a-a' axis, positive values indicate amounts of red while negative values indicate amounts of the b-b' axis, yellow is positive and blue is negative. For both axes, zero is neutral gray: [31]

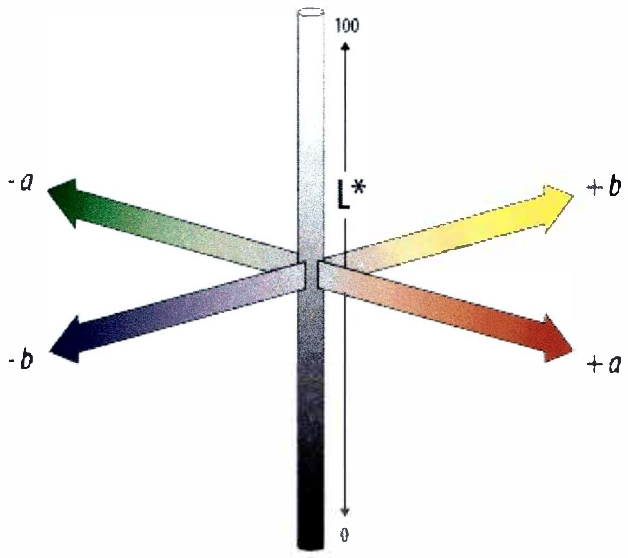

Figure 7. CIELAB

Therefore, values are only needed for two color axes and for the lightness or grayscale axis (L*) [31]. CIELAB has become very important for desktop color and is used for color management as the device independent model of the ICC (International Color Consortium) device profiles [31].

CHAPTER 6

PROBLEMS WITH PRINTING COLOR

The components of each of these color spaces are normally represented as a value between 0.0 and 1.0. When using a different system of representation, normalization can be accomplished by dividing each component by the maximum value. If the system representation of color is 8-bits per component, then the normalized values would be [32]:

$$Cn_n = Cs_s / Mc_c$$

Where: Cn_n is the component color normalized

Cs_s is the component system representation

Mc_c is the component system maximum value

If the component value is 128, then:

$Cn_n = 128 / 255 = 0.502$

Since the RGB and CMY color spaces are the complement of each other, it would follow that the conversion of one color space to the other is a simple matter. Theoretically, each color space could be transformed to the other by the following formula [32]:

$Cr_r = 1.0 - Cc_c$ and $Cc_c = 1.0 - Cr_r$

Where: Cr_r is the component in RGB color space Cc_c is the component in CMY color space

Color decisions can be very subjective and include the input of a number of parties, viz., designers, prepress houses, printers, inksuppliers, salespeople, and costumers. However, printers must exist in the not so perfect physical world. In the physical world there are many factors that cause the transformation to be non-linear. Some of these factors are [32]:

- Digital printing
  - Dot size (amount of ink per dot)
  - Resolution (number of dots per inch)
- Ink characteristics
  - Dye or pigment color
  - Viscosity
  - Drying time
- Media characteristics (paper, cloth, etc.)
  - Color
  - Absorption rate
- Environmental conditions
  - Humidity
  - Temperature

Each of these factors, and others, cause the transformation from one color space to the other to be more complicated. Dot size and resolution may cause the image to appear grainy and change the lighter and darker colors. One of more of the ink colors is not a 100% accurate primary color, causing the transformation to be inaccurate. The ink viscosity and dry time affect the dot size and mixture of the colors. The color of the media, if not white, causes the color transformations to be incorrect. The absorption rate of the media affects the dot size and the mixture of the colors. The environment affects the dry time and absorption of the ink [32].

CHAPTER 7

COMPONENTS OF COLOR MANAGEMENT

Color management attempts to simplify color reproduction by putting the color expertise and science into software. Much as desktop computers changed publishing, color management attempts to make color adjustments automatically so that less technical or experienced users can reproduce color easily, accurately, and without frustration.

Color Management Components

Color management is made-up of basically two components:

- Device characterization
- Color transformation

The ICC profile is a method used to characterize color devices, which meets the International Color Consortium standard. This standard was developed in an attempt to provide a cross-platform profile to characterize color devices. The ICC profile contains only the data required for the characterization of the device [31].

What is a Color Profile?

A "color model" is defined as a means of associating names or numbers with colors. A "color profile" (as the term is used by the ICC and other color management authorities) is an association between two different color models [3,32,].

Printers prefer to express color in CMYK. By printing a set of CMYK patches, and measuring them with a colorimeter, we can construct a table that records which CIE LAB numbers are associated with which CMYK values. [32]

Table 1 in which the CMYK (in percentages) sent to a printer are next to the CIE LAB measured by a colorimeter. [32-33]

Table 1. Comparison of CMYK & CIE LAB Values

Description	CMYK	CIE LAB
A red	0, 100, 91, 0	50, 71, 54
A darkish blue	100, 69, 0, 0	32, 34, -71
A yellow	6, 0, 91, 0	95, -17, 99
A green	100, 0, 79, 9	56, -81, 32

Table 2 in which the RGB voltages (0-255) sent to a monitor are next to the CIE LAB measured by a colorimeter. [32-33]

Table 2. Comparison of RGB & CIE LAB Values

Description	RGB	CIE LAB
A red	203, 0, 23	50, 71, 54
A darkish blue	0, 46, 160	32, 34, -71
A yellow	255, 243, 0	95, -17, 99
A green	0, 139, 74	56, -81, 32

If the above tables are stored in a computer, and have hundreds of entries rather than just four each, they will be "device color profiles". [32-33]

Notice that in the above two tables, each color has exactly the same CIE LAB numbers. The two tables could therefore be combined, to form what is called a "link profile", establishing a relationship between color on a CMYK printer and on an RGB monitor. Here again, a real link profile in a computer will have hundreds or thousands of entries, rather than just four. [32-33]

Table 3. Comparison of CMYK, CIE LAB & RGB Values

Description	CMYK	CIE LAB	RGB
A red	0, 100, 91, 0	50, 71, 54	203, 0, 23
A darkish blue	100, 69, 0, 0	32, 34, -71	0, 46, 160
A yellow	6, 0, 91, 0	95, -17, 99	255, 243, 0
A green	100, 0, 79, 9	56, -81, 32	0, 139, 74

The more points are stored in the table, the more precision can be expressed in the color matching function. The ICC Profile format, which is just a file format for storing these tables, is flexible. Many monitor profiles are distributed are only 10 K bytes in size, while the link profiles used by programs are commonly over 700 K bytes [34].

Color Characterization

The objective of color management is to make it easier to get accurate, repeatable color reproduction. The many software and hardware options, however, make it challenging to configure a color-managed workflow. The ‘three C’s (Calibration, Characterization, Conversion) of color management is a model that is useful for understanding the steps to follow in setting up and maintaining a color management system [2,34].

Many people use the term “calibration” to mean all steps necessary to achieve accurate color during the production process, perhaps implying that reproduced colors are “calibrated” to match the original. Color management is a more meaningful term for matching color on different input and output devices, since the calibration of each device is only the first of three steps necessary to achieve accurate and consistent color throughout the reproduction process [2,34].

Calibration ensures that all devices (scanner, monitor, and printer) conform to an established state or condition, often specified by the manufacture, be it RGB illuminance, CMYK density, or CMYK dot area [2,34].

Characterization is a way of determining the output of a system in response to a known input, where input and output are defined colors and system signals. Characterization provides a way of deriving the color gamut and reproduction characteristics of a particular device in a specified (calibrated) state. It is a way of determining how an input device captures color or an output device records color when it is calibrated. Characterization data provides the input to profile creation [2,34].

Conversion (also known as color transformation or, in closed-loop color, color correction) refers to translating a color image from the color space of one device to that of another under known conditions. Color conversion can be done by manually correcting the image or automatically by using color management software [2,34].

To achieve the goals of color management, calibration, characterization, and conversion must be done in this sequence. Calibrating a device to specification serves as a foundation for characterization and conversion, and a device must be characterized before color data can be converted for accurate rendering [2,34].

Printer Characterization

Making a CMYK output profile involves printing a color target containing numerous color patches, and reading the color values of these patches into the color management program using a colorimeter or spectrophotometer. A standard target for characterization of CMYK printing processes and devices is the IT8.7/3 (ISO 12642). The IT8.7/3 "Basic Ink Value Data Set" includes 182 color patches, while the "Extended Data Set" consists of 928 patches [2,35].

Whereas almost all publishers of ICC-compliant software have agreed to use standard IT8.7 scanner characterization targets, most use proprietary targets for output device characterization. Programs that now support the IT8.7/3 target include Agfa ColorTune, Pictographics ColorSynergy, Itec ColorBlind, GretagMacbeth ProfileMaker Pro, Kodak ColorFlow, Fugifilm Colourkit, Linotype CPS PrintOpen, and Praxisoft Comass- Printer [2,35].

Color management software publishers differ widely in the number of patches they feel are required to make a profile. Programs with the smallest numbers of patches include Kodak's ColorFlow Profile Editor (30-200 patches), RIT Profile/80 (80 or 161), and Linotype CPS PrintOpen ICC (210). Programs with large numbers of patches include Pictographic ColorSynergy (504), Itec ColorBlind (350-1,200), Light Source Profile Factory (1440), Monaco Systems Monaco PRINT (754), and Radius Color Match Separation Lab (1,120) [2,35].

Color Management in Print Production

Once color management profiling software has been used to characterize the scanner, monitor, and printer, it is necessary to apply the profiles to the image according to the desired "matching" objectives [2,35].

Profiles Standards

The development of color management solutions with proprietary profile formats made it difficult for users to take advantage of profiles within different applications. In 1993, the ICC was founded by Adobe, Agfa, Apple, Kodak, Microsoft (since resigned), Silicon Graphics, Sun Microsystems, and Taligent (which has since resigned). Today there are over 40 members. The goal of the ICC was to create a standard profile format that could be used on any platform. The first solution to support the ICC profile format was ColorSync 2.0, introduced at Seybold seminars in March 1995. Since then, the format has been widely adopted and is supported on numerous platforms – including Windows, Macintosh and UNIX. ICC profiles are the foundation of today's color management solution [2,35].

Output Profile Rendering Intent

The ICC allows output profiles to contain four rendering intents – perceptual, absolute colorimetric, relative colorimetric and saturation. It is possible to store these intents as forward lookup tables relating profile connection space (PCS) to device and as reverse lookup tables relating PCS to device and a reverse lookup tables relating device to PCS. For our profiles we are going to use absolute colorimetric, because we are going to verify profiles on press with maximum gamut spacing and measured colorimetry [(37-39)].

Note that unlike other ICC workflows, once the special input profile has been made the rendering intent route through the output profile must not be changed. If relative colorimetric or perceptual intent was used in generating the input profile then the same intent must be used when processing images through the forward part of the output profile [(39)].

CHAPTER 8

STATEMENT OF THE PROBLEM

Problems with Color Today

Even the most experienced designers struggle at times with the four-color print production process. Perhaps the comp doesn't match the colors on-screen, or the contract proof doesn't match the comp, or the final piece doesn't match the original scan.

Color shifts can occur at many points in a workflow, but most problems are related to the fact that different devices and applications measure and produce color differently. Monitors display color in RGB, for example, and proofing devices and presses print in CMYK. These are two different color spaces, or ranges of color, that devices use to describe color. CYMK is a smaller color space than RGB, but CMYK can produce certain hues that RGB cannot, and vice versa. So one might be frustrated that comps or contract proofs don't match the colors when viewed on-screen. Or the blue sky that comes off the press might be a little more cyan than the original scan — and if they wanted to reproduce it exactly, they might be disappointed.

