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A File preparation tutorial to digital printing for graphic designers

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A File Preparation Tutorial to Digital Printing for Graphic Designers

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Certificate of Approval

~

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Dedication

To my parents,
Samir & Rosa,
for so much love and support

A mis padres,
Samir & Rosa,
por tanto amor y apoyo

jose

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A File Preparation Tutorial for Digital Printing to Graphic Designers

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Abstract

Background and Significance

New technologies within the printing industry open new challenges, enable innovative ways of reaching prospective clients and bring ever more stringent demands to both graphic designers and printers. Printers must implement the emerging technologies that best suit their customers and the evolving needs of the marketplace; designers must acquaint themselves with new technologies and learn to design with respect to the output device to make best use of the equipment. A short step beyond desktop technology are digital printing systems, "the culmination of many technologies that have been in various stages of development for over 20 years and have finally caught up with each other."[1]

Digital printers are capable of printing "directly from digital information residing in an electronic file on a computer,"[2] "bypassing the multiple and time-consuming steps of film output, proofing, imposition and plate-making required by traditional methods."[3] As of today, digital printing is targeted to the short-run and on-demand segments of the industry. "Eventually, digital approaches will apply to just every facet of graphic communication, whether it has to a run of 1,000,000 or just one."[4]

Statement of The Problem

The all-time myth roaming in pressrooms that designers know nothing about printing is not entirely untrue. Often, a design is finished and approved in a studio without the minimal consideration for printing and finishing. The consolidation of a digital workflow today in the printing industry increases the need for designers to acknowledge printing in their brainstorming sessions to create designs that can be produced through emerging technologies. By doing so, they can reduce problems associated with file transfer and output such as missing images and typefaces. The ease of operation of digital presses that can receive a file and print much as a desktop printer does makes them highly attractive to designers and entrepreneurs, providing these a means for printing without all the makeready procedures associated with traditional printing processes.

Statement of The Project Goals

The purpose of this thesis project is to evaluate the color reproduction of digital printing systems most common in industry through the creation of a universal test instrument with respect to which all the systems will be compared. The results of the test will be used to assess the capabilities of the equipment and determine their ideal applications within the graphic communications industry. A file preparation and specification guide for each of the devices tested will be compiled.

The audience at which this study is targeted is graphic designers, who could benefit by learning about the advantages and disadvantages of the various systems and learning to design with these in mind. As a result, particular attention will be paid to the impact these emerging technologies have in designers' approach to producing their work.

This thesis project does not suggest the equipment to be tested is the best in the market-place. Its results, however, may be used in determining which system is most suitable for implementation.

Methodology

This thesis project will provide a color reproduction evaluation and comprehensive guides for designers to prepare and expedite files to the following digital presses:

- •Xeikon DCP-32D
- •Indigo E-Print 1000
- •Xerox DocuColor 40
- •Heidelberg Quickmaster-DI

The criterium defining the color reproduction evaluation and the elements used in the test instrument is the following:

> Graphic designers, the audience at which this thesis project is targeted, think in terms of memory colors; red, green, and blue. As a result, the elements comprising the test instrument will be those which designers deal with: text and images. The printed samples will be measured with a X-Rite 938 spectrodensitometer, and the results will be complemented with a visual evaluation done under standard lighting conditions.

Test Instrument

The test instrument will be comprised of the following:

- •CMYK patches and bars
- •4-color black patches
- •Images of different sources and resolutions
- •Line art
- •Type
- •Overprinting circles
- •Color bars
- •RIT Neutral Balance Target for SWOP
- •RIT 4-Color Spokes Target

Evaluation

- •Tone reproduction
- •Solid ink density
- •Total ink density
- •Gray balance
- •Dot gain
- •Resolution
- •Ghosting

The second part to this thesis project will involve the compilation of guides to expedite files to each output device. In addition, manufacturers' specifications will be collected to determine the requirements for preparing variable data printing documents.

ENDNOTES ABSTRACT

[1]DocuColor 40 product information, in Xerox Corporation Website; available from http://www.xerox.com/print/products/dc40/index.htm#productsummary; Internet; accessed 13 January 1999.

[2]Noel Jeffrey, *Digital Printing: A Guide to the New World of Graphic Communications* (Torrance, CA: Micro Publishing Press, 1996), 8.

[3]Xeikon DCP/32D product information, in Xeikon Website; available from http://www.xeikon.be/; Internet; accessed 10 March 1999.

[4]Frank J. Romano, *Pocket Guide to Digital Prepress* (Albany, NY: Delmar Publishers, 1996), 284.

Chapter One
Introduction

Background and Significance

New technologies within the printing industry open new challenges, enable innovative ways of reaching prospective clients and bring ever more stringent demands to both graphic designers and printers. Printers must implement the emerging technologies that best suit their customers and the evolving needs of the marketplace; designers must acquaint themselves with new technologies and learn to design with respect to the output device to make the best use of the equipment. "The creative area has been the most affected by desktop technology. Most art and design professionals now create their pages with desktop computers. It is the byproduct of this process that results in electronic pages."[1] A short step beyond desktop technology are digital printing systems, "the culmination of many technologies that have been in various stages of development for over 20 years and have finally caught up with each other."[2]

Digital printers are capable of printing "directly from digital information residing in an electronic file on a computer,"[3] "bypassing the multiple and time-consuming steps of film output, proofing, imposition and plate-making required by traditional methods."[4] As of today, digital printing is targeted to the short-run and on-demand segments of the industry. The majority of systems use electrophotography. A few others combine traditional methods like offset lithography with digital technology, creating presses that accept PostScript files, process plates on press and print, all in a single system. "Eventually, digital approaches will apply to just every facet of graphic communication, whether it has to a run of 1,000,000 or just one."[5]

Reasons of Interest

Interest in this topic is a result of the transition from being a graphic designer to becoming a printer. The relative ease with which digital presses can be operated provide many non-printers the possibility to engage in production. As such, acquainting oneself with new and revolutionary printing technologies allows learning about the advantages and disadvantages of the equipment, thus helping in the design process. "There are economies to be achieved for people who first select the process that best fits their job and then design their projects to take maximum advantage of the press size available to them."[6] One advantage of digital presses is that, unlike a conventional press, they require less makeready and eliminate all the painstaking and time-consuming procedures of outputting film, proofing, and platemaking. "Before digital presses existed, streamlined digital creative workflow and prepress production came to a screeching halt at the imagesetter, where labor- and chemically-intensive processes of generating film, image assembly, proofing, and platemaking had to be employed in order to get a project on press."[7] In addition, the physical characteristics of most digital presses allow for these to be operated in office environments, increasing the likelihood of advertising agencies, design studios, and others in the creative segment of the industry to engage in printing.

An exclusive advantage of digital printing is that some devices are capable of combining marketing databases with digital files at Raster Image Processor (RIP) level and printing personalized documents. For designers this translates to a myriad possibilities that enable the inception of individualized documents to target specific segments of the population; mass marketing is no longer the only viable solution.

Statement of The Problem

The all-time myth roaming in pressrooms that designers know nothing about printing is not entirely untrue. Often, a design is finished and approved in a studio without even minimal consideration for printing and finishing. The consolidation of a digital workflow today in the printing industry increases the need for designers to acknowledge printing in their brainstorming sessions to create designs that can be produced through emerging technologies. By doing so, they can reduce problems associated with file transfer and output such as missing images and typefaces.

"Because of the cost of making a set of plates, mounting them on the press, and running the press until the printing is in register and colors are correct, [traditional printing processes like offset lithography and gravure] had required fairly long press runs to be economically feasible."[8] "Addressing small target groups, a greater up-to-dateness of printed matter and minimum storage costs are all demands that are made on printed products [today]. Until recently these requirements were difficult or even impossible to meet."[9] Emerging technologies such as digital printing and computer-to-plate systems are meeting these demands.

The ease of operation of digital presses that can receive a file and print much like a desktop printer does makes them highly attractive to designers and entrepreneurs, providing these a means for printing without all the makeready procedures associated with traditional printing processes. "The familiar steps of generating and proofing film from an imagesetter and exposing that film for platemaking for the press simply disappear"[10] when using digital printing systems. Differentiation can be achieved by graphic designers who expand their commercial operations to include printing, obtaining a competitive advantage in the market and improving customer satisfaction. In the same way, many printers have expanded their prepress departments to offer graphic design solutions to their customers.

This thesis project will provide a color reproduction evaluation and comprehensive guides for designers to prepare and expedite files to the following digital presses:

- Xeikon DCP-32D
- Indigo E-Print 1000
- Xerox DocuColor 40
- Heidelberg Quickmaster-DI

The evaluation of the above listed equipment will be done by creating a universal test instrument that is to be printed on all devices using the same substrate. The test instrument will include text and images in ways that designers deal with to check for, among others, solid ink densities, registration, accuracy of memory colors, and text sharpness and inconsistencies.

Chapter One Endnotes

[1]Howard Fenton and Frank J. Romano, *On-Demand Printing: The Revolution in Digital and Customized Printing* (Pittsburgh, Pennsylvania: Graphic Arts Technical Foundation, 1995), 21.

[2]Michael H. Bruno, *A Summary of Digital Printing Systems* (Pittsburgh, PA: 1995), preface.

[3]Noel Jeffrey, *Digital Printing: A Guide to the New World of Graphic Communications* (Torrance, CA: 1996), 8.

[4]Xeikon DCP/32D product information, in Xeikon Website; available from http://www.xeikon.be/; Internet; accessed 10 March 1999.

[5]Frank J. Romano, *Pocket Guide to Digital Prepress* (Albany, NY: Delmar Publishers, 1996), 284.

[6]Noel Jeffrey, *Digital Printing: A Guide to the New World of Graphic Communications* (Torrance, CA: 1996), 16.

[7]Ibid., 12.

[8]Frank J. Romano, *Pocket Guide to Digital Prepress* (Albany, NY: Delmar Publishers, 1996), 37.

[9]Quickmaster-DI 46-4 product information, in HeidelbergUSA Website; available from http://www.heidelbergusa.com/03_pro/direct_imaging/qmdi.htm; Internet; accessed 13 January 1999.

[10]Noel Jeffrey, *Digital Printing: A Guide to the New World of Graphic Communications* (Torrance, CA: 1996), 11.

Chapter Two
Theoretical Basis

Digital Printing

There are as many definitions of this term as imaginable. Nevertheless, authors and manufacturers agree that digital printing involves a digital file, usually created in a page layout application, that can be directly expedited to an output device and printed without the need of film. "A more advanced definition of digital printing would be any printing that uses a rasterization process to produce image carriers or to replicate directly to substrate from digital document files."[1] "Without film and, in some instances, printing plates, [digital printing] has the potential for more faithful reproduction of the electronic file."[2]

How the image is transferred onto the substrate through digital processes can take place in various ways; the commercially predominant digital printing methods are electrophotography, digital offset, and direct-imaging offset lithography. The relative ease with which digital printing systems are operated provides designers and other non-printers the means to engage in production. Digital printing "combines the computer's ability to collect and manipulate text and image information in electronic form with the press's ability to deliver large numbers of high-quality printing pieces."[3]

The ideal applications for digital printing are:

"-very short and short-run full color projects
-printing on demand
-'distribute-then-print' projects
-rapid short-run work
-test marketing
-personalization"[4]

DIGITAL PRINTING PROCESSES

Electrophotography

"Electrophotography, as the name suggests, is a process in which an image can be reproduced by means of electricity and light. Commercially, the most significant invention in the field of electrophotography was the discovery of the process most commonly known as xerography."[5] Derived from the Greek, the word xerography means "dry writing". It was developed from original inventions in 1938 by Chester Carlson, a physicist and patent attorney. "Like many other great inventions, [the] financial and market success [of electrophotography] did not happen overnight. In fact, it was not until 1944 that Carlson persuaded Battelle Memorial Institute to conduct additional experiments with his process."[6]

"Xerography is arguably the most significant development in the field of electrophotography. [Carlson's] findings indicate the basic stages of the process:

•The photoconductor is first charged in the dark
•The plate is then partially exposed to illumination in order to produce an electrostatic image

•The image is then developed with a fine powder
•The developed image is transferred to the receiving substrate (paper, cloth, overhead transparency, etc.)
•The image is fixed to the substrate
•Discharge and cleaning of the photoconductor"[7]

"Although the basic concept proposed by Carlson had to undergo considerable refinement to produce a commercially viable product, modern photocopiers and laser printers still operate by the basic process established in the 1940s."[8] According to Professor Frank Romano in *Pocket Guide to Digital Prepress*, the electrophotographic process is subject to three deficiencies:

"1. Charge voltage decay between the time of charging the photoconductor, exposing, and toning can affect image density and tone reproduction, as the amount of toner transferred is dependent on the exact voltage of the charge on the image at the instant of toner transfer.
2. Toner chemistry is not completely understood, which can cause variations in batches of the same toner and high cost for formulating special toners.
3. In liquid toner systems, the isopar used to disperse the toner is a volatile organic compound which might require venting and is subject to environmental regulations."[9]

P. Gregory, editor of *Chemistry and Technology of Printing and Imaging Systems*, names cost the major limiting factor of electrophotography. Although fairly inexpensive for monochromatic printing, "when volumes become large enough, the cost of conventional printing technology is extremely competitive."[10]

The above mentioned disadvantages nonetheless, electrophotography is a dominant process in industry that enables variable data printing. Because the image carrier must be imaged for every copy printed, variable information can be merged with a master page. The Xeikon DCP-32D part of this thesis project is capable of variable data printing by having the master page RIPed once and merging the variable data on the fly during the print run. Fixed and variable data are independent, therefore the amount of variation is only limited by the file size of the run; the disk array of the system's front end computer is 32 GB.

Electrophotographic presses may be most appealing to designers among other digital printing systems because makeready is minimal. As is the case with the Xeikon DCP-32D and the Xerox DocuColor 40, the file is expedited, the press is brought to speed, and the printing process is initiated. The first print serves as the proof. If color adjustments are necessary, these are enabled by the software running the machine.

Digital Offset Technology

Digital offset, used by the Indigo E-Print 1000, involves transferring the image "from a plate to a blanket to the sheet of paper that moves between the blanket and the impression cylinder."[11] Unlike its name may suggest, this is an electrophotographic technology that uses "laser imaging, a special new liquid toner called ElectroInk, and essentially a single color offset press with plate, heated blanket and cold impression cylinders, paper pile infeed, pile delivery system, and means for turning prints over and printing the reverse side."[12] "However, unlike conventional offset printing, Digital Offset

Color printing creates a new ink image with each impression and—due to the unique qualities of Indigo's proprietary ElectroInk—leaves no residual ink on the blanket."[13] "According to Indigo, print from the E-Print has a better definition or acutance. The acutance is higher because there is no wicking or bleeding of the ink as it hits the paper, which occurs in a wet ink transfer."[14] In addition, ElectroInk is capable of approximating SWOP (view page 20 for definition) and other process color standards and is available in easy to handle cartridges that many users refer to as "spray cans."

ElectroInk "is a liquid ink that can be electrostatically charged to produce high resolution and high quality color images. Unlike xerographic toners, ElectroInk provides a density and richness of color directly comparable to offset print."[15] It "consists of micron-size pigment toners dispersed in a thermoplastic resin diluted in a light mineral oil (isopar). It is applied to the image on the photoconductor immediately after exposure by laser. The mineral oil is squeegeed from the surface of the imaging cylinder and returned to the toner reservoir, leaving just the toner/resin mixture on the image transferred to the heated blanket. This heated dispersion of toner pigment and resin sets when it transfers to the cold paper. . . . Because of the 100% ink transfer the plate is claimed to be clean and ready for the next image, which can be the same as the last one or a completely new image."[16] "When the ink contacts the paper, it hardens to a surface that peels away from the blanket completely. Since the ElectroInk particles are bonded to the surface of the paper, 'show through' to the other side of the sheet is minimized. This bonding also prevents dot gain because the ink is not mixing with water and flowing into the surface of the paper."[17]

Shortly after its introduction, "ElectroInk was found to have an erasability problem: the ink rubbed off the paper too easily."[18] "In conventional printing the ink binds with the paper. . . . The ElectroInk does not sink into the paper, and thus it has a lower degree of adherence."[19] "To Indigo's credit, the problem was acknowledged and a paper treatment, called saphire [*sic*] treatment, was developed to resolve the situation while the company worked on the ink itself."[20] Sapphire "is a pretreatment of the paper with a chemical. According to company officials, this process is not unlike to running the paper through a press with the water dampening on. This process may work by allowing the paper fibers to rise off the paper so the ElectroInk in the ink film stage adheres to the fibers."[21] Another issue with ElectroInk is that Indigo is the sole distributor of the ink. One distributor means only one price in a market devoid of competition.

Offset Lithography

Offset lithography is the major plate printing process in the industry which involves thin metal plates with the image and non-image areas essentially on the same plane. The two basic differences between lithography and other processes are:

1. Lithography is "based on the fact that oil and water do not mix
2. It uses the offset principle in which ink is offset from the plate to a rubber blanket on an intermediate cylinder, and from the blanket to the paper on an impression cylinder

"On a lithographic printing plate, the printing areas are oil- and ink-receptive and water repellent, and the non-printing areas are water-receptive and ink-repellent. When the plate mounted on the plate cylinder of the press is rotated, it comes into contact with rollers wet by a water or dampening solution and rollers wet by ink. The dampening solution wets the non-printing areas of the plate and prevents the ink from wetting these

areas. The ink wets the image areas which are transferred to the intermediate blanket cylinder. The inked image is transferred to the paper as it passes between the blanket cylinder and the impression cylinder. Letterpress and gravure can also be printed by the offset principle. But because most lithography is printed this way, the term offset has become synonymous with lithography.

"A main advantage of the offset principle is that the resilient rubber blanket produces a clearer impression on a wide variety of paper substrates and other materials with both rough and smooth textures. Also it increases plate life and reduces press makeready. Offset printing can be recognized by a smooth print without embossing, ink ring, or serrated edges which are characteristic of letterpress, flexography, gravure, and screen printing."[22]

"The offset press is responsible for four important advantages of lithography:

1. The rubber blanket surface conforms to irregular printing surfaces, resulting in the need for less pressure and makeready and improved print quality of text and halftones on rough surfaced papers
2. Paper does not contact the printing plate, increasing plate life and reducing abrasive wear
3. The image on the plate is right reading rather than reverse reading
4. Less ink is required for equal coverage, drying is speeded and smudging and set-off are reduced"[23]

Waterless Offset Lithography

Waterless offset lithography is a "method of printing that relies on special properties of the printing plate surface, rather than water-based dampening solution, to prevent ink from adhering to non-image areas. It prints with higher resolution of 200 to 600 dots per inch (dpi) and lower dot gain. Because the process does not require adjusting ink and water balance, it reduces makeready time and paper waste associated with makereadies"[24] allowing press operators to maintain a more consistent image. In addition, emulsification, the change of the ink character because of its contact with fountain solution, is eliminated. Consequently, the paper absorbs less ink and halftone dots are not distorted. Waterless offset lithography has several environmental benefits because the harsh chemicals associated with fountain solutions are avoided and the elimination of water reduces volatile organic compounds emitted into the air. On the other hand, "inks used with waterless offset require higher densities and tack"[25] and tight temperature control.

Waterless offset plates are comprised of "an aluminum base with a photopolymer or photosensitive layer, a silicon/rubber layer and [a] transparent membrane. The silicon layer repels ink, thus eliminating the need for the fountain solution used with traditional offset plates. . . . The plates physically separate the ink from non-image areas that support transfer of the dot image from plate to blanket, resulting in 30 to 50 percent less dot gain."[26]

Direct-Imaging Offset Lithography

Offset lithography presses with direct-imaging technology are capable of imaging digital information directly to plates mounted on press through emissions from laser beams that strike a rotating plate cylinder. The direct-imaging press included in this thesis project is

Heidelberg's Quickmaster DI, a waterless press rated at 10,000 sheets per minute. In its operation, "the Raster Image Processor (RIP) integrated in the Quickmaster DI [first] converts PostScript Level 2 data into bitmap files corresponding to the four-color separations. These are in turn used to control infrared laser diodes in the press. . . . The light emitted by the laser diodes is led via fiber-optic cables to lenses that focus them into a single, precise beam of light. This high-intensity beam burns very small, sharp-edged depressions in a special multilayer plate. . . . This reveals the underlying backing material which accepts ink. Everywhere else (in the non-image areas) the ink-repelling silicone layer remains intact."[27] The prepress procedures of outputting film and processing plates off-press are eliminated.