To make matters worse, there are multiple CMYK and RGB color spaces. For example two monitors of the same make and model will produce slightly different colors. This is because each hardware device has its own gamut, or range of reproducible colors. (Age, ambient lighting, and other environmental conditions also affect how a monitor displays color, while consumables and environmental conditions affect how printers produce color).

The Role of Color Management

Color management attempts to simplify color reproduction by putting the color expertise and science into software. Much as desktop computers changed publishing, color management attempts to make color adjustments automatically so that less technical or experienced users can reproduce color easily, accurately, and without frustration.

The Role of Color Profiles

Color management attempts to make color more predictable within the limitation of the devices in use. It translates color between devices in use. It translates color between devices using a device-independent profile connection space and standard profiles for each device. A profile characterizes a device's color reproduction capabilities. Color transformation is performed by a color management module, or CMM. By using a profile for each device and CMM, applications can offer a wide range of features that can reduce the time and cost of reproducing color.

CHAPTER 9

OBJECTIVES

The main objectives are:

1. To generate ICC profiles for two substrate that is been used on the Shinohara Offset Press
2. To generate ICC profiles for two substrate that is been used on the HP Designjet 755 CM Printer.
3. To generate ICC profiles for three substrate that is been used on the Tektronix Phaser Solid Ink Printer.
4. To test the created profiles for accuracy.
5. To obtain better color matching (proof to press) by using our created profiles for each substrate on the respective devices.
6. Printability analysis for each substrate with respect to printing devices.

CHAPTER 10

MATERIALS

Items

IT8.7/3 Target, Macbeth Color Checker Chart (Lab version), Wikoff Color Corp Inks for Sheetfed Offset, Dowagiac Dense Black, High Speed PC Cyan, High Speed PC Magenta, High Speed PC Yellow, Tektronix Ink cartages for Yellow, Magenta, Cyan and Black Ink, HP Designjet 755 CM Plotter Ink Cartages for Yellow, Magenta, Cyan and Black Ink, Phoeno-star-plus (coated) 80 lbs text Offset Paper, Satin-kote-plus (Uncoated) 60 lbs text Offset Paper, Tektronix Uncoated Paper, Tektronix Premium Color Paper, Tektronix Glossy Paper, HP Coated Paper Roll, HP High Gloss Paper Roll, Offset Printing Plates, Shinohara 2 Color Sheetfeed Offset Press, Tektronix Xerox 8200 Solid Ink Printer and HP Designjet 755 CM Plotter, AFGA-Proset 9550 Imagesetter.

Software

Adobe Photoshop 7.0, Illustrator 10.0, Indesign 2.0, Gretag Macbeth Profile Maker 4.1.5, Mac Excel 2000, Chromix Color Think 2.1, Navigator RIP 6.2.

Hardware

Gretag Macbeth Spectroscan Spectrophotometer, Macintosh Power PC (G4 processor).

CHAPTER 11

EXPERIMENTAL PROCEDURE

- Test chart for Shinohara Sheetfeed Offset Press, HP Designjet 755 CM Plotter, Tektronix Phaser 8200 Solid Ink printer were made and printed it on different substrates.
- Plates were made for Shinohara two color Sheetfeed Offset Press, for each color including printing test charts.
- For Characterizing Output trials for Shinohara two color Sheetfeed Offset Press were conducted.
- Print the color management output profiling target on the desired printing device (press, paper, ink), ensuring that the printer has been calibrated or that printed samples conform to specification.

Output Device Profile

Steps involved in output profile evaluation were as follows.

1. Making output profile.
2. Method of testing output profile.
3. Viewing the gamut of profile.

Making Output Profile

Making a CMYK output profile involves printing a color target containing numerous color patches, and reading the color values of these patches into the color management program using a spectrophotometer.

- The first step was to build a profile for the Tektronix Phaser 8200 color Laser printer, HP designjet 755 CM plotter and Shinohara two-color sheetfed offset for various substrates.

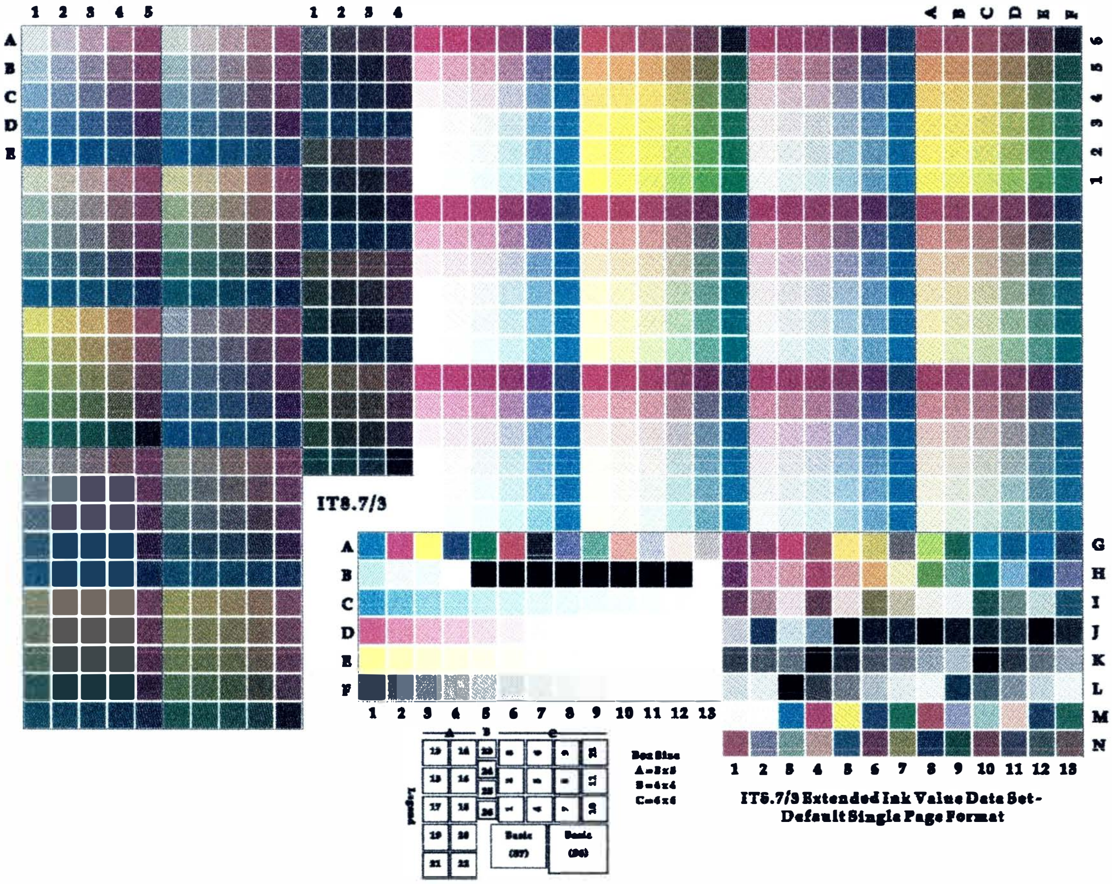

Figure 8. IT8 7.3 CMYK TIFF

- The software used for making profile was Gretag Macbeth Profile Maker 4.1.5
- The reference target selected within software was IT8 7.3 CMYK reference and the instrument was Gretag Macbeth Spectroscan. Figure 8 shows the target used for constructing the profile.
- The target was printed on the desired substrate for each printer and press. The purpose of printing the target on different substrates was to use the profiles to differentiate between substrates, as the substrates greatly affects the color values.
- The printed target was placed on the bed of the spectroscan spectrophotometer. This enabled the device to scan and measure the Lab values from the target, which were used to build the profile.
- The created output profiles must be saved in the Colorsync profile folder under system folder, so that the profile can be assigned in the path.

Method of Testing Output Profile

- The profile once created was checked for its accuracy. First we compare IT8 7.3 CMYK original Lab values with measured Lab values for both the profiles[40].
- By comparing visually the original Lab values and measured Lab values by the Spectroscan Spectrophotometer of the printed sample on Tektronix Phaser Solid Ink printer look alike.
- As an additional test we use the TIFF of the Macbeth Color Checker target (Figure 9) in Lab mode for testing output profile.

- Download the Macbeth- color chart from www.Munsell.com [7]

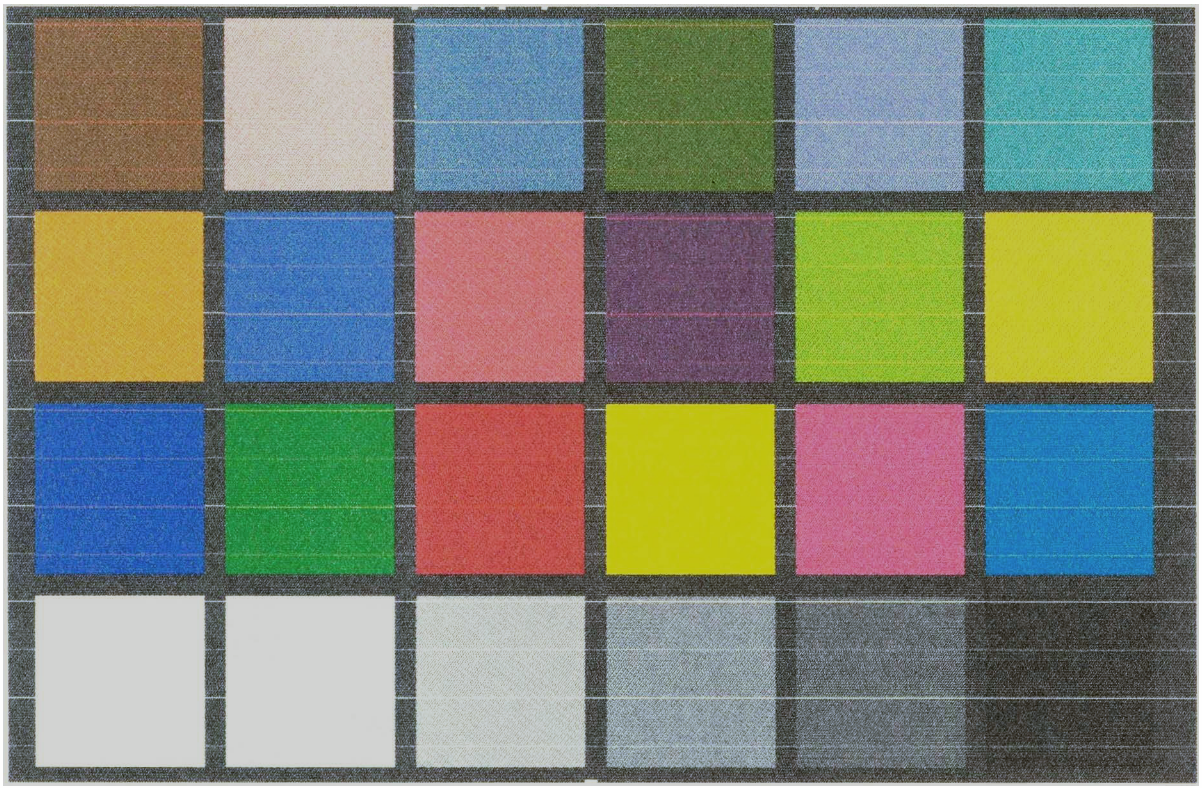

Figure 9. Macbeth Color Checker Chart

Source: A digital image from Munsell Color web site
Used with permission GretagMacbeth 2002.

- Import and open image in Photoshop 7.0.
- Under file menu go to color settings-CMYK setup. Select ICC profiles created. The other settings within this dialogue box should be engine – apple color sync and absolute colorimetric.