"The Quickmaster DI images all four color separations simultaneously in perfect register in just six minutes."[28] Speed is definitely one of the advantages of direct-imaging technology. Nevertheless, unlike electrophotographic digital presses, direct-imaging presses are not capable of producing personalized documents; once the plates are imaged, "the electronic information cannot be removed and changed after each impression is printed."[29]

COLORANTS

Toner

Toner is the thermoplastic imaging material used in electrophotography that consists of a resin, an ion-binding polymer, and at least one dye that has been complexed to the ion-binding polymer. Used for the first time in 1938 as a powder by electrophotography inventor Chester Carlson, toner "has stable triboelectrical characteristics for extended time periods and . . . an improved dispersion of the resin and wax [of which is made of]."[30] "Just as each conventional plate printing process requires different inks with special requirements, each digital plateless printing process uses different materials called toners with special characteristics."[31]

There are three kinds of toners:

DUAL COMPONENT

This is the most common type of toner in use today, made up of two parts—toner and carrier beads. The most common way of developing dual component toners is called cascade development, which is based on triboelectrification, "the process of exciting toner particles by causing an electric charge through the use of friction. The triboelectrification process causes excited toner particles to cling to beaded carriers."[32] Dual component toner "is used in over 90% of the current xerographic copiers and digital printers. Printers such as the Xeikon [DCP-32D] and the Xerox DocuTech use dual component toners for the development of their images."[33]

MONO COMPONENT

Mono component toners are different from dual component toners in that they require no carrier beads for development. Mono component toners can be charged by either induction, contacting, corona charging, ion beam, or traveling electric fields. The easiest and most commonly used method is induction charging, through which "a conducting particle sitting on a negative surface 7

becomes negatively charged. Because the opposite charges repel each other, the negatively charged particle is repelled by the negative plate and drawn to the positive plate. Through this process, particles lose their negative charges and become positively charged. Once toner particles become positively charged, they can be transferred to the substrate. This change in charge causes toner to move in an opposite direction of a magnetic roller forming a conductive path. It is then attracted to the latent image and adhered to the substrate by a photoreceptor and Coulomb force ['a measure of the amount of an electric current that passes a given point in a conductor in a given time'[34]]. Most low-end printers from Cannon, Ricoh, Xerox, and Toshiba use one of these mono component toner charging methods."[35]

LIQUID TONER

Liquid toners consist of toner and solvent, which replaces the developer present in other types of toners and causes it to be liquid instead of solid. "Liquid toner solvents are nonconductive and primarily made up of thermoplastic resin particles, which are suspended in a saturated hydrocarbon. In many respects, liquid development is related to or considered with powder-cloud development. In both cases, freely moving charged toner moves under the action of the electrostatic field."[36] "Currently, Indigo is the only major user of liquid toners; their printing devices account for over 90% of the liquid toner being used. [Marketed as ElectroInk,] Indigo's liquid toner consists of 1-2 μm toner particles suspended in a highly refined kerosene known as isopar, which acts as the controlling agent of the solution, by carrying the charge placed on it. The magnitude and polarity of the toner charge is critical. The charge on the toner must have the correct polarity or no development will occur. The magnitude of the charge is also critical because the development force is directly proportional to toner charge. Development will occur when the electrostatic development force exceeds the adhesive force."[37]

"Until 1978 when the first laser printer was introduced toners were used entirely for copying. Since the first 135 [pages per minute] laser printer was introduced in 1989 and two digital color presses in 1993, . . . these are more widely used than ion or electronic deposition, magnetography, thermal transfer, dye sublimation or electro-coagulation systems."[38] "The toner transfer efficiency of the printers and copiers is 85%. The 15% scrapped off the photoreceptor is waste. In the USA, around 21 million [pounds] of waste toner is disposed of annually. It is nontoxic and inert, so it is put into landfills. It resists ultraviolet light and being black, is unsightly. Economic incentive to recycle toner is minimal, and less than one percent of [U. S.] waste toner is recycled. Because of low volume and unreliability, recycling options are local and limited."[39]

Process Inks

"In general, all [process] inks consist of pigments, resin vehicles in which the pigment is dispersed, solvents or other fluids to control body and other additives to induce drying and/or impart necessary working properties to the inks."[40] The most important properties of ink are:

COLOR

"Color and other optical properties like opacity or transparency are imparted to inks by pigments which are finely divided solid materials. Some pigments such

as alumina hydrate, chrome yellow and iron blues are inorganic but most of the pigments in use are insoluble derivatives of organic dyes."[41]

BODY

"Body refers to the consistency, stiffness or softness of inks. Ink consistencies vary widely from very stiff inks for collotype to very soft, fluid inks for newsprint, gravure and flexography. Associated with the body is the term viscosity which is a measure of the flow characteristics of soft or fluid inks. Stiff inks can have a false body which is called thixotropy. Conventional letterpress and offset inks are shear thinning. They set to a fairly stiff mass in the can, but worked on a slab with an ink knife become quite fluid and flow freely. This is a reason why so many ink rollers are needed on letterpress and lithographic presses."[42]

LENGTH

"Length is a property associated with the ability of an ink to flow and form filaments. Inks can be long or short. Long inks flow well and form long filaments. They are undesirable, specially on high-speed presses because they have a tendency to fly or mist. Newsprint inks are characterized by this property. Short inks have the consistency of butter with poor flow properties. They have a tendency to pile on the rollers, plate or blanket. Most satisfactory inks are neither excessively long nor short."[43]

TACK

"Tack is the stickiness of the ink, or the force required to split an ink film between two surfaces. It is an important requirement in the transfer of ink in the ink train to the plate and then to the paper in letterpress or to the blanket and paper in offset. Tack also determines whether the ink will pick the surface of the paper, will trap properly in wet multicolor printing, or will print sharp, clean lines and halftones. If the tack of the ink is higher than the surface strength of the paper, the paper will pick, split or tear. In wet multicolor printing, as in letterpress and lithography, the first ink down must be tackier than the next ink at the instant of transfer, or the second ink will not transfer to (trap on) the first color. Offset inks must be tacky to print sharp images and resist excessive emulsification with the fountain solution. Compromises must be reached when jobs contain both solids and halftones since tacky inks do not print smooth solids. Ink tack can be measured on an Inkometer or Tackoscope."[44]

DRYING

"Drying of inks is important because a printed piece cannot be handled or used until the liquid or plastic ink film has solidified and dried. Printing inks dry in a number of ways: absorption, selective absorption, oxidation, polymerization, evaporation, precipitation, and curing by radiation. Most inks dry by a combination of two or more of these mechanisms. The first stage in drying is setting, and often this is more important in printing the actual drying."[45]

The only press evaluated in this thesis project that uses inks is the Heidelberg Quickmaster DI. A direct imaging waterless offset lithography press, the QM-DI uses standard waterless offset inks. These "are like letterset inks, but are specially formulated to resist heat effects that can cause toning of non-image areas of waterless printing plates. These plates have silicone compounds on the non-image areas which resist wetting by ink

without the need for dampening solution. They are, however, very temperature sensitive, as a rise in ink temperature of over 10° F can cause toning in the non-printing areas. Most presses used for waterless printing have temperature controlled inking rollers. A waterless ink/waterless plate system has been developed to facilitate press operation."[46]

ADVANTAGES OF DIGITAL PRINTING

For designers, digital printing involves new opportunities and challenges for creating innovative pieces. Electrophotographic systems allow color reproduction for runs as short as one while direct-imaging offset lithography enables fast offset quality without all the makeready necessary with traditional lithography. Other advantages of digital printing are:

- Elimination of film
- Short-runs can now be printed in color and in a cost-effective way
- Because electrophotographic presses do not involve image carriers, they do not require off-press proofs for checking color. Page layout can be checked with any desktop printer. Once the digital file is ready for submission, it can be directly sent to press; the first copy of the job serves as the proof
- Personalization of documents targeted to small groups is possible today only with electrophotographic digital presses
- Documents can now be printed as they are needed, in the amounts needed and wherever they are needed, eliminating storage and transportation costs as well as unnecessary printing to meet a printer's minimum run. Electrophotographic systems allow press runs as short as one; if more prints are required, these can be timely processed whenever the need arises
- Because often times client, designer and printer are seldom in the same area, file transfer has often been an issue in the graphic arts industry. The improvement of phone line file transfer systems and digital presses enable the distribute-then-print workflow. A designer can transmit files to a printer close to where the printed items will be used, eliminating transportation costs and speeding workflow
- Variables associated with imagesetters adversely affect proper color reproduction. "If the laser of the imagesetter has degraded in intensity due to focal problems or lifespan, the density and the darkness of the imagery being exposed onto film will loose quality. If chemicals in the processor are not replenished on time, imagery on the film will be adversely affected."[47] Such problems are avoided with digital printing processes because there is no film involved
- Misregistration of color imagery is rarely a problem with digital presses
- Digital presses "require less manual skills than printing on conventional plate presses"[48] In addition, most equipment are copier-like. As a result, they can be handled in office environments

DISADVANTAGES OF DIGITAL PRINTING

- "In today's digital world, consistent, repeatable color is what customers demand and what most imaging shops deliver most of the time. In fact, after accurate binding, color production remains the single most important variable in profitable operations."[49] The electrophotographic presses part of this thesis project produce a lower resolution and color quality with respect to traditional

offset lithography presses. The Quickmaster-DI, a direct-imaging offset press, is the only exception, capable of printing at 1,270 dpi
-Limitation to four-color reproduction. The Xeikon DCP-32D and the Indigo E-Print 1000 are capable of printing one and two more colors respectively only after being retrofitted. The Xerox DocuColor 40 can only print four colors
-Xeikon DCP-32D has to condition itself to the substrate in use in order to achieve optimal print quality, which involves at least 11 meters of paper wasted
-Slow speed. Digital technology is considerably slow with respect to traditional printing processes
-Mechanical reliability. Machines tend to break down easily
-Limited press sheet size
-The cost per print of a digital press is much higher than that of a traditional press, although in the short-run segment of industry, a digital press is the most competitive
-"With any digital prepress workflow, the integrity of digital files is of the utmost importance. If an image file or graphic file becomes altered unintentionally or deliberately, colors, file formats, design element spacing, or any graphic characteristics of a design may cause problems."[50] In addition, because files are directly expedited from page layout applications to the press, file sizes are limited by the capabilities of front end devices.

APPLICATIONS OF DIGITAL PRINTING

Variable-Data Printing

Enabled by electrophotographic digital presses, variable-data printing, also known as personalization or customization, allows varying the content of every impression to better target the recipient and increase response rate. This process involves designing a master page or template for the fixed information of the document. This page is then merged with consumer databases used to determine what images and text are most appropriate to target a prospective client. "With the trend in modern marketing toward increasingly targeted promotion, personalizing individual items within a print run is at the top of the value added scale."[51]

Every digital press has its own way of dealing with variable-data printing. From the systems featured in this thesis project, the Heidelberg Quickmaster-DI, a Direct Imaging offset press, does not have the capabilities to print variable data. The Indigo E-Print 1000, for example, is capable of modifying images and text from page to page thanks to "a QuarkXpress extension for the Macintosh called the Indigo Layout Xtension [which defines] layout and job parameters of personalized products."[52] The Xeikon DCP-32D "handles personalized documents in two different ways, with and without Barco's Print Streamer. In either case, there is a master page for fixed info that is RIPed once, followed by processing variable information records. The actual merging of the master page and the variable information happens on the fly during the print run."[53] Because "fixed and variable [information] are both independent pages [which can be created in page layout applications,] there is no limitation on the amount of variation on the page, as long as the total run fits into the 32 GB disk array."[54]

"The ability to print variable information is a unique, exclusive, and important characteristic of digital printing systems"[55] and "the best opportunity for it to become a premium, high-margin service for print customers."[56] "Printing markets are now limited

to multiple quantities of images by fixed-image plate printing processes. Digital printing systems provide more cost-effective means of producing printed products with variable information. They will stretch the capabilities of systems now being used for the personalization of documents to enable the production of special editions of magazines, catalogs, newsletters, and other publications according to professional, occupational, regional and/or demographic interest, and open other new markets for printers."[57]

On-Demand Printing

"On-demand printing is specialty printing, as the product is a combination of printing and binding or finishing. On-demand printing requires both an imaging engine and a means of combining, in consecutive, uninterrupted operations, the printed pages into finished products—college textbooks, out-of-print books, insurance policies, research reports, business proposals, or any other products."[58] "In a generic sense, the concept of on-demand is basically one of short notice and quick turnaround. In the printing industry it is also associated with shorter and usually more economical printing runs. When all of this is combined, the definition becomes 'short notice, quick turnaround of short, economical print runs.' When all criteria are met, it results in lower inventory costs, lower risk of obsolesce, lower production costs, and reduced distribution costs."[59]

"In 1992, Heidelberg introduced the GTO-DI, the first printing system to introduce the concept of on-demand color reproduction. In concept, it created printing plates on a traditional printing press, effectively solving the registration problem associated with the 4-color printing process. The plates were created with a spark discharge which then allowed them to print without water, effectively solving the ink and water balance problems associated with offset lithography."[60] Albeit a press with no in-line finishing capabilities, the GTO-DI offers environmental benefits and allows faster makereadies by printing waterless.

"In the graphic arts world, no black-and-white printing system has had the impact of the Xerox DocuTech family. The DocuTech Publishing Series can digitize hard copy originals and accept digital data from a variety of platforms. Text, line art, photos, and halftones can be merged into the system and emerge as finished, near offset quality publications."[61] The series uses electrophotography. A DocuTech Publishing Press is made up of five major components: the document scanner, the controller, the operator console, the printer, and an inline finisher. "All the components are integrated to allow file processing, printing, and finishing functionality into a single 'print shop' system."[62] The end result is a finished product ready for distribution.

The Indigo E-Print 1000 offers similar finishing capabilities as the DocuTech Series. "As a sheet is finished, it moves to the Booklet Maker where booklets are automatically gathered and folded, stapled, and stacked. From the job setup, the Booklet Maker knows how many sheets to grab to make the booklet, whether to staple, etc."[63] , allowing the completion of booklets without manual intervention.

Short-Run Printing

Short run refers to cost-effectively print in small quantities, anywhere from one to 5,000 copies. "Almost 56% of commercial, book, and office printing including duplicating and copying falls in the category of run lengths from 500 to 5,000 impressions. It is interesting that only 2.8% of this printing is done in four or more colors."[64]

"Addressing small target groups, a greater up-to-dateness of printed matter and minimum storage costs are all demands that are made on printed products. Until recently these requirements were difficult or even impossible to meet."[65] However, emerging digital printing technologies are bringing color to products that would have not been produced otherwise because of prohibitive prepress costs for short runs. It is estimated that "by the year 2000 the amount of four-color in this run-length market will more than quadruple to 11.5%. In fact, color will increase as a percentage of total reproduced pages as it becomes easier to accomplish on new and traditional equipment."[66]

Distributed Printing

Distribute-then-print or distributed printing is a workflow model that consists of distributing what is to be printed electronically whether through magnetic disks or phone lines to a printing plant close to where the printed matter is to be used. Digital printing coupled with Adobe System's Portable Document Format (view page 18 for definition) are enabling the revolutionary concept. This long-predicted shift in industry from the predominant print-then-distribute model seems most logical in a digital age, eliminating shipping costs and accelerating processing time.

COLOR NOTES

Gray Balance

This refers to "the ability to reproduce a neutral gray object in the original as perfectly neutral gray in the reproduction. To accomplish this goal requires the correct yellow, magenta, and cyan percent dot area in addition to having the correct solid ink density for the yellow, magenta, and cyan ink [or toner]. . . . Gray balance is also important to achieve because it has a direct relationship to the reproduction of color."[67] If a gray object in an original is reproduced as perfectly neutral gray, it is assumed that color may be reproduced accurately. "The reverse of this would mean that if the gray object is printing with a color cast (blueish gray instead of neutral), then the colors of the reproduction are also printing wrong."[68]

A typical gray balance test for web offset lithography may indicate the following requirements for making separations:

	YELLOW	MAGENTA	CYAN
highlight	5%	5%	7%
middletone	50%	50%	63%
shadow	90%	90%	97%

"If gray balance is achieved, in theory, there is no need for a black separation [or impression]. Nevertheless, the chances of maintaining that neutrality through press are none. . . . Gray balance must be used to compensate the contamination in the ink [or toner] set in use."[69] To measure gray balance in printing processes such as lithography and gravure, a step tablet is used. This is a "neutral carbon dye transmission scale, consisting of separate steps of density which vary in increments of 0.15 and range from 0 to 3.0."[70]

Hue & Hue Error

Hue is "the attribute of color by means of which a color is perceived to be red, yellow, green, blue, purple, etc. White, black and grays posses no hue."[71] "It has bee [*sic*] stated that the printing inks used in process color printing are not perfect. They do not conform to the description of subtractive color theory [that is the colorant of the object will absorb some portion of the visual spectrum (light) and the portion that is not absorbed will reflect to the eye determining the color that is seen. As a result of its imperfection,] . . . the ink absorbs more than one third of the spectrum, indicating that it must contain contamination. [This contamination prevents an accurate reproduction with the ink, resulting in an altered appearance from that of a perfect process color unless it is compensated for through the color correction process.] The proper term for this contamination is hue error. . . . The hue error can be determined by measuring the ink samples with a reflection densitometer through a red, green, and blue filters."[72] These numbers are then applied to the hue error formula:

$$\text{hue error} = \text{unwanted density} / \text{wanted density}$$

Tone Reproduction

"To achieve a quality color reproduction, not only does the color of the printed image have [*sic*] to match the original, but the tone values must also match. . . . For the tone values to match the original, the reproduction must have the correct contrast. If the tones of a printed image look too dark or too light, it means the contrast or tone reproduction is wrong!"[73] According to research held in the 1970's, the human observer has the ability to distinguish subtle differences between dark tones. For this reason, the most important part of a reproduction is the highlight to midtones. If these tone values are perceived to be printed too dark or too light, the reproduction will not be accepted.

"The proper procedure [to evaluate the tone reproduction of a printing device] is to plot the tone reproduction of the printed piece. An ideal reproduction would be a reproduction that densitometrically matches the original. This means that the density (tone values) of the reproduction exactly matches the density of the original, tone for tone. This can be illustrated graphically by plotting the relationship between the density of the original and the density of the reproduction to produce a tone reproduction curve [based upon the density values of a grayscale]."[74] A straight 45° line serves to represent an ideal or perfect reproduction of the original. Against it, the curve representing the actual reproduction is plotted. A reflection densitometer is used to determine the readings on the press sheet.

Dot Gain

"The spread or enlargement of the halftone dots on the press sheet when compared to the dot sizes on the halftone film"[75] is referred to as dot gain, which causes changes in color or tones on the press and results in a loss of details in the image. "Plate exposure, pressure needed to transfer the image from the plate to the offset blanket, the pressure to transfer the image to the substrate and the ink absorbing into the substrate will cause the 50% dot from the film to enlarge on the press sheet. Although the dots increase in size throughout the entire range of the printed image, it causes the biggest problem where the dots begin to link-up in the middletone area."[76]

An inherent characteristic of offset lithography, dot gain cannot be eliminated from this printing process. The Heidelberg Quickmaster-DI, albeit a filmless printing press, is a waterless offset lithography press capable of printing with less dot gain than a conventional lithography press. "Dot gain is not considered a printing fault, but rather an inevitable fact of life that must be monitored and controlled through the printing process. The amount of dot gain can be easily computed from the measured dot area relative to the desired absorption into paper during printing, resulting in darker tones."[77] To minimize dot gain, graphic arts professionals use dot gain compensation, "the technique of reducing the printing dot sizes of halftone separation films to compensate for the expected dot gain on press. The reduction is mostly with the middletones."[78] Although there is no film involved in the electrophotographic process, dot gain is a phenomenon that also takes place in presses that use this method of printing.