- Once the settings on the picture are made, there are adjustments that need to be made in the print dialogue box. Under the print command in Adobe Photoshop 7.0 select space as CMYK color then go to printer specific options and keep color correction at none, print quality as 600 by 600 dpi, image at off and O/P as face up. For HP Designjet 755 CM we used 300 dpi print quality and output was through Navigator RIP 6.2.
- Convert the CMYK with the output profile.
- Print the image on desired printer and on the desired substrate.
- Measure the each patch of target output by Spectroscan Spectrophotometer.
- Calculate ΔE between original values and printed values.
- Convert the original tiff file into different modes i.e. CMYK, RGB and compare the Lab values on the printed substrate with the Photoshop file for each format including the original Lab file.
- Calculate the ΔE_{rms} between original values and printed values.

Determining the relative error in the Lab values of profile with the original.

- To calculate the ΔE_{rms} between the Lab values of the output profile, Lab values in Photoshop on the monitor and Lab values as measured by the Gretag Macbeth Spectroscan spectrophotometer.
- To calculate the ΔE_{rms} between the Lab values of the Macbeth_Color chart, Lab values in Photoshop on the monitor and Lab values as measured by the Gretag Macbeth Spectroscan Spectrophotometer in different modes.

Following steps involved in obtaining values

- Software used for this is MS Excel. Lab values of each Substrate are compared with the Lab values in Photoshop of the target with applied profile, with Lab values in Photoshop of original target without profile applied on it and with Lab values of the original target as measured with a spectrophotometer.
- This will give us a definite relation between the loss in quality as well as color that we are getting for different profiles.
- After measuring the Lab values of the target for output profiles and comparing them to the Lab valves measured in Photoshop, we also checked the ΔE_{rms} value as compared with the target. This will tell us the error values when printing on desired printer without a profile.

Viewing the Gamut of Profile.

The gamut of profile can be viewed using different profile maker software; we used Chromix Color Think 2.1 for viewing the gamut of created profiles.

- Open the Chromix Color Think 2.1
- Click on 3D Graph
- In 3D Graph click on add.
- Add desired profile from original source where profile has been saved.
- Adjust the desired position and capture a screen shot.

Printability Analysis

After successfully testing final set of profiles, printability analysis of each printed substrates would be done for analyzing the print quality of the press with respect to substrate. For that following things to be measured & calculated of each substrate.

- Reflective Density (x-Rite 408 reflection densitometer)
- Specular Gloss (Gardener gloss meter)
- Ink Mottle (Mottle Tester)
- Print Contrast
- Ink Trapping
- Image Analysis (Hitachi HVC 10 camera)
- Dot Gain

Reflective Density (X-Rite 408 Reflection Densitometer)

Reflective density is determined by using x-rite 408 reflection densitometer.

Specular Gloss (Gardener Gloss Meter)

The gardener gloss meter determines specular gloss.

Ink Mottle (Tobias Mottle Tester)

Ink mottle is determined with the help of Tobias mottle tester.

Mottle = Unevenness in print density or print gloss. Mottle = Substrate ability to produce a uniform flat printed tint.

Print Contrast

Print contrast measures how well shadow detail is maintained on a printed sheet. It is a ratio of the 75% screen dot density to solid density and it is calculated as follows:

$PC = D_s - D_{75} / Ds * 100$

Where, PC = Print Contrast

D_s = Density of Solids

D_{75}= Density at 75% Screen

Print Contrast should only be used as a comparison of one print to another. In general, a print with higher contrast will produce an image with greater shadow balanced detail. Print contrast is required for good color balance.

Ink Trapping

Trapping is a method of adjusting areas where two distinct colors meet so that press misregistrations won't cause unsightly white spaces. Printers also use the word trapping to describe how inks overprint. Ink trapping refers to the way ink adheres to previously printed color ink. For example, printing cyan on top of yellow can result in either good or poor ink trapping. When there is poor ink trapping, the yellow ink (which may be wet or dry) does not allow all of the cyan to stick to it. In good ink trapping, the cyan properly sticks to the previous layer of ink. It is the important characteristics of printing on multi-color presses. It affects the appearance of printed product. It is the ratio of ink transfer on printed surface to ink transfer on unprinted surface.

Correct trap: the same amount of ink transfers to previously printed as to unprinted & overprint has correct L*a*b* values.

Undertrapping – less ink transferred to previously printed ink. Overprint weak in strength and hue distorted to underlying color.

Overtrapping – more ink transferred to previously printed ink & Overprint is strong, hue distorted towards overprinting color.

Trap affected also by ink opacity and gloss changes, therefore trapping is more correctly referred to apparent trap.

Apparent trap:

Red trap: Magenta – printed over yellow:

% Apparent Trap $R_{(M/Y)} = (R_G - Y_G)/M_G$ Where

R_G = density of red solid overprint through green filter

Y_G = density of yellow solid through green filter

M_G = density of magenta solid through green filter

Green trap: Cyan (blue) – printed over yellow:

% Apparent Trap: $G_{(C/Y)} = (G_R - Y_R)/C_R$

Where G_R = density of green solid overprint through red filter

Y_R = density of yellow solid through red filter

C_R = density of cyan solid through red filter

Image Analysis (Image Xpert 9.1)

An Image analysis to be done at 15 % tone by means of Image Xpert 9.1.

Dot Gain (Murray Davis Equation & X-Rite 408 Reflection Densitometer)

Darkening of halftone image due to ink absorption in paper causing halftone dots to enlarge. It is a defect that occurs in the reproduction process in which dot print larger than they should, causing darker tones or colors. Dot gain to be measured by Murray Davis equation

Murray Davis Equation = $1\text{-}10^{-tint}/1\text{-}10^{-solid} * 100$ – Nominal dot area.

By X-Rite 408 Reflection Densitometer we will measure total dot area. To calculate dot gain by formula,

Dot Gain = Total Dot Area – Nominal Dot Area.

CHAPTER 12

RESULTS AND DISCUSSION

Output Profile

The Reference Lab values in the chart and measured Lab valves in profile were compared and ΔE_{rms} value is calculated for each profile is in table 4.

Table 4. The RMS ΔE Value for Each Profile

Sr No	Name of the Profile	RMS ΔE
1	Tektronix Glossy ICC Profile for Tektronix Glossy Paper	0.71
2	Tektronix Uncoated ICC Profile for Tektronix Uncoated Paper	0.80
3	Tektronix Premium ICC Profile for Tektronix Premium Paper	0.78
4	HP Coated ICC Profile for HP Coated Paper	0.63
5	HP High Gloss ICC Profile for HP High Gloss Paper	0.63
6	Coated 1 ICC Profile for Coated Offset Paper	2.15
7	Coated 2 ICC Profile for Coated Offset Paper	2.29

Table 4 – Continued

Sr No	Name of the Profile	RMS ΔE
8	Coated 3 ICC Profile for Coated Offset Paper	2.17
9	Avg Coated ICC Profile for Coated Offset Paper	2.16
10	Uncoated 1 ICC Profile for Uncoated Offset Paper	1.79
11	Uncoated 2 ICC Profile for Uncoated Offset Paper	1.80
12	Uncoated 3 ICC Profile for Uncoated Offset Paper	1.88
13	Avg Uncoated ICC Profile for Uncoated Offset Paper	1.39

From Table 4 the lowest RMS ΔE value is for HP Coated ICC Profile for HP Coated Paper and highest RMS ΔE is for Coated 2 ICC Profile for Coated Offset Paper. However, all are in the acceptable range.

The white point for each profile in XYZ is shown in Table 5

Table 5. White Point Value for Each Profile

Sr No	Name of the Profile	X	Y	Z
1	Tektronix Glossy ICC Profile for Tektronix Glossy Paper	0.8524	0.8719	0.8017
2	Tektronix Uncoated ICC Profile for Tektronix Uncoated Paper	0.7966	0.8248	0.6977
3	Tektronix Premium ICC Profile for Tektronix Premium Paper	0.8531	0.8726	0.8024
4	HP Matte Coated ICC Profile for HP Coated Paper	0.7915	0.8065	0.7731

Table 5 – Continued

Sr No	Name of the Profile	X	Y	Z
5	HP High Gloss ICC Profile for HP High Gloss Paper	0.8070	0.8389	0.7385
6	Coated 1 ICC Profile for Coated Offset Paper	0.8262	0.8519	0.7384
7	Coated 2 ICC Profile for Coated Offset Paper	0.8326	0.8591	0.7441
8	Coated 3 ICC Profile for Coated Offset Paper	0.8280	0.8543	0.7397
9	Avg Coated ICC Profile for Coated Offset Paper	0.8262	0.8519	0.7384
10	Uncoated 1 ICC Profile for Uncoated Offset Paper	0.8210	0.8427	0.7359
11	Uncoated 2 ICC Profile for Uncoated Offset Paper	0.8172	0.8391	0.7338
12	Uncoated 3 ICC Profile for Uncoated Offset Paper	0.8253	0.8476	0.7404
13	Avg Uncoated ICC Profile for Uncoated Offse Paper	0.8212	0.8431	0.7367

From Table 5 the lowest value for white point value Matte is for HP Coated ICC Profile for HP Coated Paper and highest value for white point value is for Xerox Glossy and Premium Paper.

By using the profile for each paper substrate and printing the Macbeth Color Checker chart in CMYK mode on each substrate and then comparing the measured Lab values in CMYK by Gretag Macbeth Spectroscan Spectrophotometer with original Lab values in Photoshop following ΔE_{rms} values where obtained is shown in table 6

Table 6. The RMS ΔE Value for Each Profile Using Macbeth Color Checker Chart

Sr No	Name of the Profile	RMS ΔE
1	Tektronix Glossy ICC Profile for Tektronix Glossy Paper	2.44
2	Tektronix Uncoated ICC Profile for Tektronix Uncoated Paper	2.32
3	Tektronix Premium ICC Profile for Tektronix Premium Paper	1.39
4	HP Coated ICC Profile for HP Coated Paper	2.80
5	HP High Gloss ICC Profile for HP High Gloss Paper	1.94
6	Avg Coated ICC Profile for Coated Offset Paper	2.95
7	Uncoated ICC Profile for Uncoated Offset Paper	2.60

From Table 6 the lowest RMS ΔE value is for Tektronix Premium ICC Profile for Tektronix Premium Paper and highest RMS ΔE value is for Avg Coated ICC Profile for Coated Offset Paper.

Calculations:

$\Delta E = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$

L_1^*, a_1^*, b_1^* - Reference Values

L_2^*, a_2^*, b_2^* - Comparison Values

$\Delta E_{rms} = \sqrt{\sum(\Delta E)^2 / n}$

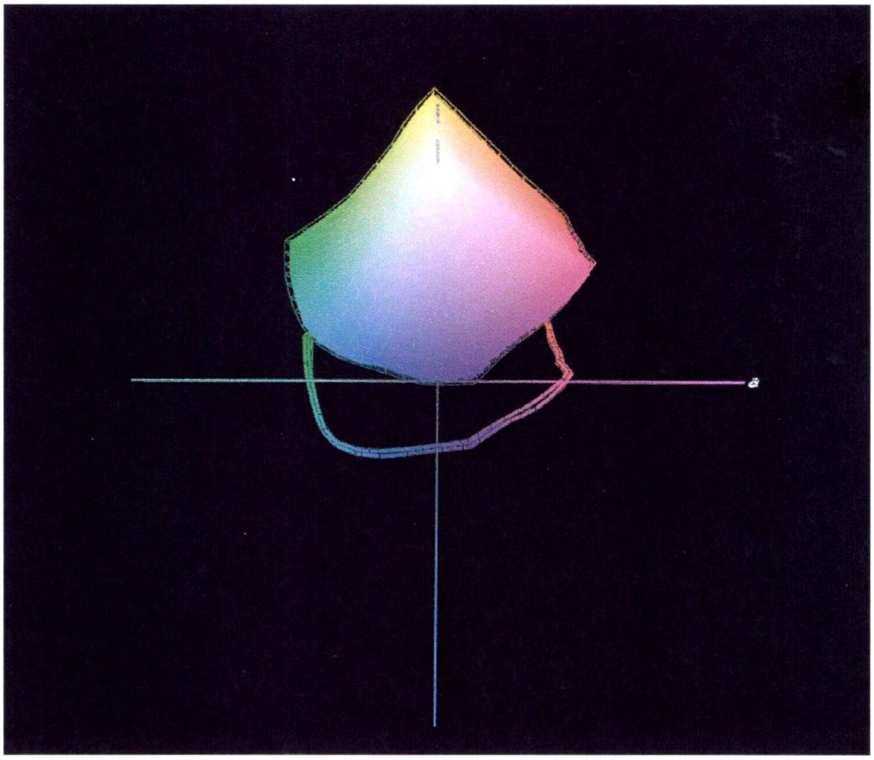

Figure 10. 3D Gamut View for Tektronix Glossy, Uncoated and Premium Paper ICC Profile

Figure 10 shows the 3D gamut view for glossy, uncoated and premium paper ICC Profile. The gamut for glossy paper profile is in wire frame mode, for premium paper profile is in smooth mode and the gamut for Tektronix uncoated paper profile is in flat mode for so that we can differentiate between three profiles. From above figure we can see that gamut for Tektronix glossy paper profile is slightly higher than gamut for Tektronix premium paper profile and Tektronix uncoated paper profile. One can hardly differentiate between the gamut for Tektronix premium paper profile and Tektronix uncoated paper profile.