Memory Colors

"Color is subjective and a person's color perception is based on prior experience. . . . [Memory colors are those] an individual has assigned to specific objects based on [his or her] experiences since early childhood."[79] As an example, more often than not, the word apple brings to mind the color red, even though there are yellow and green apples as well. Memory colors become an important issue in the printing process when color judgements must be made. Research indicates that in the approval of a press sheet, observers spend more time trying to determine if the color of the objects they are viewing are acceptable to them with respect to their experiences rather than to the original they must compare the press sheet to.

Color Gamut

Color Gamut is "the complete range of hues and strengths of colors that can be achieved with a given set of colorants such as cyan, magenta, yellow, and black ink printed on a given paper and printing press."[80]

Standard Lighting Conditions

One of the factors that affects the way humans perceive color is light or the source of spectral energy. "All light sources emit red, green and blue in its spectrum. However, depending on the type of light sources being used, each will emit different amounts of red, green and blue. [For example,] a florescent light will emit a high amount of blue with a lesser amount of red and green. This would explain why a florescent light may be described as being a bluish light. An incandescent light [on the other hand] gives off a large portion of red with a lesser amount of blue and green in its spectrum."[81] As a result, most people will describe this kind of light as warm or yellowish.

To minimize problems associated with varying lighting conditions, professionals in the graphic arts industry view press sheets and originals under standard conditions. "The American National Standards Institute (ANSI) developed [in the 1960s] standards for the color temperature of the most common, industry-wide illuminant under which artwork, proofs, and press sheets are viewed—the D5000 light source. [This light source] displays the color temperature of a black body at 5000° Kelvin (K). The letter 'D' stands for daylight, as a D5000 illuminant simulates what the eyes perceive as a bright, sunny day. . . . [To the contrary, a typical fluorescent light has a color temperature of 3200° K.] The advantage of the D5000 light source lies in its color balance. All materials viewed under

it are neutrally illuminated. Therefore . . . it is ideal for spotting color and imagery inaccuracies."[82]

A typical viewing booth is equipped with a transparency illuminator and an overhead light both 5000° K. The booth itself is painted in gray to provide the required neutral surround. The correct use of a viewing booth involves the evaluation of only two objects at a time. "This would be the transparency on the viewer and the proof being examined or the proof and the press sheet being used to check color in the pressroom."[83] Any other objects in the booth may affect the perception of the items under evaluation. "It is . . . critical that the viewing conditions remain the same throughout the entire process or there will be misunderstandings and confusion as to what the job should match."[84]

The visual evaluation of proofs or press sheets is subjective. "Opinions regarding color accuracy and image quality differ from person to person. Standard viewing conditions were created for the purpose of narrowing such differing subjective opinions."[85] Nevertheless, human factors such as memory colors influence the subjective perception of objects.

OTHER APPLICABLE HARDWARE AND SOFTWARE

PostScript Page Description Language

PostScript is "a page description language developed by Adobe Systems, Inc., [in the 1980s] to describe an image for printing. It handles both text and images, which can be controlled with mathematical precision."[86] With PostScript, type is described as vectors or outlines, "thus allowing type to be infinitely modified and distorted. Previously, most type had been bitmapped, which allowed no change in size and style. . . . The PostScript language consists of over 300 verbs or commands that instruct the program to move to certain points, draw lines, fill boxes, select type, etc. [In addition, Adobe Systems] developed the PostScript interpreter, which processes the PostScript page file for printout"[87] by generating a data stream to drive a digital output device such as a desktop printer, a platesetter, or a digital press.

"The first publishing application to generate PostScript page description was Pagemaker, developed by Aldus, a software company . . . [which] became part of Adobe in a friendly takeover in 1983. The first PostScript printer was the Apple Laserwriter 300 dpi monochrome laser printer. These products, along with the Macintosh computer, launched the desktop publishing revolution."[88] Nevertheless, it was not until the introduction of the first high-resolution PostScript imagesetter, the Linotype L-300, that PostScript began having an impact in industry. "PostScript page description could be sent directly from a Macintosh computer to the RIP for output on the L-300 to produce graphic arts films at a maximum resolution of 2,540 dpi."[89]

"The first generation of PostScript technology was not designed for color printing, and was especially deficient when used for reproducing process color images. The algorithms that were used to convert contone images into screened halftones for print applications were primitive—adequate for grayscale reproductions but not for color. The quality of the separations was poor, and PostScript technology was relegated to low-end applications where any color was considered a step up."[90] It was not until 1990 that Adobe published PostScript Level 2, an upgraded version that satisfies the requirements for high-end color printing. Additional capabilities of PostScript Level 2 include support to high-

end applications such as downloading "a color rendering dictionary to a PostScript RIP to convert images to the output color space on the fly. This makes it possible to embed color management functionality in the RIP."[91]

A disadvantage to PostScript is its lack of structure. "There is no way for a processor to know what is in a PostScript file until the file is processed from beginning to end. There is practically no limit to the number of objects that can be on a single PostScript page. It is also very difficult or impossible to detect where one page ends and the next one begins in a long PostScript document. This makes it impossible to predict how much time will be required to process any given page or to process pages independently of one another."[92]

PDF—Portable Document Format

PDF, Portable Document Format, is a compact, cross platform file format that does not require the image files and typefaces used in a document nor a copy of the application in which it was originally created for it to be printed, published in the Internet or CD-ROM, or distributed via e-mail. This enables users to rely on a single version of a file, eliminating any confusions resulting from keeping several formats of a single document. An invention of Adobe Systems, a PDF is created with Acrobat Distiller, a program which embeds the typefaces and images used in a file. To expedite a file, Acrobat Reader is required. This software program is available free from the manufacturer's website.
A PDF is composed of the following:

> "•a view file that displays the page as [created]
> •embedded type: Adobe Type 1 and TrueType
> •graphic objects: bitmaps and compressed vector images
> •links for variable forms data
> •sound, QuickTime, hypertext-like linking"[93]

Adobe Acrobat is based upon PostScript, which "instructs an output device like a copier or printer how and where to put text and graphics on a page. . . . Since PostScript is device-independent, if properly prepared, a document saved as a PostScript file can be generated through any PostScript-compatible printer, copier, or other output device with little or no modification."[94] Unfortunately, "PostScript contains procedures, variables and control constructs that may cause unpredictability."[95] Its major fault: the file cannot be viewed. "The PDF page approach eliminates the variability of PostScript and provides a foundation for effective digital print production workflow. High-end printing and color controls can be integrated with the PDF file."[96] And yes, the document can be viewed through Acrobat Reader.

The benefits of PDF, as listed by Adobe, are the following:

> "•PDF files can be distributed globally via e-mail, the Web, corporate intranets or CD-ROM
> •Acrobat Reader's navigation and zoom features enable closer review of PDF file text and images . . .
> •PDF files can be easily viewed and printed a page at a time
> •Links, annotations, live forms, security options, video, and sound can be added to PDF files for enhanced online viewing with Adobe Acrobat 3.0"[97]

On the other hand, the same characteristics that make PDF ideal for the printing and publishing industries deem it inadequate when last minute editorial changes are needed. Once the file is created and type and images embedded, modifications and editorial changes of any kind are not possible. Currently, Adobe Systems is changing this by increasing the editorial capabilities of Acrobat Distiller.

RIP—Raster Image Processor

A raster image processor or a RIP is "a combination of computer software and hardware that controls the printing process by calculating the bit maps of [typography and] images and instructing [the raster-based] printing device to create the images [and type]."[98] Most PostScript systems have built into the output device a hardware RIP, the speed of which "determines how fast a printer can produce the first copy of a complex page."[99] "Raster means lines. For each line (and there could be from 300 to 3,000 lines to an inch) the laser is either on or off for each possible position. Since almost all output today is based on dots, a RIP is required. The RIP is connected to a marking engine which uses lasers to put dots that create images on a substrate, such as film (imagesetter or imposetter) or plate (CTP) [view page 20 for definition] or directly on paper using toner, ink-jet or dye sublimation methods."[100] When a file is expedited, it is converted into PostScript and is sent over the network to the RIP on the output device. Regardless of its kind, whether a desktop printer, film or platesetter, the output device must receive the PostScript code at the RIP for it to be processed for printing. "The end product of the RIP is a bit map of zeroes and ones that describes where every dot is located. This data is used by the marking engine to turn the laser on or off to place the dots in position. The laser scans across the substrate line by line, turning on or off to make marks (images) on film, plate, paper or any other substrate."[101]

SWOP—Specifications for Web Offset Publications

SWOP is a set of standards established "by magazine printers and publishers because they work with film from various advertisers and their agencies, combine that film with editorial film, and then print the entire job. The extremely wide variety of film sources and manufacturers led to a correspondingly wide variety of film formats and quality levels, making the printer's job nearly impossible."[102] "The mission of SWOP, Inc. is to raise the level of quality of publication printing. This can be accomplished by providing a way for the suppliers of input materials to publication printers to prepare and proof the film supplied to a common set of specifications. If this is done properly, all film received by the printer can be reproduced as intended and desired by the advertiser with minimal difficulty. Quality should be measurable and veritable at each step in the process of reproduction, and the printer should be able to monitor and improve his performance by statistical methods."[103]

GRACoL—General Requirements for the Applications of Commercial Offset Lithography

GRACoL, General Requirements for Applications in Commercial Offset Lithography, is "a new set of guidelines for the offset litho print industry developed to allow designers, print buyers, separators and printers to communicate accurately about printing conditions."[104] Based on four types of paper, GRACoL provides graphic arts professionals a series of the ideal numerical conditional for line screen, TAC, solid ink density, total dot gain, and

print contrast. Depending on the kind of paper to be used, a printer can tell a prospective client what are the expected ink densities, dot gain, screen rulings, and total area coverage.

CTP—Computer-To-Plate

"Within a CTP workflow, no films are produced. The calibration issue lies between the front end of the digital press, its press attributes, and the digital proofer. The CTP workflow eliminates one very large group of variables—those associated with the imagesetter."[105]

Chapter Two Endnotes

[1]Howard Fenton and Frank J. Romano, *On-Demand Printing: The Revolution in Digital and Customized Printing* (Pittsburgh, Pennsylvania: Graphic Arts Technical Foundation, 1995), 8.

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[4]Noel Jeffrey, *Digital Printing: A Guide to the New World of Graphic Communications* (Torrance, CA: Micro Publishing Press, 1996), 26.

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[13]Company Profile Brochure, apparently written at Indigo headquarters in Woburn, MA, 1998.

[14]Howard Fenton and Frank J. Romano, *On-Demand Printing: The Revolution in Digital and Customized Printing* (Pittsburgh, Pennsylvania: Graphic Arts Technical Foundation, 1995), 165.

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[33]Ibid.

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[58]Ibid., 291-292.

[59]Howard Fenton and Frank J. Romano, *On-Demand Printing: The Revolution in Digital and Customized Printing* (Pittsburgh, Pennsylvania: Graphic Arts Technical Foundation, 1995), 3.

[60]Frank J. Romano, *Pocket Guide to Digital Prepress* (Albany, NY: Delmar Publishers, 1996), 284-285.

[61]Noel Jeffrey, *Digital Printing: A Guide to the New World of Graphic Communications* (Torrance, CA: Micro Publishing Press, 1996), 164-165.

[62]Frank J. Romano, ed., *Delmar's Dictionary of Digital Printing & Publishing*, (Albany, NY: Delmar Publishers, 1997), 188.

[63]Howard Fenton and Frank J. Romano, *On-Demand Printing: The Revolution in Digital and Customized Printing* (Pittsburgh, Pennsylvania: Graphic Arts Technical Foundation, 1995), 162.

[64]Ibid., 6.

[65]Quickmaster-DI 46-4 product information, in HeidelbergUSA Website; available from http://www.heidelbergusa.com/03_pro/direct_imaging/qmdi.htm; Internet; accessed 13 January 1999.

[66]Howard Fenton and Frank J. Romano, *On-Demand Printing: The Revolution in Digital and Customized Printing* (Pittsburgh, Pennsylvania: Graphic Arts Technical Foundation, 1995), 6.

[67]Joseph Noga, "Color Image Processing" (M.S. class, Rochester Institute of Technology, 1998).

[68]Ibid.

[69]Ibid.

[70]Ibid.

[71]*Glossary of Color Terms* (Philadelphia, PA: Federation of Societies for Coatings Technology, 1981), 32.

[72]Joseph Noga, "Color Image Processing" (M.S. class, Rochester Institute of Technology, 1998).

[73]Ibid.

[74]Ibid.

[75]Ibid.

[76]Joseph Noga, "Color Image Processing" (M.S. class, Rochester Institute of Technology, 1998).

[77]Frank Cost, *Pocket Guide to Digital Printing* (Albany, NY: Delmar Publishers Inc., 1997), 191.

[78]Ibid., 192.

[79]Joseph Noga, "Color Image Processing" (M.S. class, Rochester Institute of Technology, 1998).

[80]Frank J. Romano, ed., *Delmar's Dictionary of Digital Printing & Publishing*, (Albany, NY: Delmar Publishers, 1997), 99.

[81]Joseph Noga, "Color Image Processing" (M.S. class, Rochester Institute of Technology, 1998).

[82]Eric Lopatin, "A Designer's Guide to the Evaluation of Digital Proofs" (M.S. Thesis, Rochester Institute of Technology, 1996), 106-107.

[83]Joseph Noga, "Color Image Processing" (M.S. class notes, Rochester Institute of Technology, 1998).

[84]Ibid.

[85]Eric Lopatin, *A Designer's Guide to the Evaluation of Digital Proofs* (Rochester, NY: 1996), 106-107.

[86]Frank J. Romano, ed., *Delmar's Dictionary of Digital Printing & Publishing*, (Albany, NY: Delmar Publishers, 1997), 483.

[87]Ibid., 483.

[88]Frank Cost, *Pocket Guide to Digital Printing* (Albany, NY: Delmar Publishers Inc., 1997), 46.

[89]Ibid.

[90]Ibid.

[91]Ibid., 47.

[92]Ibid., 51-52.

[93]Michael H. Bruno, ed., *Pocket Pal, A Graphic Arts Production Handbook*, 17th ed., (Memphis, TN: International Paper, 1997), 108.

[94]Noel Jeffrey, *Digital Printing: A Guide to the New World of Graphic Communications* (Torrance, CA: Micro Publishing Press, 1996), 10-11.

[95]Michael H. Bruno, ed., *Pocket Pal, A Graphic Arts Production Handbook*, 17th ed., (Memphis, TN: International Paper, 1997), 107.

[96]*About Adobe PDF*, in Adobe Systems Website; available from http://www.adobe.com/prodindex/acrobat/adobepdf.html; Internet; accessed 9 January 1999.

[97]Ibid.

[98]Michael H. Bruno, ed., *Pocket Pal, A Graphic Arts Production Handbook*, 17th ed., (Memphis, TN: International Paper, 1997), 223.

[99]Frank Cost, *Pocket Guide to Digital Printing* (Albany, New York: Delmar Publishers, 1997), 52.

[100]Michael H. Bruno, ed., *Pocket Pal, A Graphic Arts Production Handbook* (Memphis, TN: International Paper, 1997), 109.

[101]Ibid., 109-110.

[102]Noel Jeffrey, *Digital Printing: A Guide to the New World of Graphic Communications* (Torrance, CA: Micro Publishing Press, 1996), 47.

[103]Thomas Basemore, Chairman, *SWOP: Specifications for Web Offset Publications* (New York: SWOP Board of Directors, 1993).

[104] Southworth, Miles, "General Requirements for Applications in Commercial Offset Lithography (GRACoL)," *Ink on Paper*, June 1997, 1-2

[105]Eric Lopatin, "A Designer's Guide to the Evaluation of Digital Proofs" (M.S. Thesis, Rochester Institute of Technology, 1996), 24.

Chapter Three
A Review of The Literature

Digital printing is a topic favored by many graphic arts authors. Nevertheless, the literature published as of today only stresses the technological and commercial aspects of digital printing and the predominant equipment in industry. File preparation and the innovative possibilities digital printing enables are areas unexplored by authors, most probably because graphic designers are disregarded as an audience. The consulted literature for this thesis project includes industry periodicals, digital printing textbooks, and manufacturer's informational material published both in the internet and in manuals.

Noel Jeffrey in *A Guide to the New World of Graphic Communications* defines digital printing as "the output of . . . information from an electronic file onto a substrate of some kind."[1] His book provides a comprehensive analysis of digital printing, its ideal applications, and the equipment that "is a test-marketer's dream tool"[2] because it enables personalization. Technology is stressed throughout the publication, particularly the direct-imaging system that images digital information from the desktop computer directly to each plate on press, eliminating film output and off-press plate processing yet still providing offset lithography quality. With direct-imaging, "the operator performs a preflight check [of the digital file], final imposition and conversion to PostScript. Next, the PostScript files are digitally separated and bitmap generated via the RIP to a server and subsequently transferred to plates on press. Each plate is already mounted on each press unit and imaged simultaneously."[3] This revolutionary technology, also know as laser dot imaging, was developed by Presstek in New Hampshire and "first brought to the market on the GTO-DI from Heidelberg, a world renowned [German] press manufacturer."[4] Another revolutionary technology mentioned in this book is digital offset which involves transferring the image "from a plate to a blanket to the sheet of paper that moves between the blanket and the impression cylinder. The difference is that digital offset technology creates a new ink image with each impression. This is possible because all of the Electro Ink image is transferred to the paper with no residual ink remaining on the blanket"[5] enabling customized printing. "In addition, Indigo's on-the-fly Color Switching Technology enables each revolution of the cylinders to print each image in a different color. [In a four-color job,] the sheet of paper remains on the impression cylinder until each digital separation—C,M,Y,K—is printed."[6] Because the paper never moves, image registration is precise. According to Jeffrey, "before digital presses existed, streamlined digital creative workflow and prepress production came to a screeching halt at the imagesetter, where labor- and chemically-intensive processes of generating film, image assembly, proofing, and platemaking had to be employed in order to get a project on press."[7] Digital presses, on the other hand, eliminate all these processes. In addition, "with digital presses, the first copy of the job is typically the proof. As seasoned print buyers know, a press proof had always been the only absolute predictor of actual results."[8] These, consequently, are some of the aspects that make digital printing highly appealing to graphic designers.

Pocket Guide to Digital Prepress by professor Frank J. Romano provides a detailed explanation of the various digital printing methods available in industry, namely electrophotography, magnetography, ionography, field effect imaging, ink jet, and thermal transfer. According to professor Romano, "the cost of making a set of plates, mounting them on the press, and running the press until the printing is in register and colors are

correct"[9] have prevented traditional printing methods such as offset lithography and gravure from being economically feasible for short runs. He continues by stating that "electronic printing processes are the most applicable"[10] for short-runs and the only option for variable data printing. The digital printer "takes PostScript files directly; it images pages of type, pictures, illustrations, and color, puts them all on paper, collates and folds and binds and outputs completed units. It negates the need for film and plates."[11]

Alan Kotok and Ralph Lyman, authors of *Print Communications & The Electronic Media Challenge*, define digital printing as a combination of "the computer's ability to collect and manipulate text and image information in electronic form with the press's ability to deliver large numbers of high-quality printing pieces."[12] The authors divide digital printers according to the type of colorants these use:

> -Dry Toner Printers: They use "the same basic principles of photocopiers and laser printers connected to personal computers. In these systems, a light-emitting diode (LED) sends a laser beam that exposes the image on a photoconductive drum. The image becomes electrically charged and picks up the dry toner through static electricity. The drum then transfers the image to the substrate through a heat fusing process. As with laser printers, manufacturers of the basic print engines will sometimes license the technology to other manufacturers, who then add a series of features to the basic system,"[13] as is the case of the Xeikon DCP-32D engine, "a dry toner print engine used [by Xeikon] in its own line of digital printers, and licensed to Agfa for the Chromapress, AM Multigraphics for the AM/Xeikon line and IBM for its 3170 system. The engine uses arrays of LEDs to image eight photo-conductive drums, with four on each side of web-fed paper to support full-time duplex printing. In addition to the base 600-dpi resolution, the engine supports multiple gray levels for each color and produces excellent quality halftone images. It also has a built-in variable length cutter to create cut sheets."[14]
>
> -Liquid Ink Printers: These printers "apply the ink with either an electrophotographic print engine (comparable to dry toners) or ink-jet technology. Liquid ink printing provides for longer run jobs, but may require special paper stocks. Indigo and Scitex, two companies based in Israel, offer the leading liquid ink digital systems. The Indigo systems provide full scale printing capabilities, while the Scitex ink-jet systems offer variable-information features that printers can use either alone or as supplements to traditional printing."[15] The Indigo E-Print 1000 evaluated in this thesis project uses ElectroInk which "consists of micron-size pigment toners dispersed in a thermoplastic resin diluted in a light mineral oil (isopar)."[16]
>
> -Traditional Offset Presses: "New offset presses on the market provide printers with integrated computer-to-press solutions using digitally imaged plates. These presses enable printers to avoid problems faced by retrofitting digital platesetters in an offset pressroom."[17] A press of such characteristics is the Heidelberg Quickmaster-DI, "a four color, two page, sheet-fed press using electronically imaged plates and dry printing. It has four plates/blanket units around a common impression cylinder. Each plate unit is equipped externally with a Presstek Pearl laser digital imaging system, and internally with a spool of 35 waterless plates on a polyester base that unwind to feed a plate onto the cylinder,

plus a second spool which maintains tension on the plates during printing. The press can handle sheets up to 18⅛ by 13⅜ inches. The Quickmaster's printing system is dry except for inks, and roller and blanket cleaning solvent. The plates are not photosensitive, but the plate exposes them by special laser diodes that remove the silicon in the image areas by a special cleaning device. It cleans the blanket automatically. The system synchronizes the press so all four plate cylinder register at the same time. While the system exposes the plates, it uses internal data to set the appropriate ink fountains automatically. According to Heidelberg, Inc., this entire job-changeover process takes about eight minutes."[18] The "Quickmaster-DI takes Adobe PostScript files directly from any desktop publishing system or color electronic publishing system, and produces lithographic quality in resolutions as high as 2,540 dots per inch. It has 64 laser diodes to image at one time on its four printing units. The press speeds up makeready by automatically replacing its plates between jobs. Heidelberg . . . says the press has a top running speed of 10,000 impressions per hour, about two to five times faster than digital presses, and claims that plates have a 20,000 impression service life."[19]

In contrast to Kotok's and Lyman's classification, International Paper in its seventeenth edition of *Pocket Pal—A Graphic Arts Production Handbook* divides digital printing in three categories with respect to the technology used:

1. Computer-to-plate: image carriers are produced for conventional or modified printing presses from digital files

2. Computer-to-plate-on-press: conventional lithographic presses equipped with a RIP, a replating system, and a laser-based imaging system capable of imaging plates on press and printing from digital desktop documents

3. Computer-to-print: electrophotographic and other digital printing systems capable of printing from digital files

Three unique features of digital printing over conventional plate printing processes identified in *Pocket Pal* are:

"•Most equipment are copier-like that can be handled in office environments
•They are capable of variable printing from impression-to-impression
•They require less manual skills than printing on conventional plate presses"[20]

None of the electrophotographic systems available in the market today, however, "has achieved the speed and quality of commercial lithography, and, for printing quantities of the same reproductions, unit cost limit them to short runs of under 1,000 copies. The major markets that use these technologies are short run color, variable information, on-demand and distributed printing."[21]

P. Gregory, the editor of *Chemistry and Technology of Printing and Imaging Systems*, considers "the phenomenal growth of silicon chip technology over the past 15 years or so . . . [the force behind] a new era of printing and imaging systems, the so-called non-impact (or electronic) printers."[22] Furthermore, Gregory considers ink-jet printing and electrophotography (the technology which embraces photocopiers and laser printers) two non-impact printing technologies which have achieved remarkable commercial success.

In the field of electrophotography, the most significant invention was the discovery of the process most commonly known as xerography. Derived from the Greek, xerography means "dry writing". "It was developed out of the original inventions by Chester Carlson [in 1938]. It had long been known that certain materials could be made to accept an electrostatic charge and that this charge could be used to attract fine particles. Carlson noted that certain materials, photoconductors, when exposed to bright light would lose their charge.... He was able to demonstrate that these materials could form the basis of a device that could be used to produce an electrostatic image which, when developed with powder, could be transferred to paper.... [Carlson's] findings indicate the basic stages of the [electrophotographic] process:

"-the photoconductor is first charged in the dark
-the plate is then partially exposed to illumination in order to produce an electrostatic image
-the image is then developed with a fine powder
-the developed image is transferred to the receiving substrate (paper, cloth, overhead transparency, etc.)
-the image is fixed to the substrate
-the photoconductor is discharged and cleaned"[23]

"Although the basic concept proposed by Carlson had to undergo considerable refinement to produce a commercially viable product, modern photocopiers and laser printers still operate by the basic process established in the 1940s.... Although alternatives have appeared (most notably ink jet), the speed, quality, and ease of use of the electrophotographic copier has made it a formidable force in the market. From the single copy to medium-volume duplication, the process is reliable, rapid, and economic."[24] The major limiting factor of electrophotography according to Gregory is cost. "Monochrome laser printers are still relatively expensive, and for home computer users, and some small-business users, the initial outlay is prohibitive. As a result, the cheaper ink jet technology dominates the lower end of the market. [In addition,] ... resolution and grey-scale reproduction are as yet still limitations to the technology. Resolution is increasing and although 600 dpi is standard, 1200 dpi is emerging and in some liquid toner systems, higher resolution has been shown to be achievable. [Also,] ... the cost per copy is another factor which must be considered. Although this is fairly cheap for monochrome, when volumes become large enough, the cost of conventional printing technology is extremely competitive. [For the author,] the major rivals to the technology are ink jet for low-volume work and dye-diffusion thermal printing for full-color graphics artwork."[25]

The literature obtained from manufacturers provided the specifications for the equipment tested in this thesis project. In addition, considerable information was collected from RIT faculty, press operators, plant managers, sales agents, and designers whose insights helped determine the criteria with respect to which the presses were compared to one another.

Chapter Three Endnotes

[1]Noel Jeffrey, *Digital Printing: A Guide to the New World of Graphic Communications* (Torrance, CA: Micro Publishing Press, 1996), 8.

[2]Ibid., 37.

[3]Ibid., 124-125.

[4]Ibid.

[5]Ibid., 41.

[6]Ibid.

[7]Ibid., 12.

[8]Ibid., 13.

[9]Frank J. Romano, *Pocket Guide to Digital Prepress* (Albany, NY: Delmar Publishers, 1996), 37.

[10]Ibid.

[11]Ibid., 117.

[12]Alan Kotok and Ralph Lyman, *Print Communications & The Electronic Media Challenge* (Plainview, NY: Jelmar Publishing Co., 1997), 17.

[13]Ibid., 28.

[14]Ibid.

[15]Ibid., 34.

[16]Frank J. Romano, *Pocket Guide to Digital Prepress* (Albany, NY: Delmar Publishers, 1996), 286.

[17]Alan Kotok and Ralph Lyman, *Print Communications & The Electronic Media Challenge* (Plainview, NY: Jelmar Publishing Co., 1997), 50.

[18]Ibid., 51.

[19]Ibid., 51-52.

[20]Michael H. Bruno, ed., *Pocket Pal, A Graphic Arts Production Handbook,* 17th ed. (Memphis, TN: International Paper, 1997), 147.

[21]Ibid.

[22]P. Gregory, ed., preface to *Chemistry and Technology of Printing and Imaging Systems* (Cambridge, Great Britain: Blackie Academic & Professional, 1996), 3.

[23]Ibid., 76-77.

[24]Ibid.

[25]Ibid., 104.

Chapter Four
Statement of The Project Goals

The purpose of this thesis project is to evaluate the color reproduction of digital printing systems most common in industry through the creation of a universal test instrument with respect to which all the systems will be compared. The results of the test will be used to assess the capabilities of the equipment and determine their ideal applications within the graphic communications industry. A file preparation and specifications guide for each of the devices tested will be compiled.

The audience at which this study is targeted is graphic designers who could benefit by learning about the advantages and disadvantages of the various systems and learning to design with these in mind. As a result, particular attention will be paid to the impact these emerging technologies have in designers' approach to producing their work. In addition, the test instrument will be comprised of the elements designers deal with: type and images.

The equipment to be tested is:

- Xeikon DCP-32D
- Indigo E-Print 1000
- Xerox DocuColor 40
- Heidelberg Quickmaster-DI

All the printers to be tested require no film to print, and, with the exception of the Heidelberg Quickmaster-DI, no plates are necessary either. The Heidelberg Quickmaster-DI is a lithographic press with a unique digital plate-making system. It will be interesting to compare the reproduction capabilities of new-generation digital presses with this which combines a mature process like offset lithography with a revolutionary method to make plates on press.

This thesis project does not suggest the equipment to be tested is the best in the market-place. The results from the testing to be performed, however, may be used in determining which system is most suitable for implementation.

Chapter Five
Methodology

The color reproduction evaluation of the digital presses in this thesis project will involve the creation of a test instrument that will be printed on all the equipment. This test instrument will be designed universally at a size and format that can be reproduced without adjustments in all printing devices. To avoid any variations associated with paper, the same will be used on all machines: Monadnock Astrolite brilliant white, smooth finish, 118 grams per square meter. The run length of every press run will be of 150 sheets, which is "appropriate for a digital press to achieve the correct temperatures and densities."[1] All printing will take place in the Center for Integrated Manufacturing Studies at Rochester Institute of Technology where the machines are housed. The test instrument will be expedited to all the presses from QuarkXpress 4.0 with the exception of the Quickmaster-DI, to which it will be expedited from QuarkXpress 3.0 to avoid PostScript Printer Description conflicts arising from QuarkXpress 4.0.

The criterium defining the color reproduction evaluation and the elements used in the test instrument is the following:

> Graphic designers, the audience at which this thesis project is targeted, think in terms of memory colors; red, green, and blue. As a result, the elements comprising the test instrument will be those which designers deal with: text and images. The printed samples will be measured with a X-Rite 938 Spectrodensitometer, and the results will be complemented with a visual evaluation performed under standard lighting conditions.

The test instrument is to be printed in the following presses under the following settings:

- Xeikon DCP-32D—similar settings to SWOP
- Heidelberg Quickmaster DI 46-4—Gracol settings
- Indigo E-Print 1000—Indigo's default settings
- Xerox DocuColor 40—similar settings to SWOP

The second part to this thesis project will involve the compilation of guides to expedite files to each of the output devices. In addition, manufacturers' specifications will be collected to determine the requirements for preparing variable printing documents.

Elements Comprising Test Instrument

CMYK patches and bars

One hundred percent cyan, magenta, yellow, and black patches will be used to determine the solid ink or toner densities the equipment is capable of printing. These will be determined through the use of a calibrated X-Rite 938 Spectrodensitometer that will be "zeroed to the brightness of the press sheet before the reading is taken. The density [then becomes] the standard or specified density that will be used during makeready when setting-up the press in the future,"[2] relative to which all other tints are computed. The solid bars will be printed cross grain to evaluate the uniformity of ink or toner transfer. Tint patches in ranges of one to five

percent in one percent increments; ten to 25 percent in five percent increments; and 30 to 100 percent in ten percent increments will be used to determine dot gain, gray balance, tone reproduction curve, and maximum and minimum printable dot areas.

FOUR-COLOR BLACK PATCHES

Cyan, magenta, yellow, and black will be overprinted in equal percentages ranging from five to 100 percent in five percent increments to determine what are the total ink or toner densities that can be overprinted and how well formulated are the ink or toner sets used by the printing devices. A process ink or toner that is perfect according to the Subtractive Color Theory absorbs one third of the visual spectrum and reflects the other two thirds. Because of contamination known as hue error, the ink or toner will absorb more than a third of the visual spectrum and will not properly reproduce the colors of the original unless color correction is applied.

IMAGES OF DIFFERENT SOURCES AND RESOLUTIONS

An acrylic painting scanned at 300 dpi will be used to make a visual evaluation under standard lighting of the digital printers' reproduction capabilities. The reproduction fidelity of the printing devices will be determined through a visual comparison of the color, texture, and contrast between the original and the reproductions. In addition, an image portraying women with various skin tones will be included in 150, 225, and 300 dpi. These will help determine the resolution or "the precision with which a [printing] system can render detail in a visual image."[3] In addition, the neutral background of this image will serve as a measure of gray balance.

TYPE

Ranging in point size from 3 to 72, Minion and Minion Expert specimens regular and reversed out in black will be used to evaluate the reproduction of type, which can serve as a measure of resolution. The criteria for the evaluation of type is:

-smallest size printable
-sharpness with respect to size
-effects of output resolution on text weight
-text spot color inaccuracies
-broken characters
-jagged or blurred edges
-character weight changes

OVERPRINTING CIRCLES

Overprinting is "to print dots of one process color ink [or toner] over dots of another process color ink [or toner] to produce overprint colors or secondary colors, such as red, green, and blue."[4] Cyan at 50 percent, magenta at 39 percent, and yellow at 39 percent will be overprinted 100 percent black to determine the maximum overprinting densities. In addition, these circles will serve designers to learn on how overprinting can enhance the appearance of a color by comparing it to a 100 percent black only circle.

G4 COLOR BAR

A color bar is "a set of color and monochrome patches and patterns printed in the margin of a press sheet and used to monitor and control press operation. Color bar

elements are designed to be interpreted electronically by a densitometer, or interpreted visually by press operators. . . . Color bars show the amount of ink [or toner] used, the trapping, and the relative densities across the press sheet."[5]

RIT NEUTRAL BALANCE TARGET FOR SWOP

This test target can be used to check if the printing system evaluated can achieve gray balance according to SWOP. Gray balance is "the ability [of an output device] to reproduce a neutral gray object in the original as perfectly neutral gray in the reproduction."[6] In theory, the inner circles which are cyan, magenta, and yellow tint overprints must match the surrounding black areas. "The circles seem to be particularly difficult to reproduce on electrophotographic system: a white moon tends to form around them."[7]

RIT FOUR-COLOR SPOKES TARGET

This test target can be used to check a four-color printing system's resolution and aliasing. "The fan target gives another indication of proper exposure. It can of course not be resolved at less than one pixel. If it is not resolved at larger than 1 pixel, this indicates a spot size bigger than the addressability or not optimum exposure. The fan target is very sensitive to directional effects. The scale and number of spokes adjusts automatically to the resolution of the output device. The header of the file can be edited to define the range of pixels covered by each fan. The registration cross indicates misregistration in terms of pixels. The lines are two pixels wide. In the center, all four colors are on top of one another. Outside, each of the colors is shown relative to black."[8]

RIT FOUR-COLOR RESOLUTION TARGET

This test target is designed to check the resolution of four-color printing devices. It consists of a checkerboard pattern in four colors which, in optimal conditions, match the 50 percent reference tint. The interpretation of the output device's RIP critically influences the reproduction of this target.

Evaluation Procedure

TONE REPRODUCTION

"The proper procedure [to evaluate the tone reproduction of a printing device] is to plot the tone reproduction of the printed piece. . . . An ideal reproduction would be a reproduction that densitometriclly [*sic*] matches the original. This means that the density (tone values) of the reproduction exactly matches the density of the original, tone for tone. . . . This can best be illustrated graphically by plotting the relationship between the density of the original and the density of the reproduction to produce a tone reproduction curve. When this task is performed, ideal reproduction or perfect reproduction is illustrated as a straight 45° line on the tone reproduction graph."[9]

"To determine the quality of the tone reproduction, it will be necessary to plot the density of the original against the density of the reproduction on a graph. Because of the difficulty to take precise measurements from a photographic image and to locate these exact areas on the press sheet, it is traditional to use a grayscale for this purpose. . . . The readings are taken with a reflection densitometer that has been calibrated."[10]

SOLID INK DENSITIES

"A measure of the light transmitting or reflecting properties of an area,"[11] the densities of the 100 percent patches will be measured through the use of a calibrated reflection densitometer. The procedure of measuring densities involves to measure "the paper white first, then measure the solid. Together these define the 0% and 100% tint values relative to which all other tints are computed."[12]

GRAY BALANCE

Gray balance is "the proper amount of cyan, magenta, and yellow printing to produce a grayscale with no apparent dominant hue."[13] The grayscale in the test instrument will serve to determine whether or not the digital presses to be evaluated are capable of achieving gray balance under the settings at which these will be run. A reflection densitometer will be used to make the required measurements.

DOT GAIN

Dot gain is "a printing artifact in which dots print larger than desired, causing changes in color or tones on the press [and] resulting in a loss of details in the image. Dot gain occurs most often in long press runs, [an effect of] . . . the physical enlargement of the dot caused by the plate exposure image spread, by the pressures between the plate blanket and impression cylinder of a press, or by ink spread as it penetrates the paper."[14] "The amount of dot gain [produced by a printing device] can be easily computed from the measured dot area relative to the desired absorption . . . into paper during printing, resulting in darker tones, especially midtones."[15] A reflection densitometer is used for this purpose.

RESOLUTION

Resolution refers to "the number of discernible line pairs per inch. This is a true expression of resolution, preferable to 'dots per inch,' [the expression most commonly used,] since dots are made to overlap in many types of output."[16] The image portraying women will be printed at three resolutions: 150, 225, and 300 dpi to determine which level ink or toner fills the area between the halftone dots. Evaluation will take place under a standard color viewing station.

Equipment, Facilities, Anticipated Costs, Timetable

EQUIPMENT

-Macintosh Power PC 9600 and G3
-Howtek ScanMaster 2500 flatbed scanner
-Howtek ScanMaster 4500 drum scanner
-QuarkXpress 3.32r2
-Adobe Photoshop 5
-Adobe Illustrator 7.0 and 8.0
-Microsoft Office 98
-Trident 2.0
-Zip disks for file transportation and storage
-Printing devices
  •Xeikon DCP-32D
  •Indigo E-Print 1000
  •Xerox DocuColor 40
  •Heidelberg QuickMaster DI
-X-Rite 938 Spectrodensitometer
-Graphiclite Color Viewing Station

FACILITIES

-Gannet Multimedia Lab in the School of Printing at RIT
-Typography Lab in the School of Printing at RIT
-Electronic Color Scanning Lab in the School of Printing at RIT
-CIMSPrint in the Center for Integrated Manufacturing Studies at RIT

COSTS

-paper
-finishing and binding of thesis project book upon completion

Chapter Five Endnotes

[1]Jennifer A. Kerrigan, *Digital Color Press Technologies: Analysis of the Printing Characteristics as Compared with SWOP* (Rochester, NY: 1997), 30.

[2]Joseph Noga, "Color Image Processing" (M.S. class, Rochester Institute of Technology, 1998).

[3]Frank J. Romano, ed., *Delmar's Dictionary of Digital Printing & Publishing,* (Albany, NY: Delmar Publishers, 1997), 523.

[4]Ibid., 451.

[5]Ibid., 97.

[6]Joseph Noga, "Color Image Processing" (M.S. class, Rochester Institute of Technology, 1998).

[7]Franz Sigg, "EPS Test Target Documentation" (M.S. class, Rochester Institute of Technology, 1998).

[8]Ibid.

[9]Joseph Noga, "Color Image Processing" (M.S. class, Rochester Institute of Technology, 1998).

[10]Ibid.

[11]Frank J. Romano, ed., *Delmar's Dictionary of Digital Printing & Publishing,* (Albany, NY: Delmar Publishers, 1997), 158.

[12]Ibid., 565.

[13]Ibid., 288.

[14]Ibid., 191.

[15]Ibid.

[16]Ibid., 523.

Chapter Six
The Results

To calculate solid ink density, dot gain, and the tone reproduction curve for every color, the percent dot areas of three sheets from every press run were measured with an X-Rite 938 spectrodensitometer. These values were then averaged. For the Xerox DocuColor 40, Heidelberg Quickmaster-DI, and Xeikon DCP-32D, the fiftieth, one hundredth, and one hundred and fiftieth sheets were selected. As a result of all the problems encountered in the operation of the Indigo E-Print 1000, less than 150 sheets were delivered. Consequently, and to keep the evaluation consistent, the third, the fiftieth, and last sheet were selected for measurement.