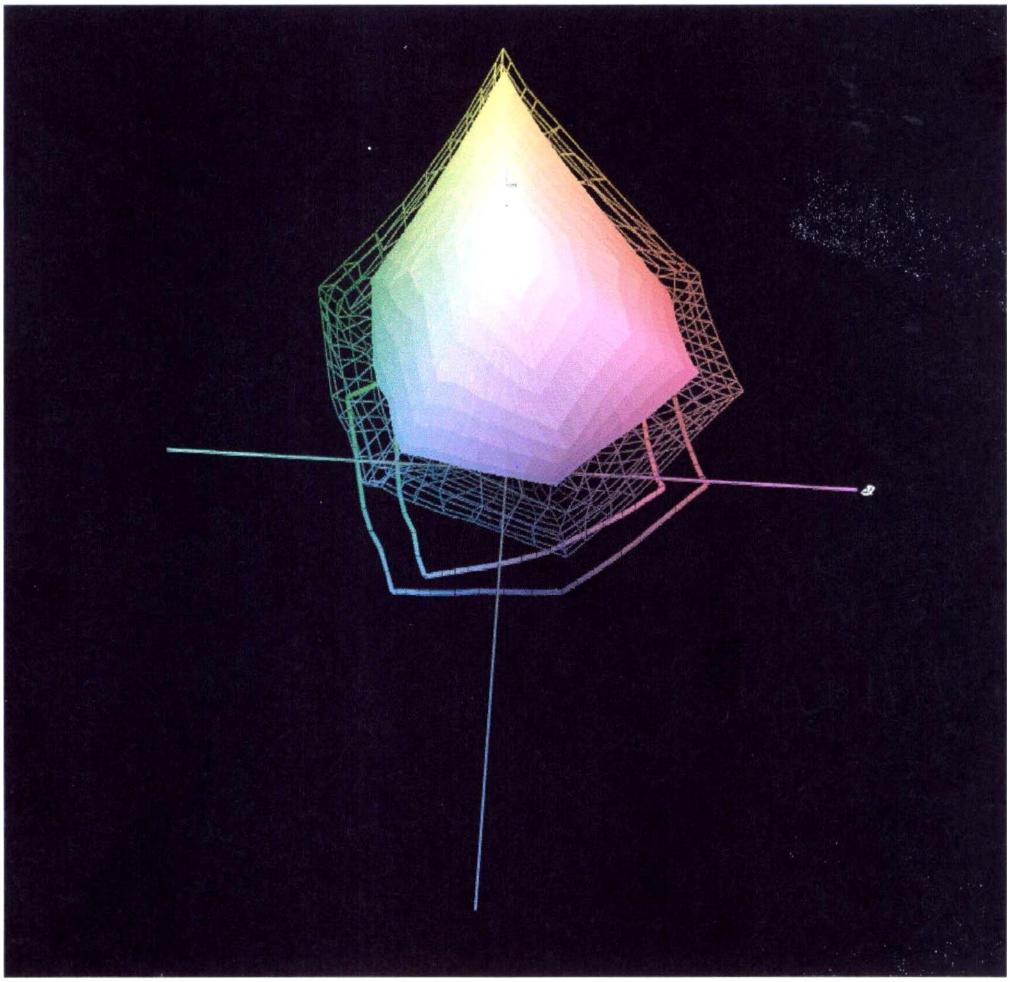

Figure 11. 3D Gamut View for Coated and Uncoated Offset Paper ICC Profile

Figure 11 shows the 3D gamut view for coated and uncoated offset paper ICC profiles. The gamut for coated offset profile is in wire frame mode and for uncoated offset paper ICC profile is in flat mode so that we can differentiate between two profiles. From above figure we can see that gamut for coated offset paper profile is much higher than the uncoated offset paper.

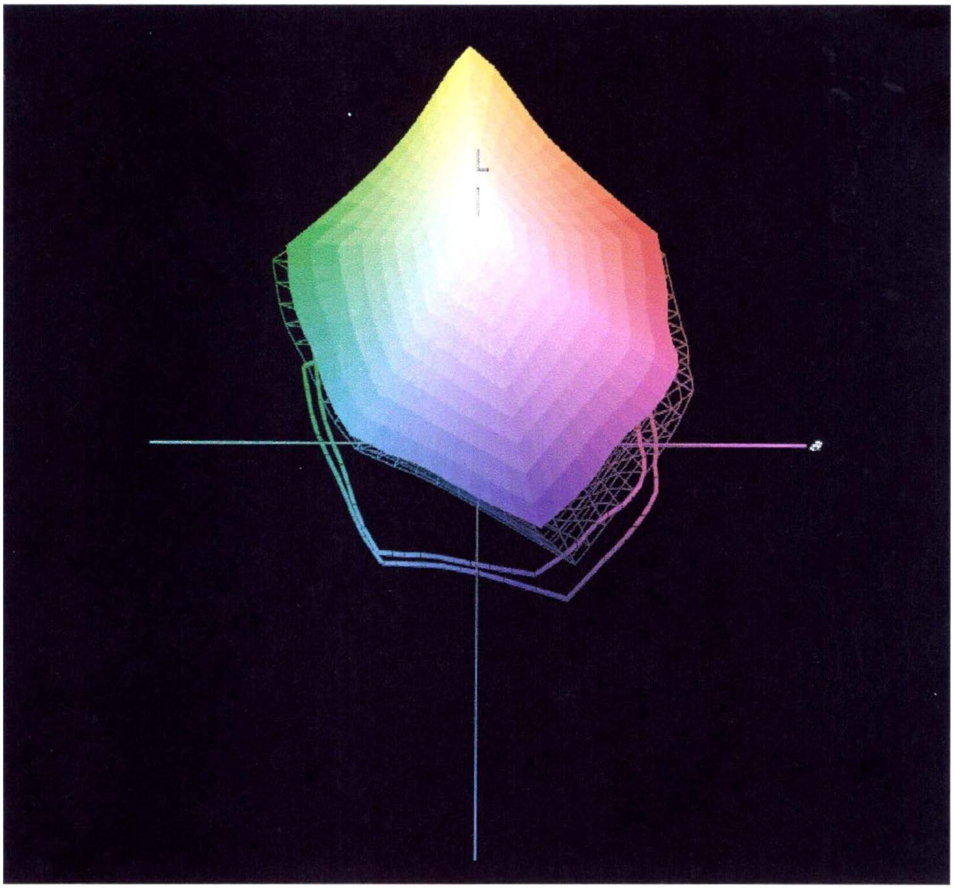

Figure 12. 3D Gamut View for HP Matte Coated and HP Coated High Gloss Paper ICC Profile

Figure 12 shows the 3D gamut view for HP coated and HP coated high gloss paper ICC Profile. The gamut for HP coated high gloss profile is in wire frame mode and for HP matte coated paper profile is in flat mode so that the differences between the two profiles can be determined. From Figure 12 it is clear that the gamut for HP coated high gloss paper ICC profile is slightly higher than for HP coated paper profile.

coated high gloss paper ICC profile is slightly higher than for HP coated paper profile.

Reflective Density (X-Rite 408 Reflection Densitometer)

X-Rite (408) reflection densitometer is used to measure reflective density of black, cyan magenta and yellow ink on various substrates. The measured density values for black ink on various substrates are given in Table 7.

Table 7. Reflective Densities for Black Ink for Various Substrates

Tonal Step	Uncoated Offset	Coated Offset	HP Coated	HP High Gloss	Tex Uncoated	Tex Glossy	Tex Premium
5	0.10	0.10	0.15	0.17	0.12	0.10	0.07
10	0.15	0.17	0.2	0.22	0.15	0.13	0.1
15	0.17	0.20	0.24	0.25	0.18	0.17	0.12
20	0.18	0.25	0.28	0.3	0.21	0.22	0.18
25	0.20	0.32	0.33	0.35	0.26	0.28	0.23
30	0.23	0.38	0.38	0.40	0.31	0.34	0.29
35	0.25	0.45	0.44	0.44	0.36	0.41	0.37
40	0.28	0.54	0.47	0.52	0.4	0.47	0.42
45	0.34	0.63	0.53	0.56	0.48	0.52	0.49
50	0.38	0.74	0.6	0.62	0.54	0.61	0.56
55	0.50	0.78	0.65	0.67	0.65	0.7	0.65
60	0.55	0.85	0.74	0.77	0.74	0.81	0.77
65	0.59	0.94	0.81	0.82	0.82	0.92	0.92
70	0.66	1.08	0.87	0.89	0.85	0.97	0.94
75	0.75	1.19	0.98	0.99	0.93	1.05	1.03
80	0.86	1.26	1.06	1.08	1.09	1.23	1.22
85	0.96	1.34	1.19	1.1	1.33	1.39	1.38
90	1.00	1.45	1.42	1.37	1.41	1.43	1.42
95	1.11	1.54	1.68	1.59	1.51	1.52	1.55
98	1.20	1.60	1.76	1.61	1.59	1.60	1.63
100	1.25	1.66	1.77	1.59	1.61	1.68	1.66

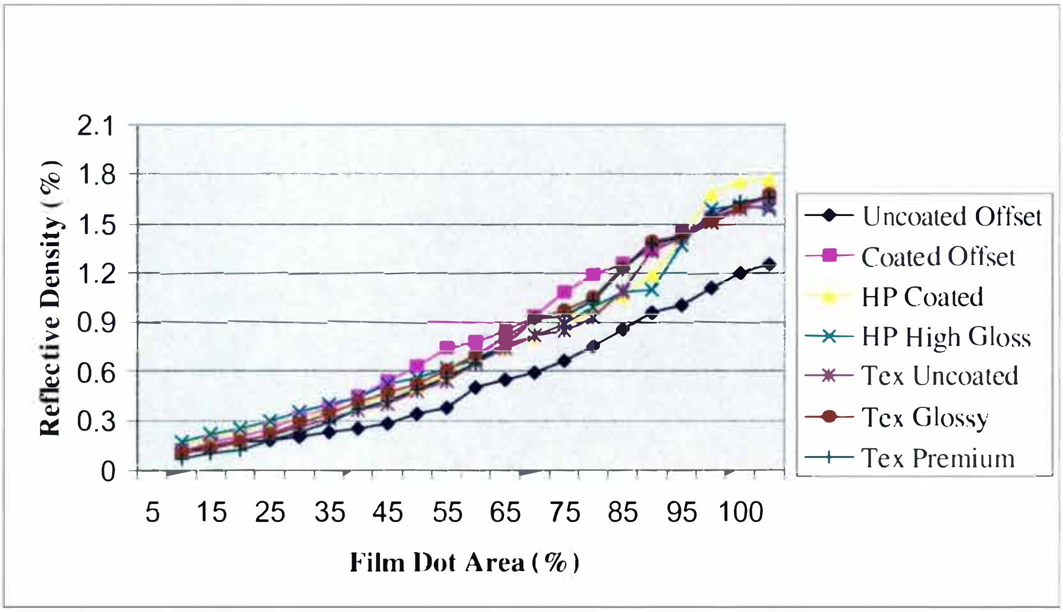

Figure 13. Tone Curve for Black Ink on Various Substrates

From Table 7 the figure 13 is generated to represent Tone Curve for black ink on various substrates. From figure 13 it seems that there is a gradual increase in density with respect to increase in film dot area, which is expected. Uncoated offset paper shows less increase in density compared to other substrates while Coated offset paper shows the high increase in density compared to other substrates with respect to increase in film dot area.