SOLID INK DENSITIES (AVERAGES)

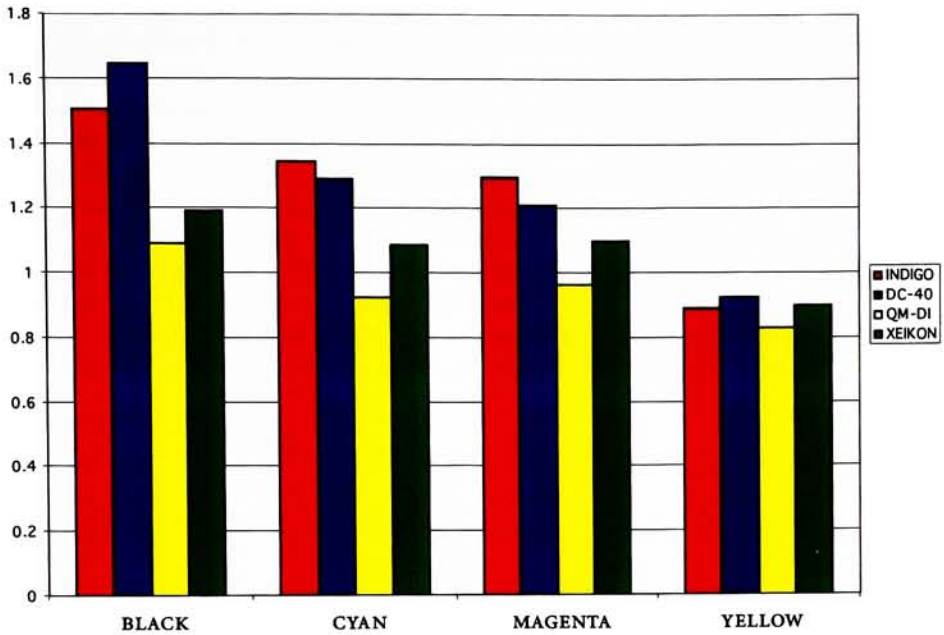

FIGURE 1 SOLID INK DENSITIES

TABLE 1 SOLID INK DENSITIES VALUES

	BLACK	CYAN	MAGENTA	YELLOW
Indigo E-Print 1000	1.51	1.35	1.30	0.89
DocuColor-40	1.65	1.29	1.21	0.93
Quickmaster DI	1.09	0.93	0.96	0.83
Xeikon DCP-32D	1.19	1.09	1.10	0.90

The Indigo E-Print 1000 had the highest densities for cyan and magenta while the Xerox DocuColor 40 had the highest densities for black and yellow. The DocuColor 40 printed satisfactorily throughout the pressrun and achieved the closest gray balance with respect to the RIT Neutral Balance Target for SWOP. The Indigo E-Print 1000, on the other hand, printed dark beyond acceptance. The Heidelberg Quickmaster DI produced the lowest densities for the four colors, evident in its faded and weak press sheets. The Xeikon DCP-32D printed somewhere in between; higher densities than those from the Quickmaster DI and lower than those from the DocuColor 40. Some areas in this press's sheets printed with a fair contrast while others printed flat.

TONE REPRODUCTION

For the purpose of this thesis project, the plate/press characteristic curve for each color has been plotted. This curve involves graphing the density of the reproduction against the percent dot area of the halftone. Since none of the tested devices require film, the percent dot allocated in the digital file is used. The main purpose of this curve is "to understand the relationship of the image carrier and the printing press as to the final characteristics (to learn how the press prints)."[1] "The main objective of a tone reproduction study is to be able to optimize the quality of the reproduction by accounting for such items as the printing method being used, the type of press, ink, ink density, ink tack, printing plate, blanket, fountain solution, dot gain, press speed and the substrate. . . . [By doing so,] it is possible to determine the adjustments that are needed in the films or digital image to produce the best possible reproduction from that particular printing condition."[2]

BLACK TONE REPRODUCTION CURVES (AVERAGES)

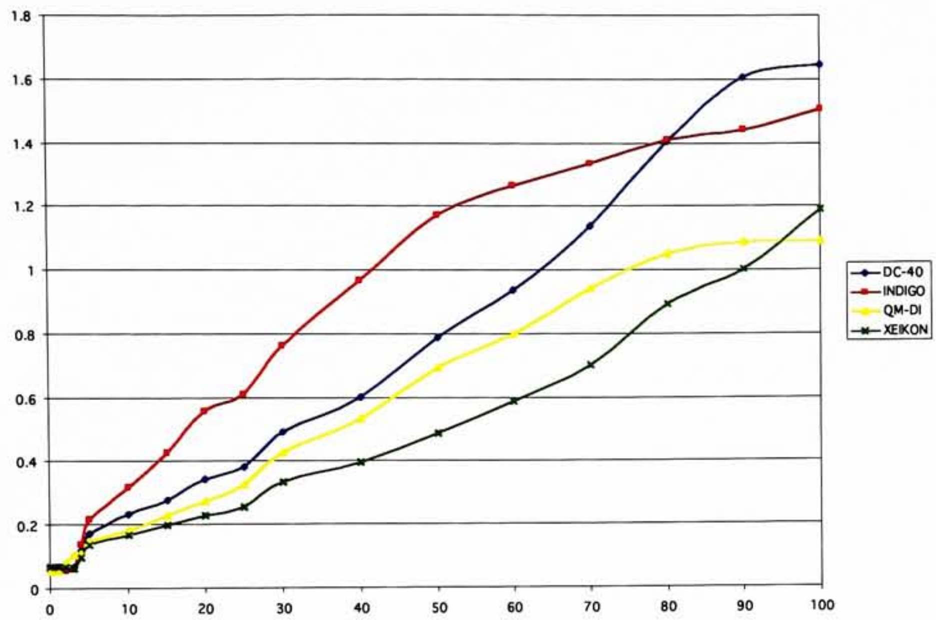

FIGURE 2 BLACK TONE REPRODUCTION CURVES

TABLE 2 BLACK TONE REPRODUCTION

PERCENTAGE	E-PRINT 1000	DOCUCOLOR 40	QUICKMASTER	XEIKON
0	0.06	0.07	0.06	0.07
1	0.06	0.07	0.06	0.07
2	0.06	0.07	0.08	0.07
3	0.06	0.07	0.11	0.07
4	0.14	0.12	0.11	0.10
5	0.22	0.18	0.15	0.14
10	0.32	0.24	0.19	0.17
15	0.43	0.28	0.23	0.20
20	0.56	0.35	0.28	0.23
25	0.61	0.38	0.33	0.26
30	0.77	0.49	0.43	0.34
40	0.97	0.60	0.53	0.40
50	1.17	0.79	0.69	0.49
60	1.27	0.94	0.80	0.59
70	1.34	1.14	0.95	0.71
80	1.41	1.41	1.05	0.89
90	1.44	1.61	1.09	1.01
100	1.51	1.65	1.09	1.19

CYAN TONE REPRODUCTION CURVES (AVERAGES)

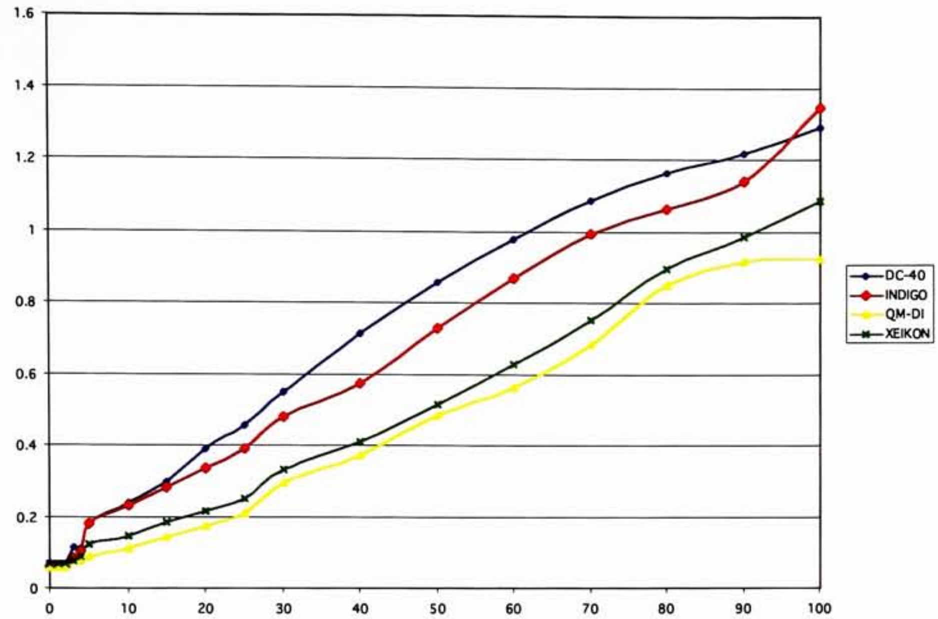

FIGURE 3 CYAN TONE REPRODUCTION CURVES

TABLE 3 CYAN TONE REPRODUCTION

PERCENTAGE	E-PRINT 1000	DOCUCOLOR 40	QUICKMASTER	XEIKON
0	0.06	0.07	0.06	0.07
1	0.06	0.07	0.06	0.07
2	0.06	0.07	0.06	0.07
3	0.09	0.12	0.07	0.08
4	0.10	0.11	0.08	0.09
5	0.18	0.18	0.09	0.12
10	0.23	0.24	0.11	0.15
15	0.28	0.30	0.14	0.19
20	0.34	0.39	0.18	0.22
25	0.39	0.46	0.21	0.25
30	0.48	0.55	0.30	0.34
40	0.57	0.72	0.37	0.41
50	0.73	0.86	0.49	0.52
60	0.87	0.98	0.56	0.63
70	0.99	1.09	0.68	0.75
80	1.06	1.16	0.85	0.90
90	1.14	1.22	0.92	0.99
100	1.35	1.29	0.93	1.09

Magenta Tone Reproduction Curves (Averages)

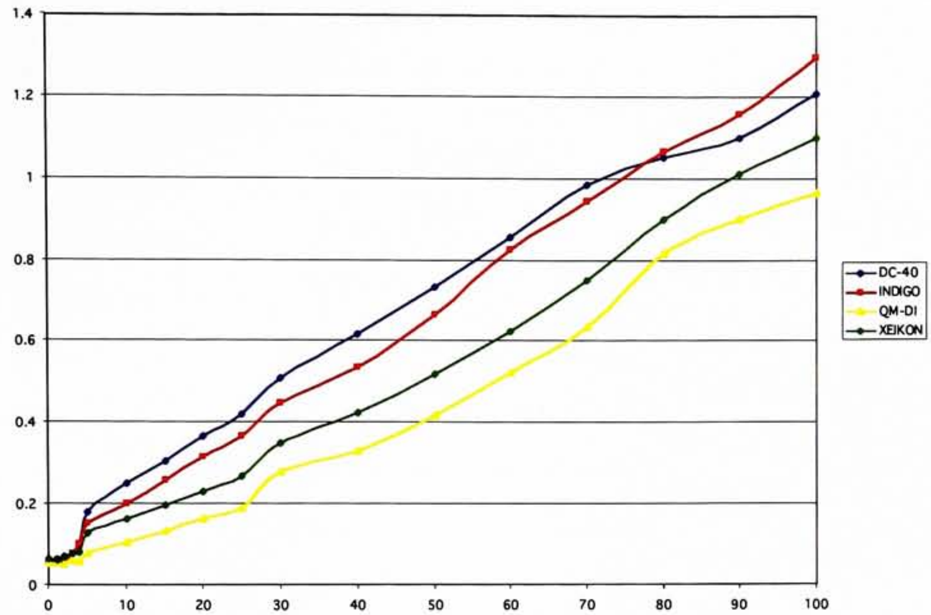

Figure 4 Magenta Tone Reproduction Curves

Table 4 Magenta Tone Reproduction

PERCENTAGE	E-PRINT 1000	DOCUCOLOR 40	QUICKMASTER	XEIKON
0	0.06	0.06	0.05	0.07
1	0.06	0.06	0.05	0.06
2	0.06	0.07	0.05	0.07
3	0.08	0.08	0.06	0.08
4	0.10	0.10	0.06	0.08
5	0.15	0.18	0.08	0.13
10	0.20	0.25	0.11	0.16
15	0.26	0.31	0.13	0.19
20	0.32	0.38	0.16	0.23
25	0.37	0.42	0.19	0.27
30	0.45	0.51	0.28	0.35
40	0.54	0.62	0.33	0.42
50	0.67	0.73	0.42	0.52
60	0.82	0.86	0.52	0.63
70	0.95	0.98	0.64	0.75
80	1.07	1.01	0.81	0.90
90	1.16	1.10	0.90	1.01
100	1.30	1.21	0.96	1.10

Yellow Tone Reproduction Curves (Averages)

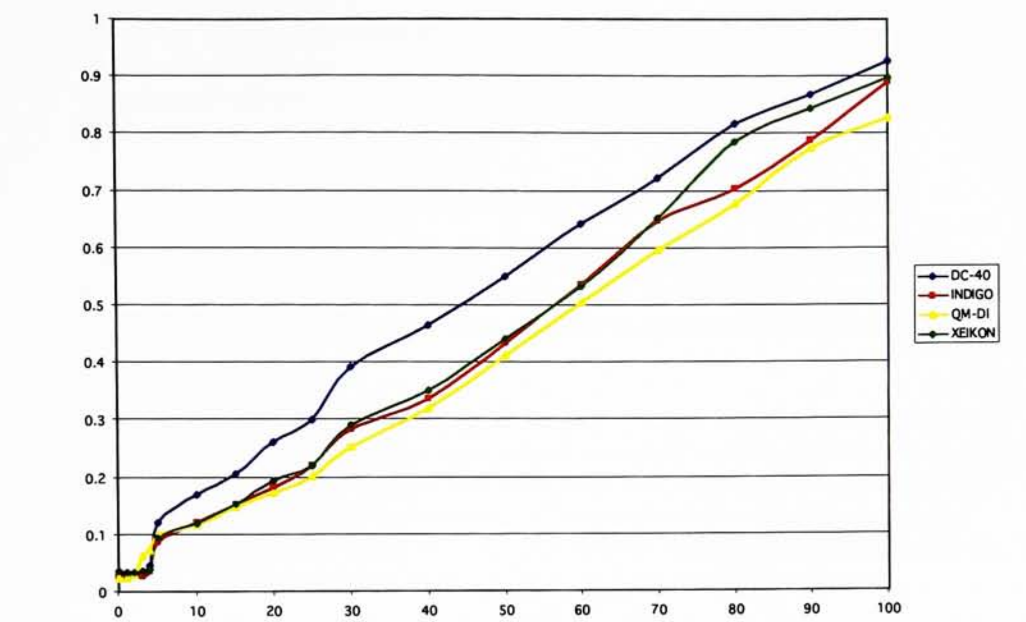

FIGURE 5 YELLOW TONE REPRODUCTION CURVE

TABLE 5 YELLOW TONE REPRODUCTION

PERCENTAGE	E-PRINT 1000	DOCUCOLOR 40	QUICKMASTER	XEIKON
0	0.03	0.03	0.02	0.04
1	0.03	0.03	0.02	0.03
2	0.03	0.03	0.03	0.03
3	0.03	0.03	0.06	0.04
4	0.04	0.05	0.07	0.04
5	0.09	0.12	0.10	0.10
10	0.12	0.17	0.12	0.12
15	0.15	0.21	0.15	0.15
20	0.18	0.26	0.17	0.19
25	0.22	0.30	0.20	0.22
30	0.28	0.39	0.25	0.29
40	0.34	0.47	0.32	0.35
50	0.43	0.55	0.41	0.44
60	0.54	0.64	0.51	0.53
70	0.65	0.72	0.60	0.65
80	0.71	0.82	0.68	0.79
90	0.79	0.87	0.78	0.84
100	0.89	0.93	0.83	0.89

Dot Gain

Dot gain is "the spread or enlargement of the halftone dots in the press sheet when compared to the dot sizes on the halftone film"[3] or digital file which results in color or tone changes and loss of detail in the press sheet. Dot gain is calculated using the Murray-Davies equation:

$$DA\% = 100 * (1 - 10^{-Dt}) / (1 - 10^{-Ds})$$

"where DA% is the dot area in percent, Dt is the density of the printed tint minus the density of the paper or film, and Ds is the density of the solid patch minus the density of the paper or film."[4] The Murray-Davies equation incorporates both physical and optical dot gain.

The DocuColor 40 produced the highest dot gain for cyan, magenta, and yellow, but the overall results were good. Images were printed with good contrast and vibrant colors. On the other hand, the high dot gain resulted in color casts, noticeable in the photograph. The blond woman's face at 150 dpi prints with a magenta cast while the neutral gray background prints with a blue overtone. The magenta cast is particularly noticeable in sheet 100. By sheet 150, her face looks more natural as a result of less magenta.

The E-Print 1000 printed with the highest black dot gain, reaching above 50 percent in the critical highlight area. Consequently, images out of the E-Print 1000 printed very dark. The three evaluated sheets were considerably saturated.

The Quickmaster DI produced the lowest dot gain for cyan, magenta, and yellow. Paired with low solid ink densities, it must not be surprising that color out of this press was weak and flat.

The DCP-32D printed with fairly low dot gain in all four colors with magenta being the highest, reaching about 23 percent. The other three colors printed with a similar dot gain, remaining consistent throughout pressrun. Black dot gain was the lowest among the four presses. Colors were weak, most noticeably in the reversed type block where black clearly appears faded.

Black Dot Gain (averages)

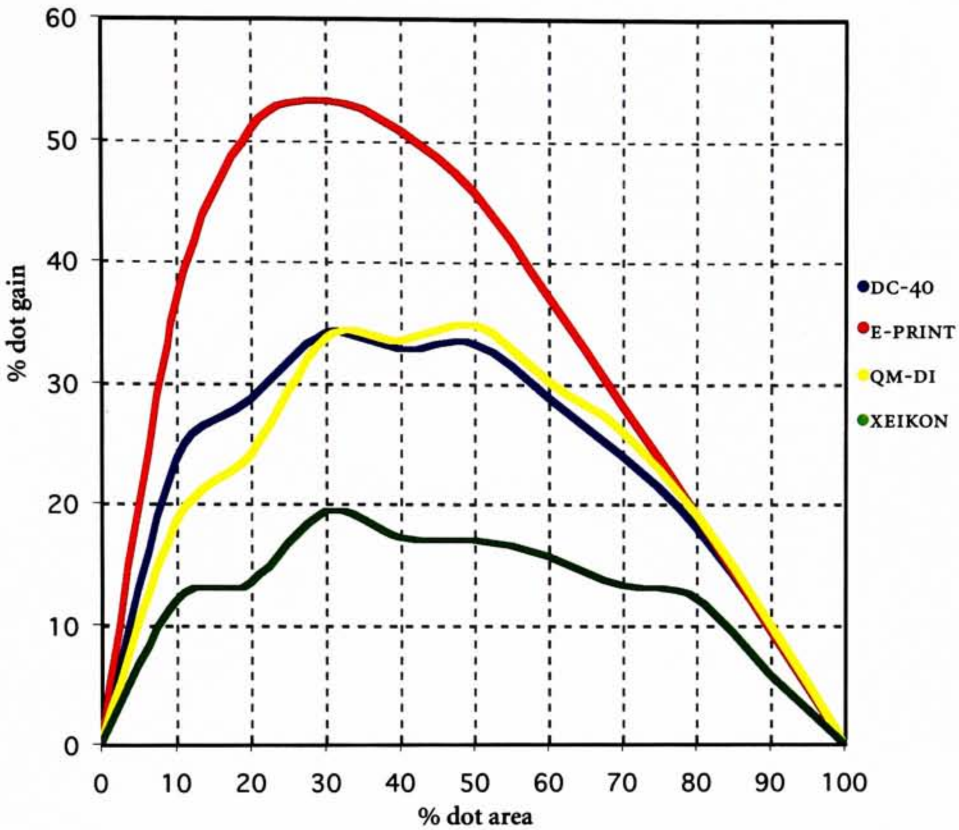

FIGURE 6 BLACK DOT GAIN CURVES

TABLE 6 BLACK DOT GAIN

PERCENT DOT	E-PRINT 1000	DOCUCOLOR 40	QUICKMASTER	XEIKON
0	0	0	0	0
10	37	24	19	12
20	51	29	24	13
30	53	34	34	19
40	51	33	33	17
50	46	33	35	17
60	37	29	30	16
70	28	24	26	13
80	19	18	19	12
90	9	10	10	6
100	0	0	0	0