The measured density values for cyan ink on various substrates are shown in Table 8.

Table 8. Reflective Densities for Cyan Ink for Various Substrates

Tonal Step	Uncoated Offset	Coated Offset	HP Coated	HP High Gloss	Tex Uncoated	Tex Glossy	Tex Premium
5	0.10	0.06	0.13	0.13	0.14	0.12	0.09
10	0.15	0.11	0.18	0.16	0.17	0.16	0.13
15	0.18	0.13	0.20	0.20	0.21	0.21	0.18
20	0.22	0.14	0.24	0.23	0.28	0.28	0.25
25	0.25	0.17	0.27	0.26	0.34	0.36	0.31
30	0.3	0.22	0.3	0.29	0.42	0.43	0.41
35	0.35	0.26	0.34	0.33	0.48	0.50	0.51
40	0.39	0.30	0.38	0.36	0.58	0.59	0.6
45	0.43	0.35	0.42	0.41	0.71	0.7	0.71
50	0.48	0.39	0.46	0.45	0.8	0.81	0.81
55	0.55	0.52	0.51	0.49	0.89	0.91	0.92
60	0.59	0.58	0.56	0.53	1.03	1.07	1.08
65	0.63	0.64	0.60	0.58	1.15	1.16	1.19
70	0.67	0.70	0.66	0.63	1.26	1.24	1.29
75	0.73	0.81	0.73	0.68	1.27	1.36	1.38
80	0.79	0.90	0.8	0.74	1.41	1.38	1.42
85	0.84	1.01	0.87	0.81	1.40	1.40	1.41
90	0.85	1.13	0.97	0.89	1.41	1.40	1.42
95	0.97	1.25	1.07	0.95	1.34	1.41	1.41
98	0.97	1.30	1.14	0.98	1.39	1.42	1.42
100	0.98	1.33	1.15	1.00	1.43	1.43	1.43

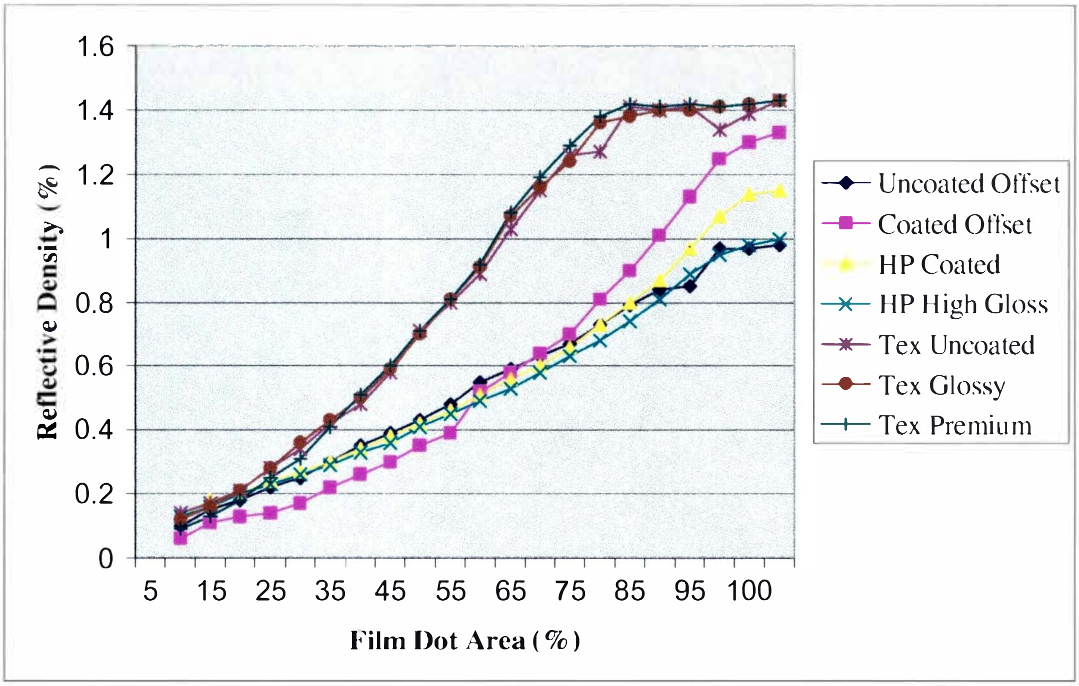

Figure 14. Tone Curve for Cyan Ink on Various Substrates

From table 8 the figure 14 is generated to represent Tone Curve for the cyan ink on various substrates. From figure 14, it seems that there is a gradual increase in density with respect to increase in film dot area. HP Coated paper shows less increase in density compared to other substrates while Tektronix Glossy paper shows a high increase in density compared to other substrates with respect to increase in film dot area.

The measured density values for magenta ink for various substrates are shown in Table 9.

Table 9. Reflective Densities for Magenta Ink for Various Substrates

Tonal Step	Uncoated Offset	Coated Offset	HP Coated	HP High Gloss	Tex Uncoated	Tex Glossy	Tex Premium
5	0.08	0.07	0.12	0.10	0.12	0.09	0.08
10	0.12	0.10	0.15	0.14	0.15	0.13	0.10
15	0.14	0.11	0.18	0.16	0.18	0.17	0.14
20	0.14	0.14	0.21	0.19	0.23	0.22	0.20
25	0.17	0.17	0.25	0.23	0.27	0.27	0.24
30	0.20	0.21	0.28	0.25	0.32	0.32	0.30
35	0.22	0.25	0.31	0.28	0.38	0.37	0.36
40	0.26	0.28	0.35	0.32	0.44	0.42	0.43
45	0.30	0.34	0.38	0.36	0.5	0.48	0.50
50	0.31	0.38	0.42	0.39	0.58	0.56	0.56
55	0.41	0.49	0.46	0.44	0.65	0.62	0.64
60	0.44	0.59	0.51	0.48	0.73	0.72	0.75
65	0.54	0.65	0.56	0.52	0.82	0.78	0.82
70	0.56	0.68	0.61	0.57	0.9	0.86	0.9
75	0.61	0.79	0.67	0.62	1.01	0.96	0.94
80	0.70	0.88	0.74	0.67	1.01	0.97	0.96
85	0.77	1.00	0.81	0.73	1.02	0.97	0.98
90	0.85	1.11	0.90	0.80	1.03	1.00	0.99
95	0.95	1.31	0.99	0.86	1.03	1.01	0.99
98	0.98	1.42	1.04	0.89	1.05	1.03	1.00
100	1.00	1.51	1.06	0.90	1.05	1.04	1.00

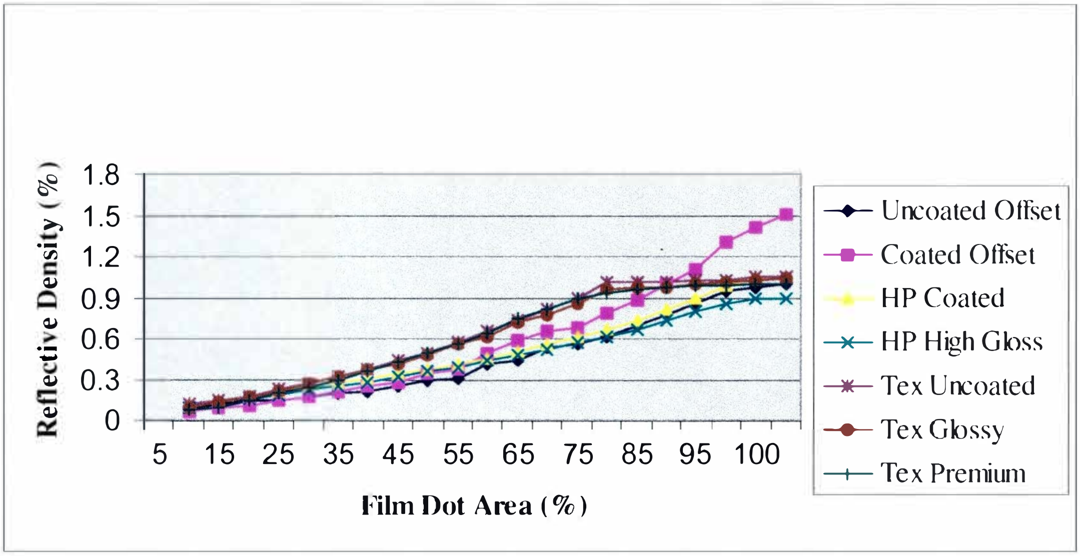

Figure 15. Tone Curve for Magenta Ink on Various Substrates

From Table 9 a tonal curve was generated for magenta ink on various substrates as shown in figure 15. HP high gloss paper shows less increase in density compared to other substrates while Tektronix glossy paper shows the high increase in density compared to other substrates with respect to increase in film dot area.

The measured density values for yellow ink on various substrates are shown in table 10.

Table 10. Reflective Densities for Yellow Ink for Various Substrates

Tonal Step	Uncoated Offset	Coated Offset	HP Coated	HP High Gloss	Tex Uncoated	Tex Glossy	Tex Premium
5	0.06	0.05	0.07	0.07	0.09	0.08	0.04
10	0.07	0.06	0.08	0.09	0.1	0.09	0.05

Table 10 – Continued

Tonal Step	Uncoated Offset	Coated Offset	HP Coated	HP High Gloss	Tex Uncoated	Tex Glossy	Tex Premium
15	0.09	0.07	0.09	0.12	0.15	0.14	0.08
20	0.13	0.09	0.12	0.15	0.2	0.2	0.15
25	0.15	0.12	0.15	0.19	0.26	0.27	0.22
30	0.18	0.16	0.18	0.22	0.31	0.34	0.29
35	0.21	0.2	0.21	0.26	0.39	0.41	0.36
40	0.26	0.23	0.24	0.30	0.47	0.49	0.46
45	0.29	0.27	0.29	0.35	0.56	0.58	0.58
50	0.33	0.33	0.32	0.39	0.64	0.64	0.65
55	0.41	0.41	0.37	0.44	0.70	0.69	0.71
60	0.45	0.45	0.41	0.48	0.79	0.77	0.79
65	0.51	0.5	0.46	0.54	0.85	0.82	0.85
70	0.55	0.54	0.5	0.59	0.88	0.84	0.87
75	0.62	0.61	0.55	0.66	0.93	0.89	0.91
80	0.66	0.68	0.61	0.71	0.94	0.9	0.92
85	0.7	0.75	0.67	0.77	0.95	0.91	0.93
90	0.76	0.81	0.74	0.85	0.95	0.92	0.93
95	0.86	0.93	0.82	0.93	0.96	0.92	0.94
98	0.86	0.98	0.86	0.97	0.97	0.94	0.96
100	0.87	1.00	0.89	0.99	0.98	0.98	0.98

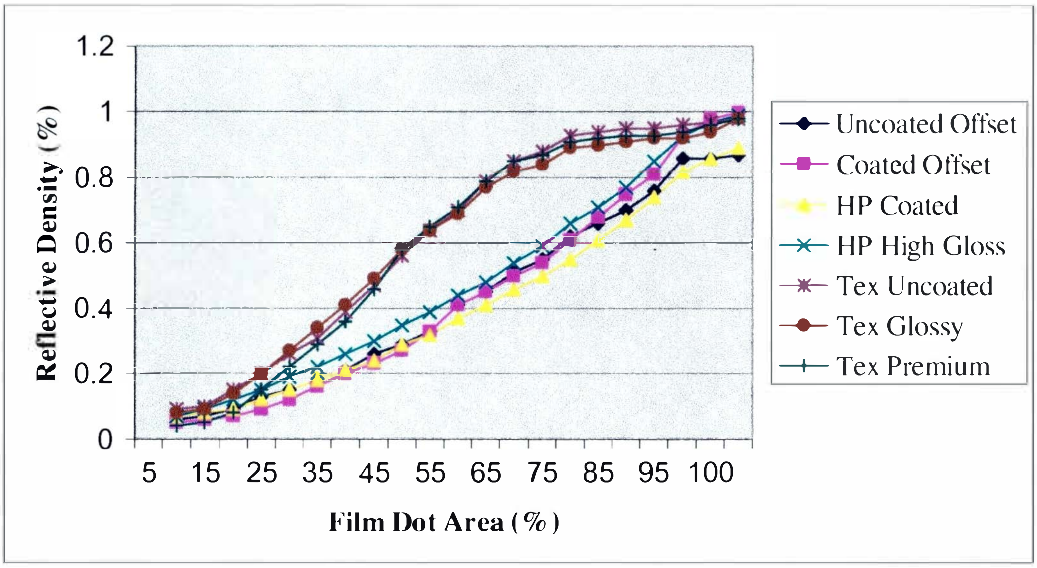

Figure 16. Tone Curve for Yellow Ink on Various Substrates

From Table 10 a tonal curve was generated for yellow ink on various substrates as shown in figure 16. The HP coated paper shows a slight increase in density compared to other substrates. The Tektronix glossy paper shows a high increase in density compared to other substrates.

Specular Gloss (Gardener Gloss Meter)

A Gardener Gloss Meter was used to measures the specular gloss at 60^0 degree and at 75^0 degree for various substrates. Generally printers measure specular gloss at 60^0 degree while paper maker's measures specular gloss at 75^0 degree.

The measured specular gloss value at 60^0 degree for different inks on various substrates is shown in Table 11.

Table 11. Specular Gloss Measured at 60^0 Degree for Various Substrates

	PAPER		BLACK		CYAN		MAGENTA		YELLOW	
	AVG	S.DEV	AVG	S.DEV	AVG	S.DEV	AVG	S.DEV	AVG	S.DEV
Uncoated Offset	3.36	0.05	4.8	0.29	3.28	0.26	3.4	0.29	3.68	0.31
Coated Offset	30.1	0.21	44.02	0.32	26.8	0.07	31.96	1.93	33.32	0.31
HP Coated	31.18	0.16	28.54	0.35	29.32	0.08	35.46	0.16	33.9	0.41
HP High Gloss	41.02	0.23	63.04	0.05	63.82	0.49	70.56	0.78	81.10	1.47
Tex Glossy	17.78	0.13	29.08	0.08	31.3	0.10	29.04	0.05	29.70	0.10
Tex Uncoated	3.66	0.05	23.1	0.10	21.68	0.13	21.56	0.15	22.94	0.15
Tex Premium	4.92	0.19	24.12	0.08	27.12	0.14	27.38	0.21	32.74	0.05

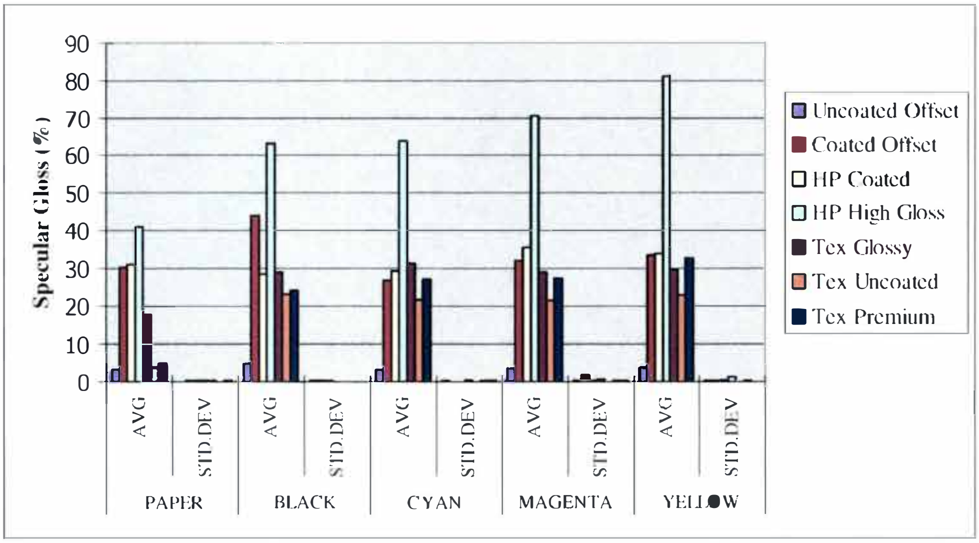

Figure 17. Specular Gloss at 60^0 Degree Geometry

From the table 11, the figure 17 is generated to represent specular gloss at 60^0 degree, for the different average paper gloss values, ink gloss values and standard deviation for various substrates. The average value for specular gloss with respect to paper, black ink, cyan ink, magenta ink and black ink is highest for the HP high gloss paper and lowest for uncoated offset paper.

Table 12. Delta Gloss at 60^0 Degree for Various Substrates

Delta Gloss at 60 degree				
Paper	Black	Cyan	Magenta	Yellow
Uncoated Offset	1.44	-0.08	0.04	0.32
Coated Offset	13.92	-3.30	1.86	3.22
HP Coated	-2.64	-1.86	4.28	2.72
HP High Gloss	22.02	22.80	29.54	40.08
Tektronix Glossy	11.30	13.52	11.26	11.92
Tektronix Uncoated	19.44	18.02	17.90	19.28
Tektronix Premium	19.20	22.20	22.46	27.82

Table 12 shows the calculated values for delta gloss at 60^0 for various substrates. Delta gloss is calculated using formula, (print gloss – paper gloss). The negative values fro coated offset paper and HP coated paper means that paper gloss is higher than print gloss. The highest value for delta gloss was obtained for yellow ink on HP high gloss paper and lowest value for delta gloss was obtained for Hp coated offset paper.

Table 13. Specular Gloss Measured at 75^0 Degree for Various Substrates

	PAPER		BLACK		CYAN		MAGENTA		YELLOW	
	AVG	S.DEV	AVG	S.DEV	AVG	S.DEV	AVG	S.DEV	AVG	S.DEV
Uncoated Offset	10.96	0.08	21.98	1.23	20.56	0.95	16.30	0.98	20.98	0.35
Coated Offset	65.30	0.85	73.07	3.22	73.28	2.15	75.72	0.32	67.36	0.83
HP Coated	67.6	1.07	74.38	3.95	72.70	0.08	78.42	0.19	80.76	0.83
HP High Gloss	73.08	2.71	86.6	1.084	84.46	0.73	75.64	1.415	85.64	4.65
Tex Glossy	55.44	1.21	62.90	0.43	69.88	5.50	62.60	3.20	63.46	3.01
Tex Uncoated	12.44	0.56	59.84	0.58	52.24	0.08	58.76	1.692	61.84	1.74
Tex Premium	17.70	0.32	62.00	0.84	67.08	2.40	66.70	1.90	70.02	0.63

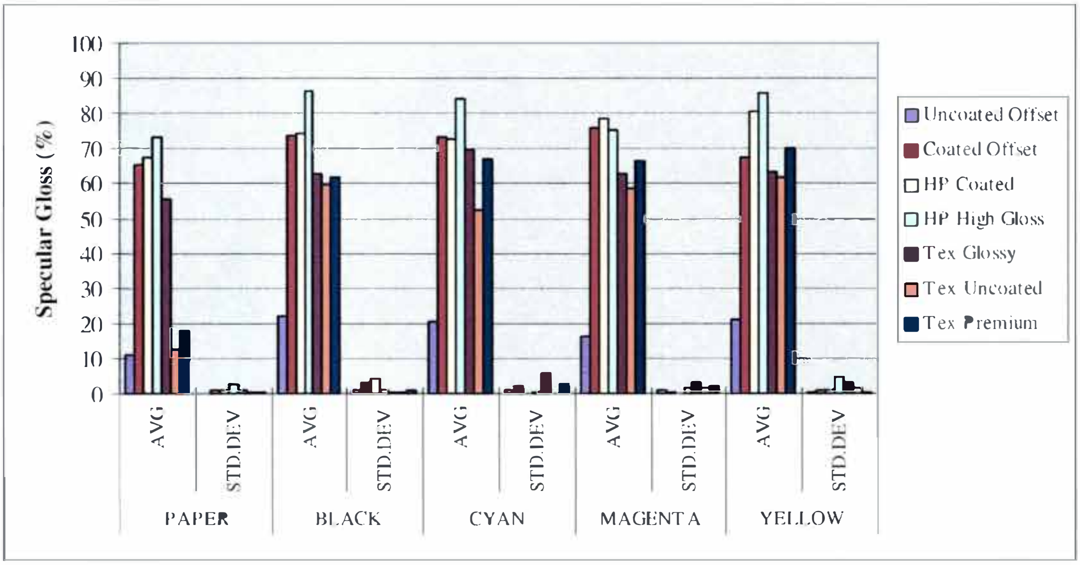

Figure 18. Specular Gloss at 75^0 Degree Geometry

Figure 18. Specular Gloss at 75^0 Degree Geometry

From the Table 13 the figure 18 is generated to represent specular gloss at 75^0 degree, for the different average paper gloss values, ink gloss values and standard deviation for various substrates. The average value for specular gloss with respect to paper, black ink, cyan ink, magenta ink and black ink. The highest Specular gloss was measured for the HP high gloss paper and the lowest for uncoated offset paper.

Table 14. Delta Gloss at 75^0 Degree for Various Substrates

Delta Gloss at 75^0 Degree				
Paper	Black	Cyan	Magenta	Yellow
Uncoated Offset	11.02	9.60	5.34	10.02
Coated Offset	8.40	7.98	10.42	2.06
HP Coated	6.78	5.10	10.82	13.16
HP High Gloss	13.52	11.38	2.56	12.56
Tektronix Glossy	7.46	14.44	7.16	8.02
Tektronix Uncoated	47.40	39.8	46.32	49.40
Tektronix Premium	44.30	49.38	49.00	52.32

Table 14 shows the calculated values for delta gloss at 75^0 degree for various substrates. The highest delta gloss value was obtained for yellow ink on Tektronix premium paper and lowest delta gloss value was obtained for magenta ink on HP high gloss paper.

Ink Mottle (TOBIAS Mottle Tester)

Ink mottle is determined with the help of Tobias mottle tester, we took 20 scan for each sample to determine mottle index. Mottle is unevenness in print density or print gloss. Mottle is also a measure the substrate's ability to produce a uniform flat printed tint. The mottle index for each ink with respect to substrate is shown in table 15.