CYAN DOT GAIN (AVERAGES)

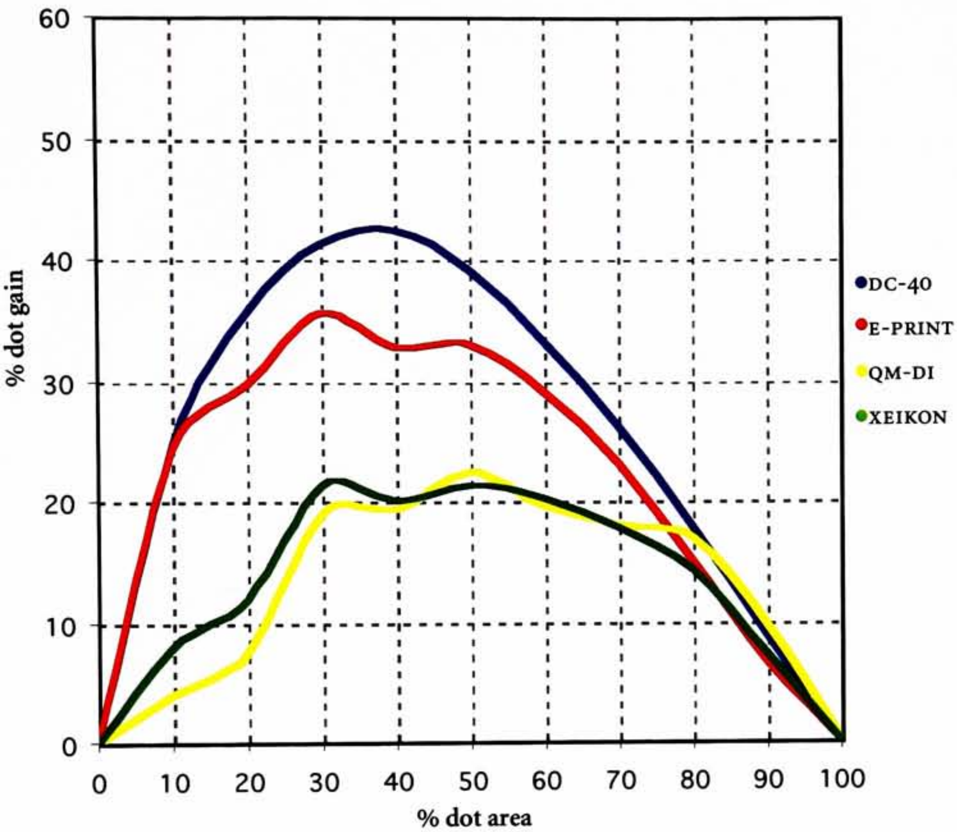

FIGURE 7 CYAN DOT GAIN CURVES

TABLE 7 CYAN DOT GAIN

PERCENT DOT	E-PRINT 1000	DOCUCOLOR 40	QUICKMASTER	XEIKON
0	0	0	0	0
10	24	25	4	8
20	30	36	8	12
30	36	41	19	21
40	33	42	19	20
50	33	39	23	21
60	29	33	20	20
70	23	26	18	18
80	15	18	17	14
90	7	9	10	7
100	0	0	0	0

MAGENTA DOT GAIN (AVERAGES)

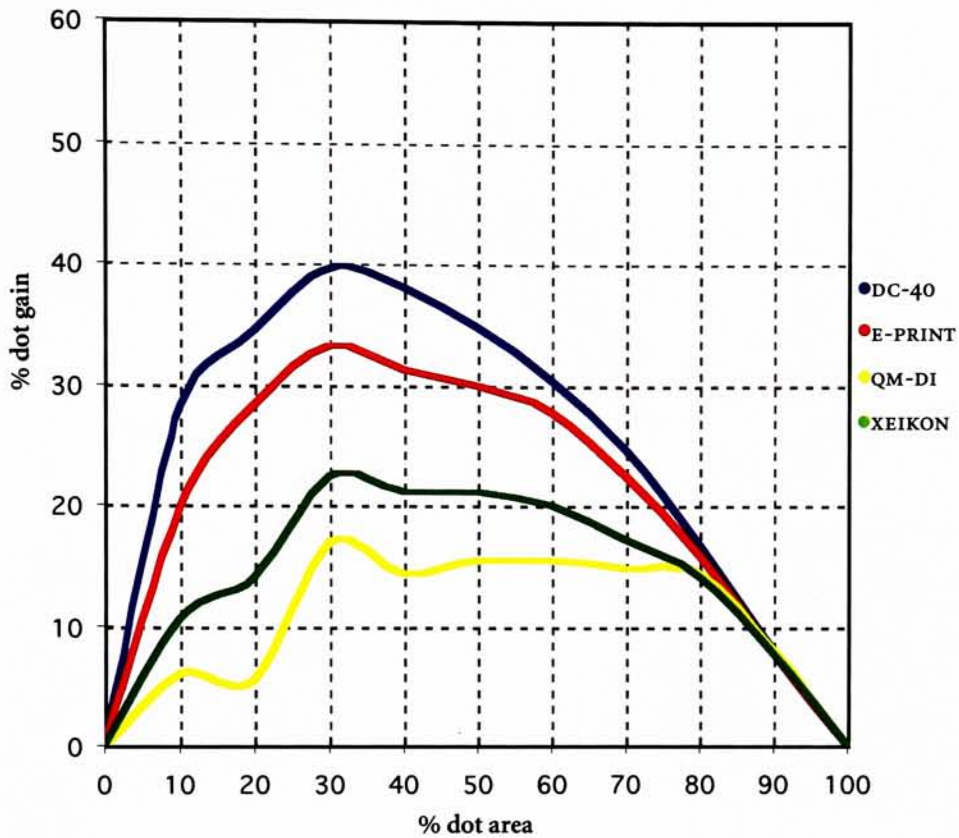

FIGURE 8 MAGENTA DOT GAIN CURVES

TABLE 8 MAGENTA DOT GAIN

PERCENT DOT	E-PRINT 1000	DOCUCOLOR 40	QUICKMASTER	XEIKON
0	0	0	0	0
10	20	28	6	11
20	28	35	6	14
30	33	39	17	22
40	31	38	14	21
50	30	35	15	21
60	28	30	15	20
70	23	25	15	17
80	16	17	14	14
90	8	8	8	8
100	0	0	0	0

Yellow Dot Gain (averages)

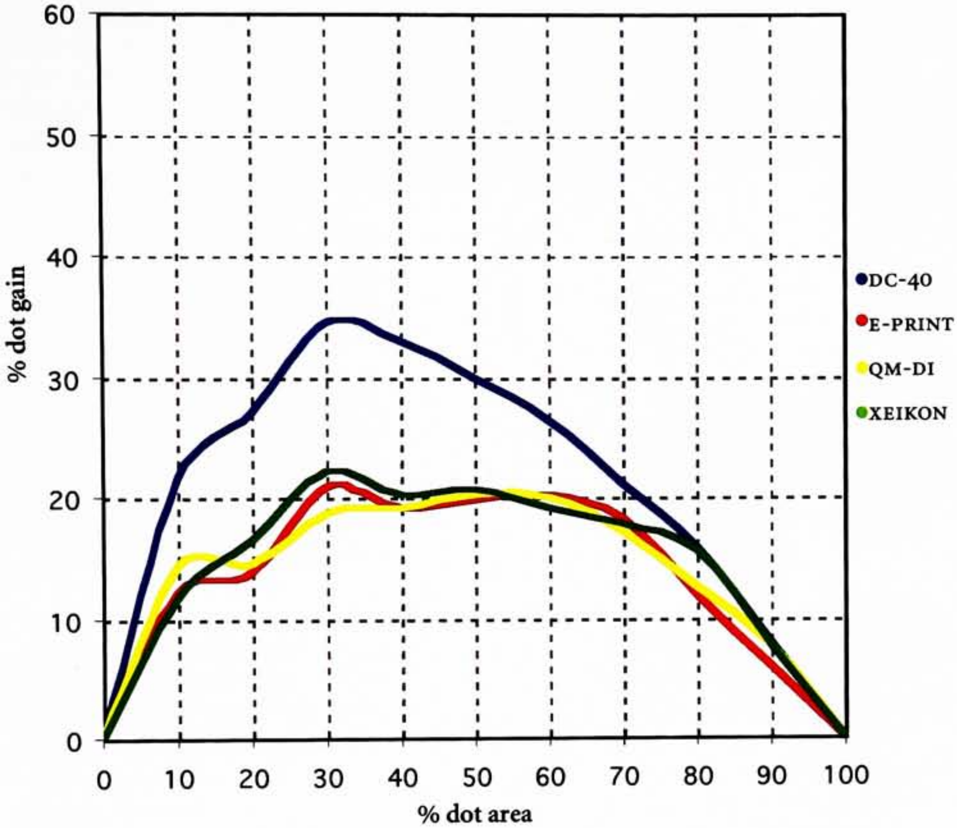

FIGURE 9 YELLOW DOT GAIN CURVES

TABLE 9 YELLOW DOT GAIN

PERCENT DOT	E-PRINT 1000	DOCUCOLOR 40	QUICKMASTER	XEIKON
0	0	0	0	0
10	12	22	14	12
20	14	27	15	16
30	21	34	19	22
40	19	33	19	20
50	20	30	20	21
60	20	26	20	19
70	18	21	17	18
80	12	16	12	16
90	6	8	8	8
100	0	0	0	0

Gray Balance

Gray balance is "the ability to reproduce a neutral gray object in the original as perfectly neutral gray in the reproduction. To accomplish this goal requires the correct yellow, magenta, and cyan . . . ink [or toner] . . . . Gray balance is also important to achieve because it has a direct relationship to the reproduction of color."[5] The RIT Neutral Balance Target included in the test instrument is meant to determine if gray balance is achieved by means of the three-color inner circles in every square. The circles correspond with the SWOP requirements for gray balance which are:

BLACK	CYAN	MAGENTA	YELLOW
25%	25%	16%	16%
50%	50%	39%	39%
75%	75%	63%	63%

None of the presses part of this thesis project printed this target correctly. In addition, the variations associated with RIP interpretation, particularly on the Indigo E-Print 1000, created a series of streaks extending from the 25 percent patch through the 50 percent patch. The DocuColor 40 printed the closest results, with the 75 percent being the closest match. The Quickmaster printed completely off, as well as the DCP-32D and E-Print 1000 which were off in every square. Please observe the enclosed samples.

As a result of presses not achieving gray balance, neutrally colored objects did not print properly. Most noticeable is the gray background in the photograph which appears with a blue overtone in the DocuColor 40 and the E-Print 1000 sheets. The Quickmaster DI sheets exhibited a blue cast, though not as saturated as other presses because of the low densities achieved during this press's run. The DCP-32D came close to achieving a neutral gray background. Because "digital presses are exceptionally sensitive to changes, such as temerature [*sic*], humidity, age of the developer and operator inconsistancies [*sic*]"[6] it is rather difficult to make a reproduction judgement based on this target.

Resolution

Resolution is "the number of discernible line pairs per inch . . . a true expression of resolution, preferable to 'dots per inch,' [the expression most commonly used] since dots are made to overlap in many types of output."[7] The purpose of including the same image at three different resolutions is to determine which level ink or toner fills the area between the halftone dots and produces the least desirable results. Surprisingly, there are few differences among the images. The quality of the photograph was not greatly improved with 300 dpi nor was it greatly diminished with 150 dpi.

The DocuColor 40 printed the 150 dpi image with a course texture unlike the others with higher resolution which appear smoother. In addition, a streak crossing the 150 dpi image from side-to-side printed and held throughout pressrun. This could be attributed to the Splash server's interpretation of the file. This server, by the way, interprets the file in lines rather than dots. Consequently, the chances for moiré to take place are increased since it is more difficult for the lines of the scanned image to match the charged couple device in a scanner.

The Quickmaster DI press sheets exhibited similar results as the DocuColor 40's, with the 150 dpi image appearing blurry. In addition, at the beginning of the pressrun the magenta concentration seems lowest, reaching a peak by sheet 150, most noticeably at 225 dpi, at which point the image starts to appear purplish.

The Indigo E-Print 1000 printed considerably dark images whose quality was reduced further by the toner migration this press's sheets suffered. It is not possible to make an objective evaluation among the images since the amount of toner migration varies across the press sheet. Nevertheless, visually the 300 dpi image does appear smoother than the two with lower resolution. Doubtfully, resolution has anything to do with the degree of toner migration.

The Xeikon DCP-32D printed the three images with a slight blur regardless of resolution, noticeable in the models' eyes. The 300 dpi photograph printed the smoothest among the three, with the other two exhibiting a slight ruffness which increases as resolution is decreased.

The RIT Four-Color Spokes Target printed considerably different among presses. The Quickmaster DI, the press with the highest resolution in this thesis project, held up the one pixel line for cyan, magenta and yellow fairly well. The yellow spokes, on the other hand, were filled almost entirely. No moiré was observed.

Memory Colors

The color bars part of the test instrument serve not only to determine how well the toner or ink stick to the paper but also to attest memory color appropriateness. Every press had its weaknesses and its strengths, color wise.

The DocuColor 40, which printed with the highest magenta dot gain, printed with a satisfactory saturation, but a bit much in the magenta side. Consequently, the blue bar printed as purple. The apple painting, on the other hand, came close to the original. The high solid ink densities contributed to the vivid reproduction of this image. The texture of the original was reproduced fine as well the handwriting around the image.

The Quickmaster DI produced considerably weak colors as a result of the low densities achieved during pressrun. Memory colors, nonetheless, appear well, with the exception of blue which printed purple. Because of the weak press sheets, the texture and detail in the apple painting have been partially lost, appearing rather flat, without contrast.

The E-Print 1000, with an exorbitant black dot gain, printed very dark. With the exception of blue which printed purplish, memory colors would appear well had it not been for the toner migration press sheets suffered. The apple though, printed with nice colors and saturation, resulting in a fairly close match to the original.

The DCP-32D printed decent memory colors with the exception of blue which appears purplish. Due to the low densities achieved during pressrun, color overall appears flat and weak. Even though the texture of the apple was reproduced well, the reproduction lacks any contrast, appearing flat.

TYPE

An important aspect of graphic design, type reproduced quite differently from press to press. The test instrument part of this thesis project included Minion serif type ranging in point size from 3 to 72, regular and reversed out in black.

The DocuColor 40 printed type with ruff, jagged edges, a characteristic increasingly noticeable as point size is reduced. Both regular and reversed specimens suffered from this throughout the pressrun. Three-point type regular was the smallest which held up, considerably jaggy and bitmapped, though. The equivalent reversed specimens disappeared in the saturated black background, with random segments of letters fading and depleting.

Because the Quickmaster DI is capable of printing at a much higher resolution than all evaluated presses, type both regular and reversed was reproduced very well. Three-point type regular was reproduced very well, holding up serifs and character weight. In the reversed specimens, characters held satisfactorily up to ten points, bellow which character weight is diminished. At three points, thin segments of characters disappear in certain letters. As the rest of this press's sheet, the reversed block appears flat and weak.

Type printed consistently throughout the DCP-32D's pressrun, with mild rough edges appearing in all characters, increasingly noticeable at small point sizes. Holding up to three points, both reversed and regular type appear jaggy but retaining its character weight. The reversed block appears faded.

Although the E-Print 1000 printed the least satisfactory among the four presses, type printed very smooth, with the reversed specimens printing better than the regular. These suffered from character weight changes, easily noticeable in the serifs of 72-point type. Serifs, originally square, became rounded losing their 90° corners. As point size is reduced, type weight increases, filling in areas in letters. The reversed specimens, on the other hand, retained their structure. Nevertheless, reversed type thins out in the background. Consequently, serifs become hairlines at about 24 points. In this process, as point size is reduced, segments of characters are lost. By ten points, letters are barely noticeable. By three points, they transform into illegible white lines.

Chapter Six Endnotes

[1]Joseph Noga, "Color Image Processing" (M.S. class, Rochester Institute of Technology, 1998).

[2]Ibid.

[3]Ibid.

[4]*Colortron* (Larkspur, CA: Light Source Computer Images, Inc., 1994), 5/52.

[5]Joseph Noga, "Color Image Processing" (M.S. class, Rochester Institute of Technology, 1998).

[6]Jennifer A. Kerrigan, *Digital Color Press Technologies: Analysis of the Printing Characteristics as Compared with SWOP* (Rochester, NY: 1997), 38.

[7]Frank J. Romano, *Pocket Guide to Digital Prepress* (Albany, NY: Delmar Publishers, 1996), 286-288.

Chapter Seven
Summary, Conclusions and Further Study

The objective of this thesis project is to evaluate the reproduction capabilities of digital presses and their impact in graphic designers' approach to the creative process. The presses evaluated have an important presence in industry. Nevertheless, it is not the purpose of this thesis project to convey these are the best in the marketplace.

Solid Ink Densities

The Indigo E-Print 1000 had the highest densities for cyan and magenta while the Xerox DocuColor 40 had the highest densities for black and yellow. The Heidelberg Quickmaster DI produced the lowest densities for the four colors. The Xeikon DCP-32D, on the other hand, printed higher densities than the Quickmaster but lower than those of the DocuColo 40.

Dot Gain

The DocuColor 40 produced the highest dot gain for cyan, magenta, and yellow, but the overall results were good. The E-Print 1000 printed with the highest black dot gain, reaching above 50 percent in the critical highlight area. The Quickmaster DI produced the lowest dot gain for cyan, magenta, and yellow which resulted in weak and flat colors. The DCP-32D printed with fairly low dot gain in all four colors with magenta being the highest, reaching about 23 percent.

Gray Balance

None of the presses part of this thesis project printed the RIT Neutral Balance Target correctly. In addition, the variations associated with RIP interpretations, particularly on the E-Print 1000, created a series of streaks extending from the 25 percent patch through the 50 percent patch. The DocuColor 40 printed the closest results, with the 75 percent being the closest match. All other presses printed completely off.

Resolution

Minimal differences among images of varied resolutions were observed. The quality of photographs was not greatly improved with 300 dpi nor was it greatly diminished with 150 dpi. A slight ruffness in 150 dpi images was observed with respect to those of higher resolution in all presses. There were no color differences observed.

Memory Colors

The DocuColor 40, which printed with the highest magenta dot gain, printed with a satisfactory saturation, but a bit in the magenta side. The Quickmaster produced considerably weak color as a result of the low densities achieved during pressrun. The E-Print 1000, with an exorbitant black dot gain, printed very dark. With the exception of blue which printed purplish, memory colors would appear fine had it not been for the toner migration press sheets suffered. The DCP-32D printed decent memory colors with the except blue which appears purplish.

Type

Type reproduced quite differently from press to press. The DocuColor 40 printed type with ruff, jagged edges. The Quickmaster on the other hand printed both regular and reversed type very well. The DCP-32D printed consistently throughout pressrun with

rough edges appearing in all characters. The E-Print 1000 printed smooth type with the reversed specimens printing better than regular.

Conclusions

With graphic designers in mind, the following conclusions have been drawn from the obtained test results:

1. According to Monadnock Paper Mills, the manufacturer of the substrate used in this thesis project, the paper used in the E-Print 1000 has the sapphire coating this press needs. Nevertheless, all the sheets from this press suffered from toner migration. Consequently, images appear very ruff and blurry, further reducing the quality of press sheets which printed dark beyond acceptance. The E-Print 1000 produced the highest dot gain for black, reaching above 50 percent at 30 percent dot in the critical highlight area.

2. The DocuColor 40 produced, by far, the best results from the digital file expedited to all presses in this thesis project. The saturation of press sheets was satisfactory, yielding vibrant images and memory colors. Nevertheless, the magenta dot gain reached 40 percent at 30 percent dot, causing blues to appear purplish. On the other hand, the reproduction of the apple painting was enhanced because of this high magenta dot gain, printing a fairly close match to original. This press can be operated much like a desktop printer and a photocopier are. Digital files can be directly expedited to the Splash Server from a page layout application. The DocuColor 40 has the capabilities of a high-end photocopier thanks to the built-in scanner which enables scanning once and printing many. This characteristics make this press easily accessible for a studio environment.