Table 15. Mottle Index for Various Substrates

Mottle Index								
	BLACK		CYAN		MAGENTA		YELLOW	
	AVG	STD.DEV	AVG	STD.DEV	AVG	STD.DEV	AVG	STD.DEV
Uncoated Offset	384	30	237	24	294	26	157	20
Coated Offset	359	35	228	15	229	32	145	20
HP Coated	708	44	184	15	278	22	133	21
HP High Gloss	689	57	166	10	232	20	157	18
Tex Glossy	336	32	171	17	219	21	161	17
Tex Uncoated	329	21	262	25	261	20	170	12
Tex Premium	379	26	188	14	192	13	182	26

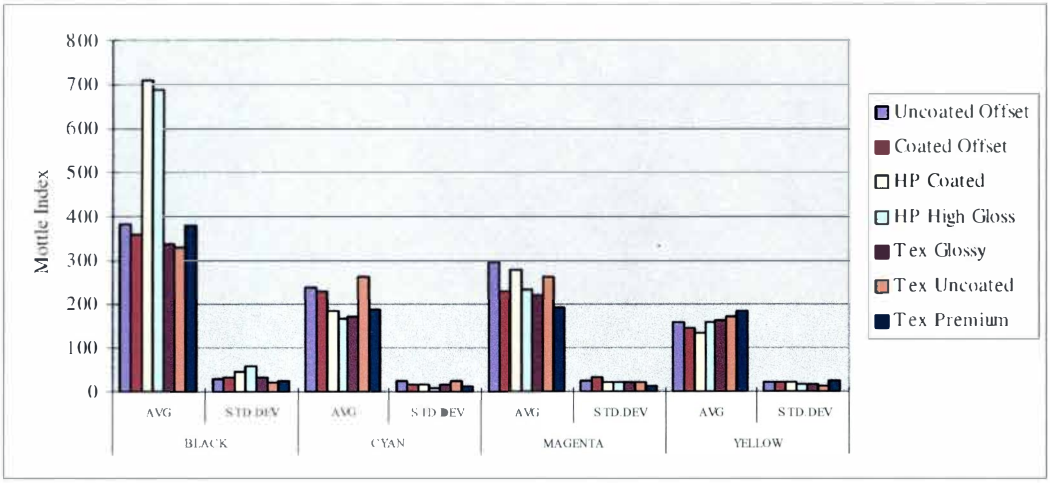

Figure 19. Mottle for Various Substrates

Figure 19 shows the mottle index of black ink for the HP coated paper is highest and lowest for Tektronix uncoated paper. For cyan ink the mottle index for Tektronix uncoated paper is highest and lowest for HP high gloss paper. For magenta ink the mottle index for Uncoated offset paper is highest and lowest for Tektronix premium paper. For yellow ink the mottle index for Tektronix premium paper is highest and lowest for Uncoated offset paper.

Print Contrast

Print contrast measures how well shadow detail is maintained on a printed sheet. It is a ratio of the 75% screen dot density to solid density and it is calculated as follows:

$$PC = D_s - D_{75} / Ds * 100$$

The table 8 shows the print contrast calculated by above formula for different inks for various substrates.

Table 16. Print Contrast for CMYK on Various Substrates

Print Contrast				
	BLACK	CYAN	MAGENTA	YELLOW
Uncoated Offset	38.05	25.51	39	28.73
Coated Offset	39.00	39.09	47.68	39.00
HP Coated	44.63	36.52	36.79	38.2
HP High Gloss	37.73	32.00	31.11	33.33
Tex Uncoated	42.23	11.18	3.8	5.10
Tex Glossy	37.50	4.89	7.69	9.18
Tex Premium	37.95	3.49	6.00	7.14

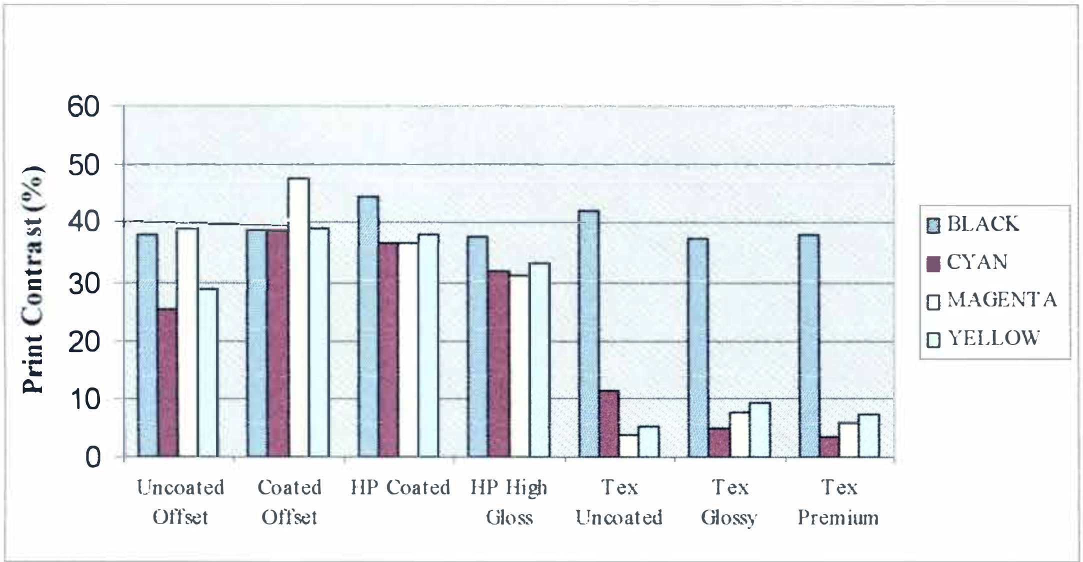

Figure 20. Print Contrast for Various Substrates

In Figure 20, the black ink the HP coated paper has high print contrast value while the Tektronix gloss paper has low print contrast value. For cyan ink the coated offset paper has high print contrast value while the Tektronix premium paper has low print contrast value. For magenta ink the coated offset paper has high print contrast value while the Tektronix uncoated paper has low print contrast value. For yellow ink the coated offset paper has high print contrast value while the Tektronix uncoated paper has low print contrast value.

Ink Trapping

The phenomenon of trapping (ink acceptance) occurs in multi-color printing when the inks are overprinted, less ink is transferred onto an existing layer of ink than onto a blank sheet. Where 100% corresponds to the quantity of ink transferred to a blank sheet. Trapping values are typically less than 100% especially in wet-on-wet printing, where the value can be less than 70%.

Trapping values yielded by a color reflection densitometer are not absolute measurements, but depends strongly on the characteristic of the color filters actually used. A set of three measurements has to be taken using the filter of the second printed color and always in the sequence:

1. First printed color
2. Second printed color
3. Overprint

For example Cyan + Magenta, solid density of cyan (D1), solid density of magenta (D2), solid density of overprint cyan + magenta (D12), filter for above measurement is magenta filter. Calculations are done by Preucil formula, which is as follows

Trapping= D12-D1/D2*100(%)

Ink trapping is calculated by the above formula for each substrate with respect to red trap, green trap and blue trap is shown in table 17.

Table 17. Ink Trap on Various Substrates

SUBSTRATES	RED TRAP		GREEN TRAP		BLUE TRAP	
	AVG	STD.DEV	AVG	STD.DEV	AVG	STD.DEV
Uncoated Offset	14.05	3.89	3.79	2.56	7.36	4.38
Coated Offset	13.62	3.33	4.96	1.35	10.17	2.16
HP Coated	32.40	5.31	42.40	2.30	32.78	1.35
HP High Gloss	78.27	2.01	41.17	1.38	22.38	1.44
Tex Glossy	12.04	1.17	6.23	2.06	3.59	1.50
Tex Uncoated	13.14	0.43	22.79	0.52	20.86	0.47
Tex Premium	12.29	0.87	20.41	0.57	18.70	0.47

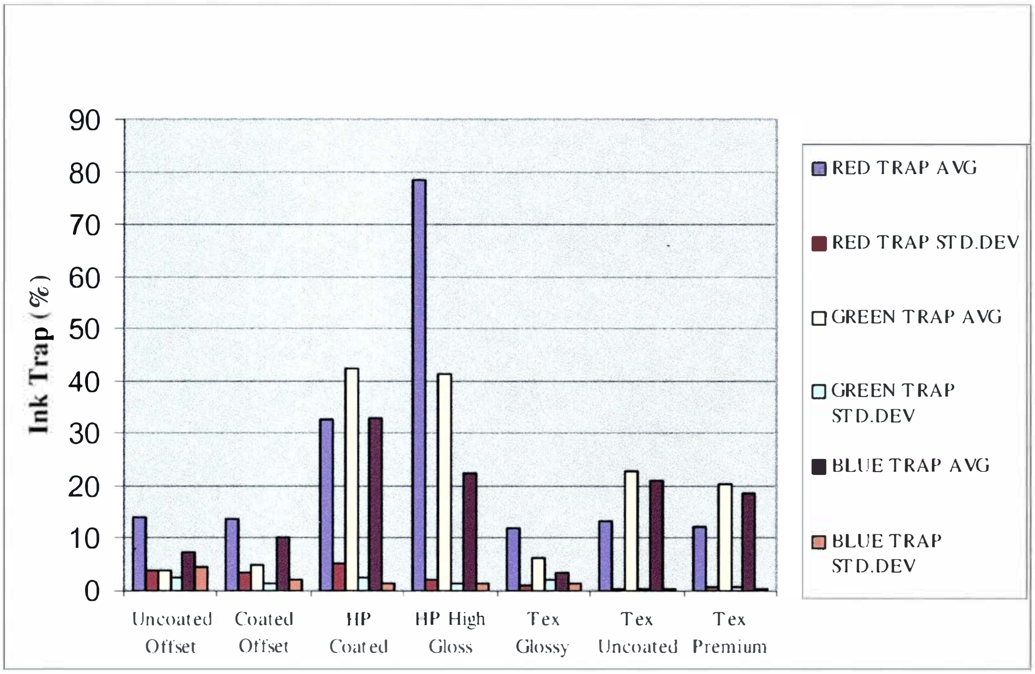

Figure 21. Ink Trapping on Various Substrates

From figure 21 it seems that with respect to red trap it is highest on HP high gloss paper and lowest on Tektronix glossy paper. For green trap it is highest on HP coated paper and lowest on uncoated offset paper. For blue trap it is highest on HP coated paper and lowest on Tektronix glossy paper.

<u>Image Analysis (IMAGEXPERT 9.1)</u>

An Image analysis to be done at 15 % tone by means of IMAGEXPERT 9.1

Image analysis with respect to roundness, dot area and dot gain is shown in table 18.

Table 18. Image Analysis for Various Substrates

	CYAN			MAGENTA			YELLOW		
	ROUNDNESS	DOT AREA	DOT GAIN	ROUNDNESS	DOT AREA	DOT GAIN	ROUNDNESS	DOT AREA	DOT GAIN
Uncoated Offset	0.63	16.07	1.07	0.69	17.46	2.46	0.73	23.44	8.44
Coated Offset	0.68	16.71	1.71	0.65	18.55	3.55	0.86	16.16	1.16
HP Coated	0.63	17.65	2.65	0.80	25.55	10.60	0.47	15.78	0.78
HP High Gloss	0.45	15.86	0.86	0.70	16.19	1.19	0.96	15.89	0.81
Tex Glossy	0.66	16.43	1.43	0.67	18.28	3.28	0.67	18.15	3.15
Tex Uncoated	0.80	18.13	3.93	0.54	29.24	14.20	0.71	21.59	6.57
Tex Premium	0.53	26.29	11.30	0.71	26.82	11.80	0.93	31.79	16.80

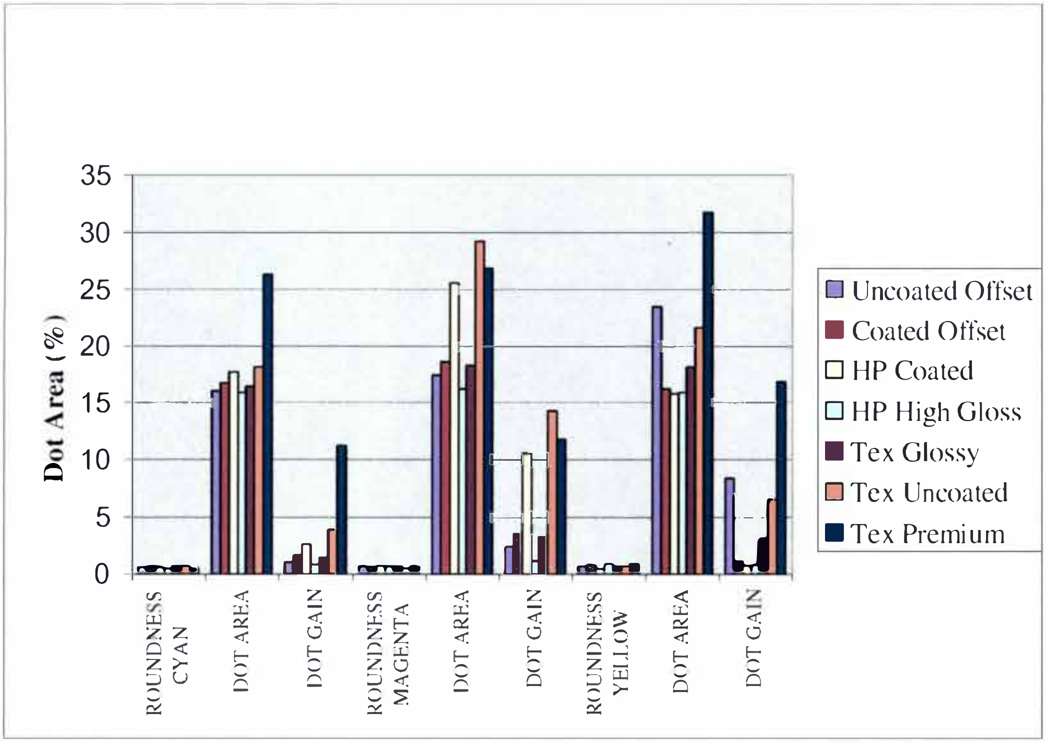

Figure 22. Image Analysis at 15% Dot

From figure 22 it seems that for the cyan ink dot, the roundness value is higher for Tektronix uncoated paper while lower for HP high gloss paper, with respect to dot gain is highest on Tektronix premium paper and lowest on uncoated offset paper. For the magenta ink dot, the roundness value is higher for Tektronix premium paper and lower for Tektronix uncoated paper, with respect to dot gain is highest on Tektronix uncoated paper and lowest on HP high gloss paper. For yellow ink dot the roundness value is higher for Tektronix premium paper and lower for HP coated paper, with respect to dot gain is highest on Tektronix premium paper and lowest on HP coated paper.

Dot Gain

Darkening of halftone image due to ink absorption in paper causing halftone dots to enlarge. It is a defect that occurs in the reproduction process in which dot print larger than they should, causing darker tones or colors. Dot gain to be measured by Murray Davis equation

Murray Davis Equation = $1\text{-}10^{-tint}/1\text{-}10^{solid} * 100$ – Nominal dot area.

By X-Rite 408 Reflection Densitometer we will measure total dot area. To calculate dot gain by formula following equation will be used,

Dot Gain = Total Dot Area – Nominal Dot Area.

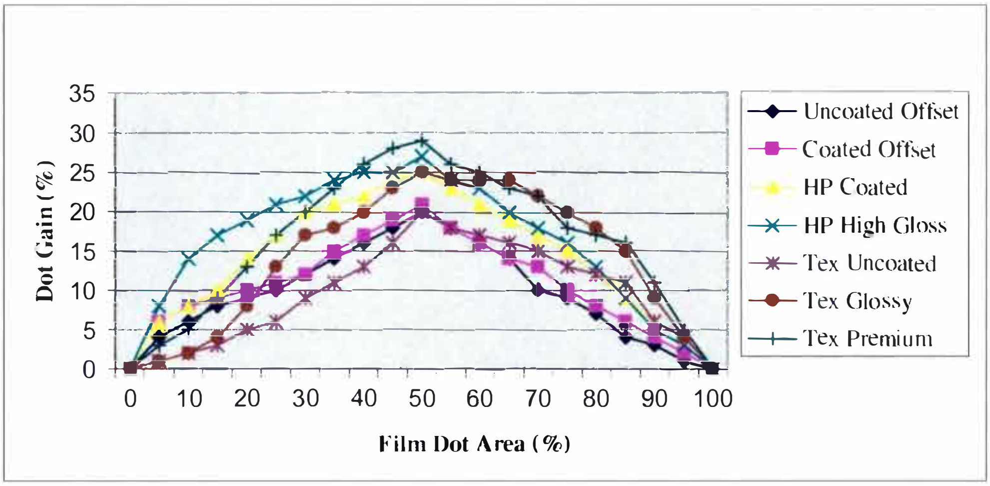

Figure 23. Dot Gain for Black Ink for Various Substrates

Figure 23 shows the dot gain for black ink for various substrates. For HP high gloss paper the dot gain is highest compared to other substrates and lowest for Tektronix uncoated paper.

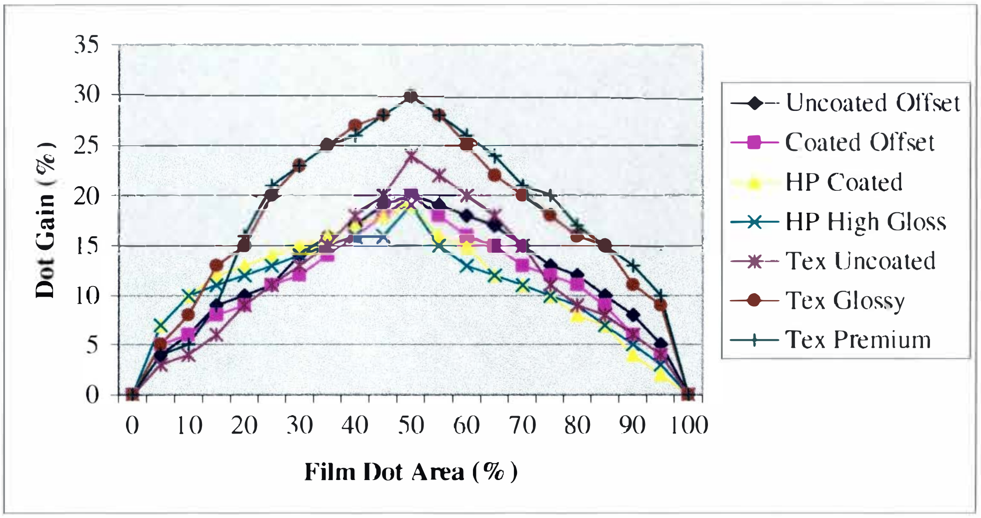

Figure 24. Dot Gain for Cyan Ink for Various Substrates

Figure 24 shows the dot gain for cyan ink for various substrates. For Tektronix glossy paper the dot gain is highest compared to other substrates and lowest for HP high gloss paper.

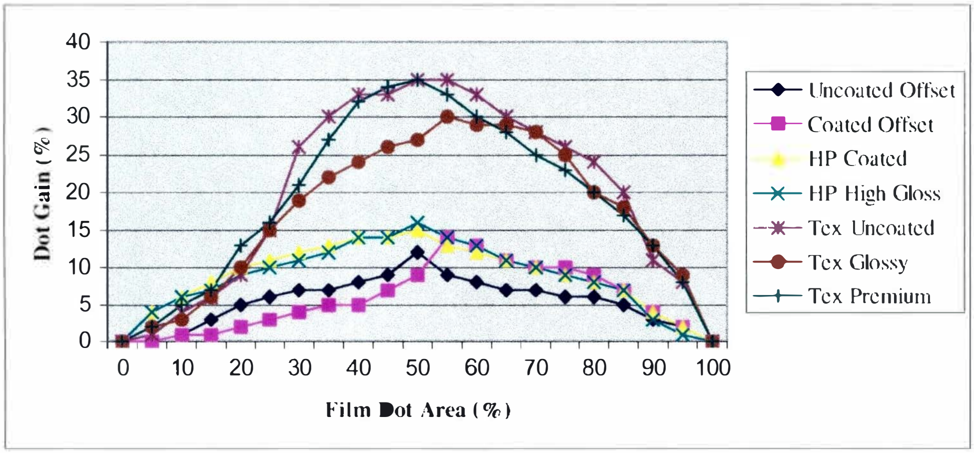

Figure 25. Dot Gain for Magenta Ink for Various Substrates

Figure 25 shows the dot gain for magenta ink for various substrates. For Tektronix uncoated paper the dot gain is highest compared to other substrates and lowest for uncoated offset paper.

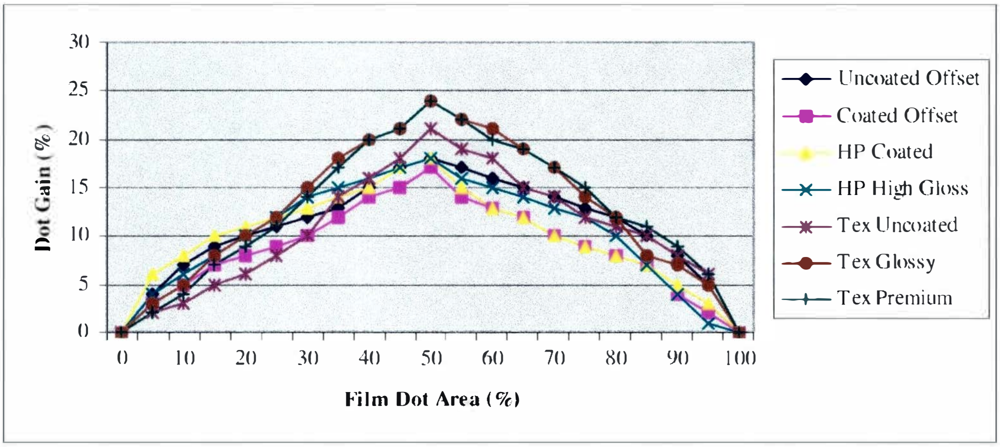

Figure 26. Dot Gain for Yellow Ink for Various Substrates

Figure 26 shows the dot gain for yellow ink for various substrates. For Tektronix glossy paper the dot gain is highest compared to other substrates and lowest for coated offset paper.

CHAPTER 13

CONCLUSIONS

The ICC Profiles for Shinohara two-color sheetfed offset, HP Designjet 755 CM, Tektronix Phaser 8200 were made for different substrates. The IT8 7.3 CMYK TIFF File was used to characterize the each printing device and ProfileMaker 4.1 was used to make the ICC Profiles. The ICC Profiles were successfully verified using a Macbeth Color Checker Chart. The gamut for each profile was viewed and compared in Chromix Color Think 2.1. A printability analysis was performed for each substrate to see how a particular paper interacts with a particular type of ink, which is important for quality color reproduction.

By using our custom made ICC Profiles one can save time, energy and labor cost for better color matching or quality color printing. The successful implementation of a custom made ICC Profiles is only possible by using the same substrate, type of ink and the printing device that were used for making the ICC Profiles, otherwise the ICC Profiles wont respond correctly or in other words, we have to create a new set of ICC Profiles for particular substrate, type of ink and the printing device.

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APPENDIX A

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