3. Depending on the finishing qualities desired, a press choice may be made. Because toner is fused into the paper in the DocuColor 40, images look glossy, having an immediate effect on the viewer, unlike the sheets of the Quickmaster DI which have a matte finish. This in addition to very low ink densities resulted in unattractive and bland press sheets from the Quickmaster DI. The flat tone reproduction curves illustrate the weak colors printed by this press. Nevertheless, its capability for printing up to 2,540 dpi enables this press for a greater detail fidelity and type sharpness than others.

4. From the evaluated presses, the E-Print 1000 and the Quickmaster DI are the only ones capable of printing more than cyan, magenta, yellow and black, with the E-Print being capable of printing two more colors and the Quickmaster being capable of full Pantone support. This capability enables designers to broaden their production resources, particularly critical when printing exclusive corporate colors and radical creations.

5. The press sheet size is a very important aspect in the creative process since it determines how many copies of a project can be produced per sheet. The DCP-32D, the only web press part of this thesis project, has a press sheet width of 12.14 inches and a length limited only by the press front end. This capability enables the production of unusually long applications such as banners and

posters which often can only be produced through tiling. All other presses part of this thesis project are limited to a press sheet size of about 11″ by 17″.

6. As the press sheets attest, differences among images with different resolution is minimal. Except for a mild ruffness, 150 dpi images did not look much different from 300 dpi images. With respect to color, differences were not noticed consistently in all presses. The only isolated case was the magenta color cast exhibited in sheets from the Quickmaster DI in which magenta reaches a peak by sheet 150, noticeably in the 225 dpi image. This must dispel from designers the thought that scanning originals beyond 300 dpi will further improve the quality of these.

7. The smallest dot held by presses was 5 percent with the exception of the Quickmaster DI which with the highest resolution among the evaluated presses printed up to 3 percent satisfactorily. Bellow 5 percent the DocuColor 40, the DCP-32D and the E-Print 1000 printed the cyan and magenta blocks in bars rather than solid. This condition persisted in the three presses up to 2 percent, most probably a result of RIP interpretation. None of this three presses printed yellow nor black bellow 5 percent. This is a critical aspect to keep in mind in the design process to avoid creating something that cannot be properly printed.

8. The relative ease with which digital presses can be operated by eliminating all the painstaking prepress procedures provide designers an opportunity to engage in production and broaden their services. By doing so, designers could meet all the needs of prospective customers. In addition, incorporating digital printing provides designers a chance for reducing artistic barriers and experiment producing new and attractive creative solutions.

9. Fairly new to the graphic arts, variable data printing is a marketing dream tool allowed today by electrophotographic presses. The myriad possibilities this aspect of digital printing enable pressures designers to learn about these innovative technology to better meet the changing needs of their customers.

Areas for Further Study

Variable-data printing, an exclusive characteristic of electrophotographic digital printing systems, is an area that poses great challenges and opportunities to broaden the reach upon prospective customers. Consequently, it is of utmost importance to study this area to ease its learning curve. Both designers and printers could benefit from a formal study of the advantages and limitations of the available technology and the innovative opportunities it allows. In addition, an evaluation of screen ruling and consistency would further broaden the knowledge about digital printing technologies and help targeting new applications.

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Appendix A: Printing Devices Specifications

Indigo E-Print 1000

type of process	digital offset
substrate capability	coated, uncoated paper; polyester fiber
colorant	ElectroInk (liquid toner)
spot color capability	two spot colors
maximum image size	11.7″ by 17.2″
speed	120 ft/min
sheetfed/web	sheetfed
perfecting	yes
collation	yes
automatic duplexing	yes
resolution	800 dpi
variable printing	yes
RIP	E-RIP—Adobe CPSI Level 2
operating system	UNIX

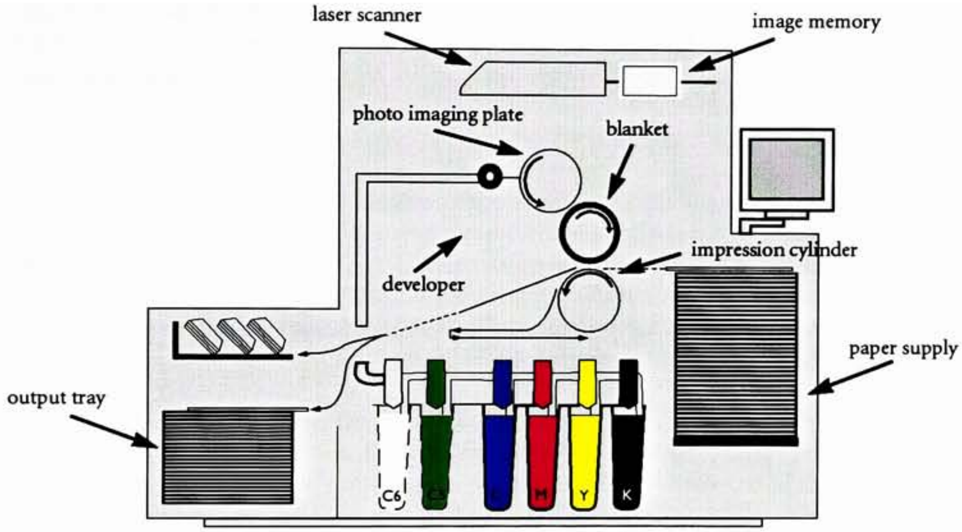


FIGURE 10 INDIGO E-PRINT 1000 PRINTING ENGINE

In 1993, the Indigo E-Print 1000 was announced as the "World's First Digital Offset Color Press." Opposite to what it may seem, the E-Print 1000 is an electrophotographic device capable of receiving digital data in PostScript and other formats from a Macintosh, PC, and other platforms. "The most unique features of the E-Print 1000 are the ElectroInk [it uses] and its image transfer system. The ElectroInk consists of micron-size pigment toners dispersed in a thermoplastic resin diluted in a light mineral oil (isopar). It is applied to the image on the photoconductor immediately after exposure by laser. The mineral oil is squeegeed from the surface of the imaging cylinder and returned to the toner reservoir, leaving just the toner/resin mixture on the image transferred to the heated blanket. This heated dispersion of toner pigment and resin sets when it transfers to the cold paper."[1]

"The E-Print 1000 comes with a Sun-based workstation, a hardware interface, and a print controller buffer containing between 32 and 640 MB of RAM. . . . The Sun graphical user interface gives the operator three choices—load, process, and print."[2] There are several

advantages to the Sun-based systems. Firstly, this kind of platform uses a UNIX-based operating system capable of true multitasking. "Therefore, all three tasks can be performed on different jobs, minimizing idle time for the press. Another advantage is that the faster Sun computers could perform the job faster. The load function pulls in desktop pages or color into the Sun station and converts it to Indigo's internal format. The process function automatically rasterizes individual elements and pages, and electronically collates them for rapid imaging."[3] In addition, the Sun systems have built-in Ethernet connectivity which enables the submission of files through the Internet.

The RIP of the E-Print 1000 can be in-line or off-line. "The off-line RIP, called the E-RIP, will allow greater overall throughput. The E-RIP is an Adobe CPSI Level 2 Interpreter, plus the Indigo software, running on a Sun workstation with a gigabyte (GB) or more of disk storage and Ethernet and TCP/IP networking. In addition to rasterizing, the off-line workstation has software for inputting job layout and parameter definitions."[4]

The E-Print 1000 has finishing capabilities that enable it not only to print but also to bind. Once a sheet is printed, "it moves to the Booklet Maker where booklets are automatically gathered and folded, stapled, and stacked. From the job setup [on the server], the Booklet Maker knows how many sheets to grab to make the booklet, whether to staple, etc. Thus, the E-Print [1000]'s final product is the finished piece itself."[5]

The E-Print 1000 is capable of variable-data printing through "a special, built-in ability to assemble an entire print job by moving images into the right place on the right sheet, electronically. Any design element that repeats from page to page is handled only once, resulting in efficiencies that no ordinary PostScript system can match."[6] Because PostScript, the industry standard print language, lacks variable-data features, the E-Print 1000 relies on these software innovations enabled by five prepress QuarkXtensions:

> **Yours Truly Layout** The most basic of Indigo's QuarkXtensions that "lets users take a multi-page QuarkXpress document and impose the page images onto the fronts and backs of press sheets. The result is what comes out of the press is finished press sheets, ready for the bindery."[7]
>
> **Yours Truly Card** This QuarkXtension allows fast, efficient step-and-repeat printing by using the entire 12" by 18" image area the E-Print 1000 has to offer. "Since most print jobs are much smaller than that, there's an opportunity to increase productivity by printing multiple copies on each sheet."[8] Regardless of how many pages per sheet, only one actual-size of the page is created. Yours Truly Card then directs the press to electronically duplicate the page as many times as desired with the spacing specified, with or without crop marks. Yours Truly Card optimizes file storage, transfers file to the RIP faster, and processes through the RIP faster.
>
> **Yours Truly Channel** This extension is used to add variable-data channels to a page. "Using the Channel tool, the operator draws a new kind of element on the page: an Indigo variable-data box. Its function is similar to Quark's familiar 'text box' and 'picture box' features, but what it does is very different: it instructs the press to insert different contents on each page at this location. The channel becomes its own small Quark document"[9] which can be filled with anything created in or imported into QuarkXpress, allowing unlimited design flexibility.

Yours Truly Link The more complex a variable-data job is, the more automation it must involve for its processing to be effective. "In today's world that means [the use of a] 'database'—an electronic file of the variable information that will go on each page. 'Yours Truly Link' is an AppleScript utility that automates getting data from a database."[10] If this resides in FileMaker Pro, a popular database program, Yours Truly Link is capable of reading it directly, extracting the specified data fields. If the database resides in a less popular format, "Link can also make the industry-standard ASCII files that all database programs can export."[11] Yours Truly Link is capable of directly "talking" to a QuarkXpress page, blending the variable data into the specified text boxes. As a result of this communication, Yours Truly Link "can even detect oversets (areas where the text won't fit) and tell Quark to reduce the point size"[12] to accommodate the text.

Yours Truly Image This QuarkXtension is for jobs using a small catalog of Quark "channel" pages repeatedly used on various sheets. As an example, a photograph may be used on sheets 2, 8, 35, and 60, but Yours Truly Image enables downloading this image only once. This powerful concept, "RIP once, print many," stores "reusable images" in the press and calls them out by name from a field in a database.

XEROX DOCUCOLOR 40

type of process	electrophotography
substrate capability	16 lb. text to 80 lb. cover; transparencies
colorant	dry toner
spot color capability	no
maximum image size	11″ by 17″
speed	40 8½″ by 11″ pages/min single sided 30 8½″ by 11″ pages/min duplex
sheetfed/web	sheetfed
perfecting	no
collation	yes
automatic duplexing	yes
resolution	400 dpi
variable printing	yes
RIP	Splash Server
operating system	Mac OS 8.1

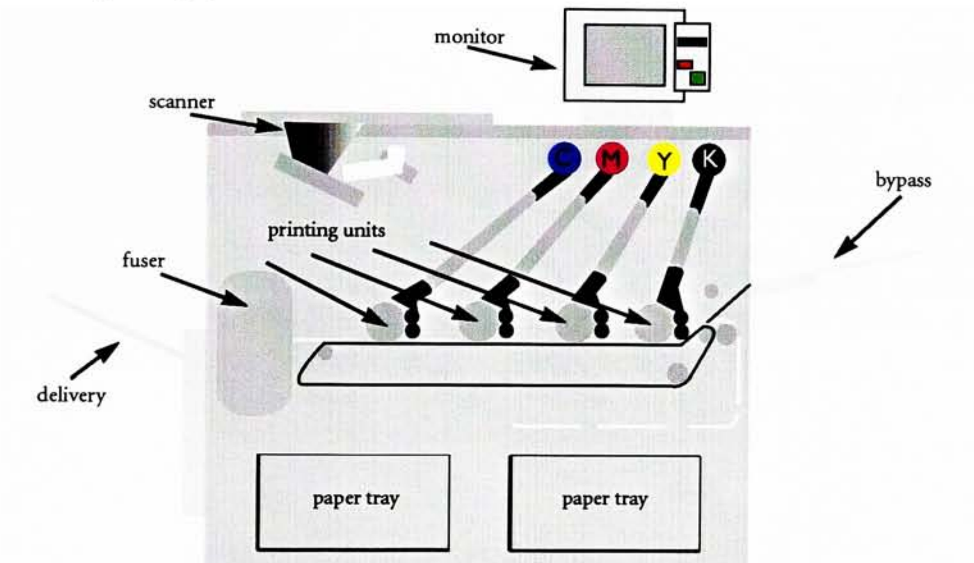


FIGURE 11 DOCUCOLOR 40 PRINTING ENGINE

Xerox Corporation, the DocuColor 40 manufacturer, declares this electrophotographic device "the total solution for printing high-quality full-color on demand."[13] The system is equipped with a digital front end that "provides true Adobe PostScript 3 support and ColorWise software tools enabling even casual users to produce outstanding color documents."[14]

The DocuColor 40 is designed with four-color printing stations that are in a straight line "for enhanced reliability and improved color registration."[15] Greater color consistency can be achieved throughout a run with the built-in scanner that performs a single pass to save the digital master from which all copies are made. In addition, HIEST (Highlight Image Enhancement Screen Technology) and TRACS (Toner Reproduction Auto Correction System), two Xerox technologies, are used in the DocuColor 40 for ensuring proper registration, reproduction, and consistency throughout a run. HIEST is a "dot placement technology [which] optimizes image structure in critical areas (10-30%

density) [by eliminating] . . . dot alignment problems that produce moiré patterns."[16] The DocuColor 40 prints CMYK patches on the paper transport belt used by TRACS to "establish the toner density values for each print job. Throughout the run, automatic densitometer readings ensure that the toner reproduction curve on the paper matches the value in the CMYK patches . . . and if necessary corrects it on the fly! The result is consistent color from start to finish on every job."[17]

The DocuColor 40 capability to run continually is enhanced by the auto-tray switching and load-while-run features. These capabilities enable the operator to refill trays without requiring the machine to be stopped. In addition, the DocuColor 40 is capable of producing:

- automatic one-to-two and two-to-two side copying
- face-up or face-down output
- consecutive page book copying from the platen without repositioning the book to the glass

The DocuColor 40 is available with any of several front ends. The machine tested in this thesis project uses a Splash Server, which enables variable data printing through Atlas PrintShop Mail. This software enables personalized printing by integrating "the information from a database into the layout of a document. The printing speed of the system is almost independent of the complexity of the layout, because the layout is sent to the printer only once. In the RIP of the printer the layout variables are replaced with the database field values of the different records."[18] Targeted to applications such as coupons, labels, invitations, and lottery tickets, PrintShop Mail can be used with QuarkXpress and Adobe Pagemaker, both of which have a strong presence in the graphic arts industry.

HEIDELBERG QUICKMASTER-DI 46-4 (QM-DI)

type of process	Direct Imaging waterless offset lithography
substrate capability	0.0024″ by 0.012″ coated, recycled, mylar, cardboard, and more
colorant	standard waterless ink
spot color capability	full Pantone Matching System support
maximum image size	12½″ by 17¾″
maximum speed	10,000 sheets/hour
sheetfed/web	sheetfed
perfecting	no
collation	no
automatic duplexing	no
resolution	1,270; 2,400; and 2,540 dpi
variable printing	no
RIP	Harlequin PostScript Level 2
Operating System	Windows NT Server 3.51

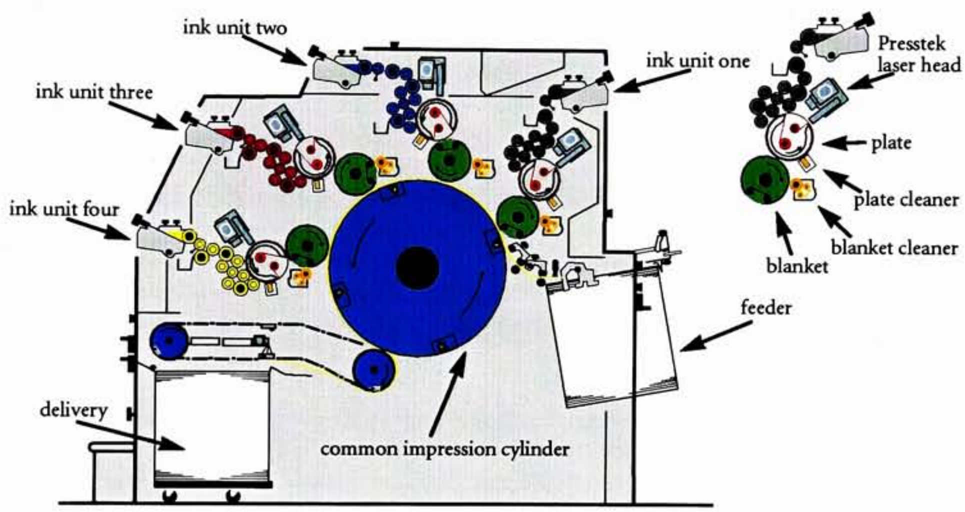


FIGURE 12 QUICKMASTER DI PRINTING ENGINE

"In 1995, Heidelberg introduced a brand new press, the Quickmaster DI 46-4, which images PostScript files directly to plates already in position on the press. . . . Rated at 10,000 sheets per hour, the core market for the QM-DI is pegged at 200 to 5,000 sheets,"[19] but according to Mr. David Jimenez, press technologist at CIMSPrint, a cost effective run in the QM-DI starts at 2,000 sheets. Bellow this, electrophotographic presses are far more competitive. The QM-DI is sold with a computer to control the Direct Imaging system and the press and a server with a software RIP. "The Raster Image Processor in the Quickmaster DI is based on a PostScript Level 2 interpreter from Harlequin. Running on a Digital AlphaStation 200 4/233 under Windows NT Server 3.51, this RIP is one of the fastest available in the marketplace."[20] This was selected over other RIPs for its PostScript compatibility, speed, and printing quality.

"Inside, the [Quickmaster DI] has just one impression cylinder and four printing units [with a laser device to image the plates on each unit]. Sheets of paper pass under the printing blanket in each unit for four-color printing in one pass."[21] This revolutionary press "has a so-called satellite configuration, with a central quadruple-diameter

impression cylinder with four printing units arrayed around it. This allows four-color printing with a single gripper closure. The sheet is gripped only once [for impression], being successively printed with each color without being transferred to another system of grippers [until completely printed, when it is transferred to a second set of grippers that transports the sheet towards delivery]. This reduces further the mechanical stresses that the press sheet is subjected to, although they are already quite low at a sheet size of . . . 13⅜″ by 18⅛″."[22] Because of the satellite configuration of its cylinders, the QM-DI cannot be equipped as a perfecting device. Nevertheless, according to Heidelberg, it has been the experience with the GTO-DI, Heidelberg's first Direct Imaging press, "that the time needed to dry the sheets is so short due to use of the dry offset process, that in many cases the pile [of printed paper] can be turned and fed back into the press for a second pass after just 15 minutes."[23]

"In each printing unit of the Quickmaster DI 46-4 infrared laser diodes are mounted on a movable carriage, emitting laser beams that strike the rotating plate cylinder. Each time the diode carriage reaches the gap of the plate cylinder it steps sideways by a distance geared to the selected imaging resolution (1,270 or 2,540 dpi). . . . [Approximately after six minutes at 1,270 dpi], the plate has been completely imaged. Then, [in approximately six more minutes] as soon as all of the polyester plates have been automatically cleaned, printing can begin."[24] "The QM-DI mounts its plates very differently from the GTO-DI. Both use special plates that are made with a base layer of ink receptive mylar; a center layer of titanium that converts the laser light energy into heat and burns itself away; and a top layer of silicon to repel ink in the image portion of the plate. But on the QM-DI, they are housed in a continuous supply roll inside each plate cylinder. After a job is printed, used plates are wound onto a take-up reel also housed in the plate cylinder."[25] The plates and its imaging device were developed in the United States by Presstek which also owns the patent.

The Quickmaster DI is a waterless offset lithography press. The name of the process is derived from "its method of printing that relies on special properties of the printing plate surface, rather than water-based dampening solution, to prevent ink from adhering to non-image areas. It prints with higher resolution of 200 to 600 dots per inch (dpi) and lower dot gain. Because the process does not require adjusting ink and water balance, it reduces makeready time and paper waste associated with makereadies. Without fountain solution, printers experience less picking and pilling, which improves yields both in makeready and running."[26] However, waterless offset lithography "requires more than just different plates. Inks used with waterless offset require higher densities and tack. Printers need to maintain tight control over ink temperatures, which requires installing hollow, water-chilled rollers. The high tack of the ink calls for paper with greater resistance to picking. Grades with higher smoothness and brightness appear to work best with waterless offset. While most waterless jobs use coated grades, printers can also use smoother uncoated grades if needed."[27] "Because dry offset involves no dampening solution, which otherwise has a cleaning effect, it is essential to use dust-free papers if possible in order to prevent hickeys."[28] A hickey is "a dust particle sticking to the printing plate or blanket, which appears on the printed sheet as dark spots surrounded by a halo."[29]

"With longer runs and intensive use, presses printing with dry offset can heat up, leading to toning problems. To counteract this, all of the ink fountain rollers of the [Quickmaster]DI 46-4 and one oscillator roller in each printing unit are water-cooled; in addition, the inking system is disengaged while the plates are being imaged. This ensures

constant, consistently good printing conditions in spite of high ambient temperatures, continuous operation, and/or frequent imaging cycles."[30]

XEIKON DCP-32D

type of process	LED array-based dry toner electrophotography
substrate capability	40 lb text, 90 lb cover; 32 cm wide roll; coated and uncoated paper, synthetic media, label stocks
colorant	dry toner
spot color capability	no
maximum image size	12.24″ width theoretically, the length is just limited by the press front end
speed	12.35 cm/s (4.86 in/s) 35 A4 double sided pages per minute
sheetfed/web	web
media width	12.6″
perfecting	yes
collation	yes
automatic duplexing	yes
resolution	600 dpi
variable printing	yes
RIP	Barco Server
Operating System	Windows NT 4.0

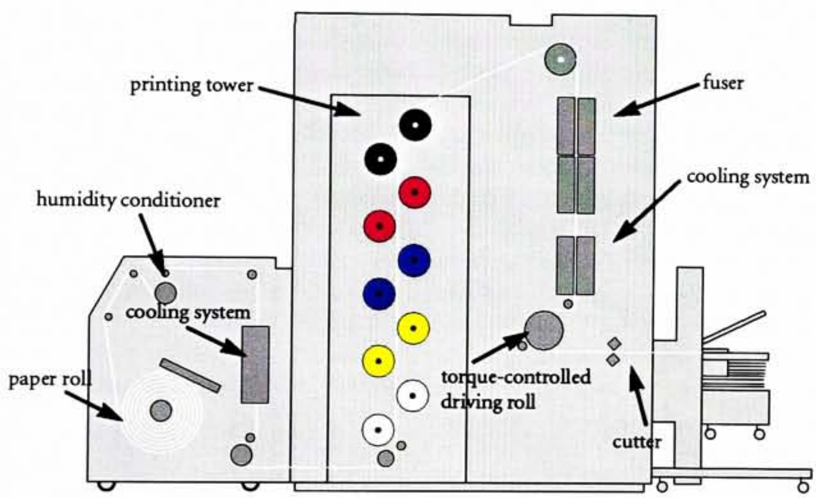


FIGURE 13 XEIKON DCP-32D PRINTING ENGINE

The DCP-32D is an electrophotographic press built by Xeikon, a Belgian company that produces its own line of digital presses and licenses its engines to Agfa for the Chromapress, Xerox for the DocuColor 70, and IBM for the InfoColor 70. The DCP-32D is designed with One Pass Duplex architecture that operates with fixed print stations. "Arrays of LEDs [are used] to image eight photo-conductive drums, with four on each side of web-fed paper to support full-time duplex printing. In addition to the base 600-dpi resolution, the engine supports multiple gray levels [64 levels for every single dot] for each color and produces excellent quality halftone images. It also has a built-in variable length cutter to create cut sheets."[31]

This printing device operates with dry small-particle dual-component toner developed and manufactured by Agfa, "specially developed for color fidelity. The colors are parallel

to Euro Standard inks and closely comparable to SWOP process color standards."[32] With an average particle size of just 7.5 microns, the toner "gives the print a smooth offset look and feel, high lightfastness and resistance to scratches and makes it waterproof. Unlike liquid toner, the Xeikon dry toner is environmentally safe."[33] "The system is capable of printing a fifth color, but this capability has not been implemented at this time."[34]

The DCP-32D is capable of printing variable information enabled by its Variable Data System, PrintStreamer, and Private-I features. These allow up to 16 segments of every page to be "defined as variable data fields so that when combined with databases, text, pictures, and full pages can be changed from item to item in full color."[35] The DCP-32D "handles personalized documents in two different ways, with and without Barco's Print Streamer. In either case, there is a master page for fixed info that is RIPed once, followed by processing variable information records. The actual merging of the master page and the variable information happens on the fly during the print run."[36] Because "fixed and variable info are both independent pages [which can be created in page layout applications], there is no limitation on the amount of variation on the page, as long as the total run fits into the 32 GB disk array."[37] "The Variable Data System (VDS) [in the DCP-32D] separates the processing of fixed and variable data, merging them only moments before printing. The merging of the master page and the variable elements is done when both are in bitmapped format, enabling the variable information to be full-color text, line art, or images."[38] Unfortunately, only specialized database printing professionals can handle VDS. As a result, Xeikon created Private-I, a front-end application which "integrates advanced desktop manipulations with today's standard desktop prepress applications. . . . On top of the master page, variable-data fields are designed by drawing text and/or picture frames in the variable-data layer. At that point, a link is made with the database file containing the variable information. Private-I is compatible with the standard DBF file format. The variables defined by the user in the document are associated with the fields in the database by dragging the field name from the database to the variables windows. As a last step, a VDS-compatible PostScript file is sent to the Xeikon press for printing."[39] The updated version of Private I, version 2.0, can create variable data documents with the PrintStreamer, "a very large and swift buffer for storing RIP-ed pages. It has a sustained aggregate data transfer rate of well over 100 MB per second to Xeikon's multi-station imaging system. With storage capacity for 240 pages in uncompressed format, the PrintStreamer can warehouse 4800 typical text pages and 500 typical magazine pages without loss of image quality. [In addition,] the pages can be printed in collated order in any sequence thus eliminating the cost and need for mechanical collating."[40]

Appendix A Endnotes

[1]Frank J. Romano, *Pocket Guide to Digital Prepress* (Albany, NY: Delmar Publishers, 1996), 286.

[2]Howard Fenton and Frank J. Romano, *On-Demand Printing: The Revolution in Digital and Customized Printing* (Pittsburgh, Pennsylvania: Graphic Arts Technical Foundation, 1995), 162.

[3]Ibid., 163.

[4]Ibid., 164

[5]Ibid., 162

[6]Variable Data Information, apparently written at Indigo headquarters in Woburn, MA, 1999.

[7]Ibid.

[8]Ibid.

[9]Ibid.

[10]Ibid.

[11]Ibid.

[12]Ibid.

[13]DocuColor 40 product information, in Xerox Corporation Website; available from http://www.xerox.com/print/products/dc40/index.htm#productsummary; Internet; accessed 13 January 1999.

[14]Ibid.

[15]Ibid.

[16]Ibid.

[17]Ibid.

[18]Ibid.

[19]Noel Jeffrey, *Digital Printing: A Guide to the New World of Graphic Communications* (Torrance, CA: Micro Publishing Press, 1996), 130.

[20]Quickmaster-DI 46-4 product information, in HeidelbergUSA Website; available from http://www.heidelbergusa.com/03_pro/direct_imaging/qmdi.htm; Internet; accessed 13 January 1999.

[21]Noel Jeffrey, *Digital Printing: A Guide to the New World of Graphic Communications* (Torrance, CA: Micro Publishing Press, 1996), 130.

[22] *Heidelberg Quickmaster DI Brochure* (Heidelberg, Germany: Heidelberger Druckmaschinen Aktiengesellschaft, 1998), 16.

[23] Quickmaster-DI 46-4 product information, in HeidelbergUSA Website; available from http://www.heidelbergusa.com/03_pro/direct_imaging/qmdi.htm; Internet; accessed 13 January 1999.

[24] Ibid.

[25] Noel Jeffrey, *Digital Printing: A Guide to the New World of Graphic Communications* (Torrance, CA: Micro Publishing Press, 1996), 131.

[26] Alan Kotok and Ralph Lyman, *Print Communications & The Electronic Media Challenge* (Plainview, NY: Jelmar Publishing Co., 1997), 43.

[27] Ibid., 43-44.

[28] Quickmaster-DI 46-4 product information, in HeidelbergUSA Website; available from http://www.heidelbergusa.com/03_pro/direct_imaging/qmdi.htm; Internet; accessed 13 January 1999.

[29] Frank J. Romano, ed., *Delmar's Dictionary of Digital Printing & Publishing,* (Albany, NY: Delmar Publishers, 1997), 303.

[30] Quickmaster-DI 46-4 product information, in HeidelbergUSA Website; available from http://www.heidelbergusa.com/03_pro/direct_imaging/qmdi.htm; Internet; accessed 13 January 1999.

[31] Alan Kotok and Ralph Lyman, *Print Communications & The Electronic Media Challenge* (Plainview, NY: Jelmar Publishing Co., 1997), 28.

[32] Noel Jeffrey, *Digital Printing: A Guide to the New World of Graphic Communications* (Torrance, CA: Micro Publishing Press, 1996), 44-45.

[33] Xeikon DCP/32D product information, in Xeikon Website; available from http://www.xeikon.be/; Internet; accessed 10 March 1999.

[34] Howard Fenton and Frank J. Romano, *On-Demand Printing: The Revolution in Digital and Customized Printing* (Pittsburgh, Pennsylvania: Graphic Arts Technical Foundation, 1995), 149.

[35] Xeikon DCP/32D product information, in Xeikon Website; available from http://www.xeikon.be/; Internet; accessed 10 March 1999.

[36] Noel Jeffrey, *Digital Printing: A Guide to the New World of Graphic Communications* (Torrance, CA: Micro Publishing Press, 1996), 49.

[37] Ibid.

[38]Tom McMillan, "A Roundup of Variable Data Software," *Electronic Publishing*, April 1998, 33.

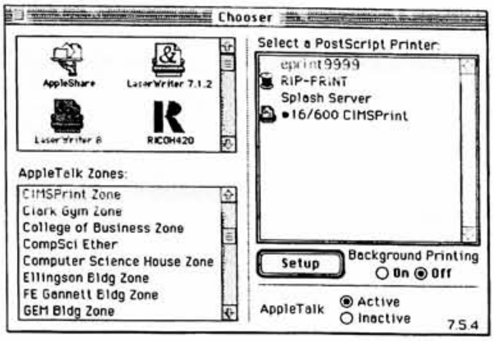
[39]Tom McMillan, "A Roundup of Variable Data Software," *Electronic Publishing*, April 1998, 33.

[40]Jennifer A. Kerrigan, "Digital Color Press Technologies: Analysis of the Printing Characteristics as Compared with SWOP" (M.S. Thesis, Rochester Institute of Technology, 1997), 17.

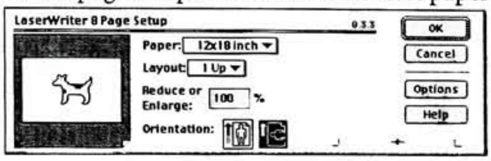
Appendix B: File Preparation

Indigo E-Print 1000

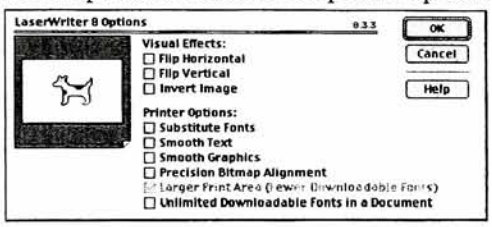
1. Select LaserWriter 8 on the Chooser and select eprint9999 Spooler to send file directly from Quark to E-Print 1000



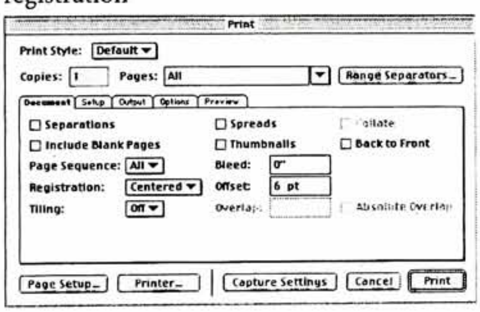
2. Check page setup and select the correct paper size in use, printer (Heidelberg PPD),



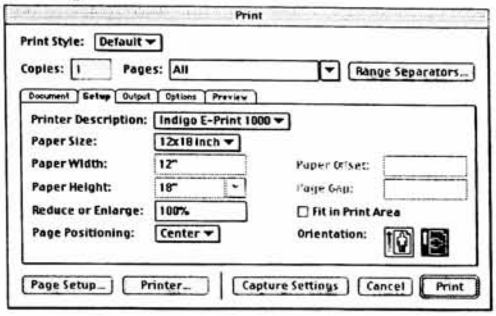
3. Select options and deselect all printer options



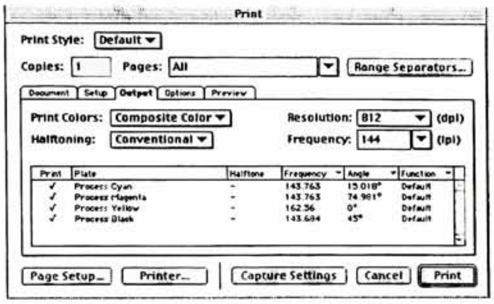
4. In the Print-Document window, determine the number of copies and select centered registration



5. In the Print-Setup window, verify the print orientation, paper size, and printer description

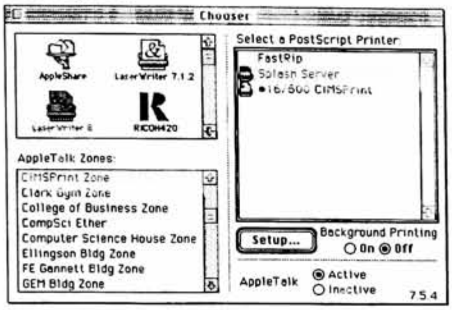


6. Select Output to establish the resolution and the screen frequency

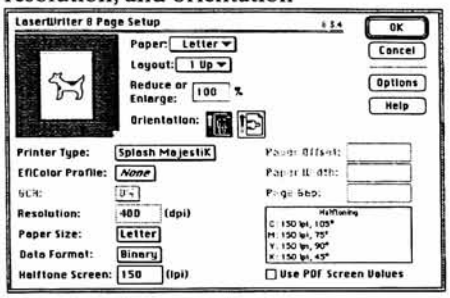


Xerox DocuColor 40

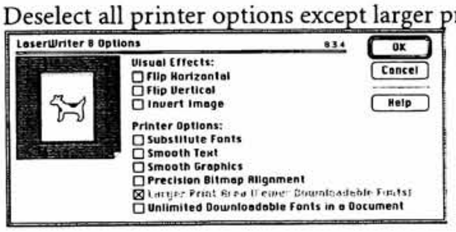
1. Select LaserWriter 8 on the Chooser and select Splash Server to send file directly from Quark



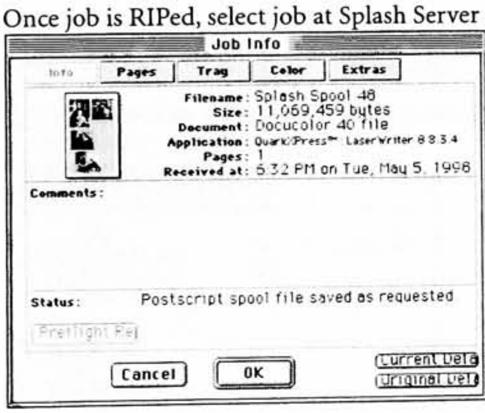
2. Check page setup and select the correct paper size in use, printer (Splash Majestic), resolution, and orientation



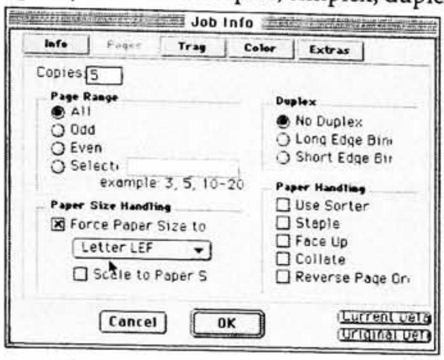
3. Deselect all printer options except larger print area



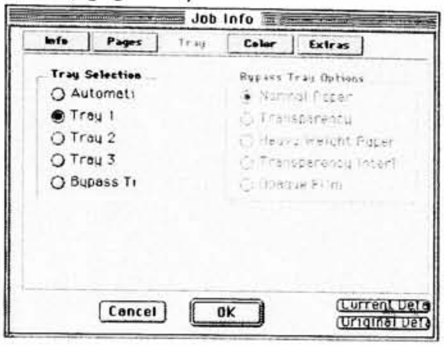
4. Once job is RIPed, select job at Splash Server and set options



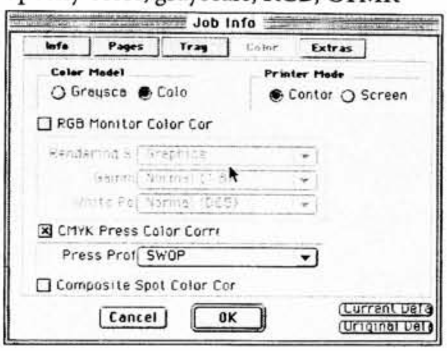
5. Specify number of copies; simplex, duplex; and paper handling



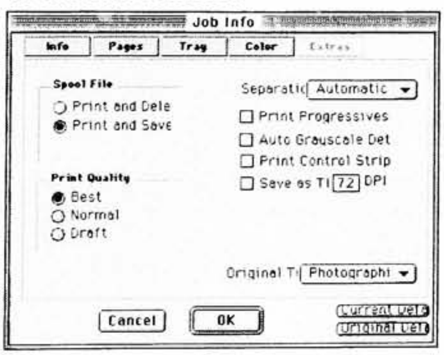
6. Specify paper tray



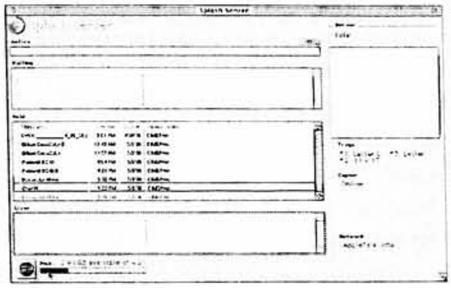
7. Specify color, grayscale; RGB, CYMK



8. Specify spool file; print quality. Once file is spooled to server, it may remain in server to be resent as needed

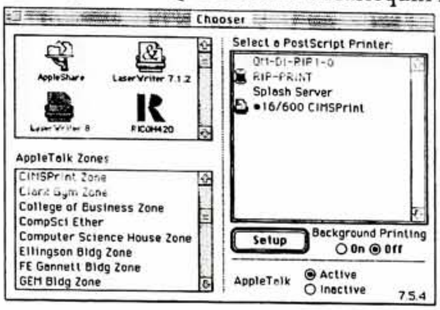


9. Once all options are set, job may be dragged from Hold to Waiting where it will be automatically sent to printer

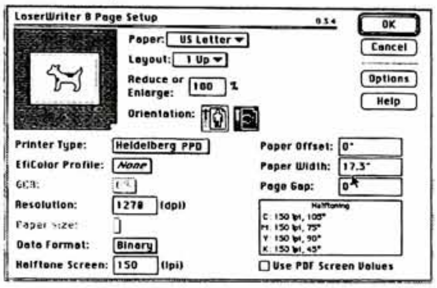


Heidelberg Quickmaster DI

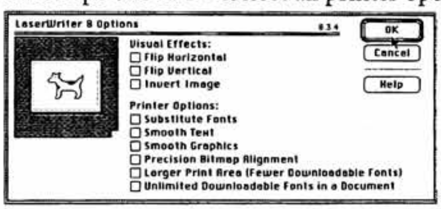
1. Select LaserWriter 8 on the Chooser and select QM-DI-RIP1-0 to send file directly from Quark to Quickmaster's Harlequin RIP



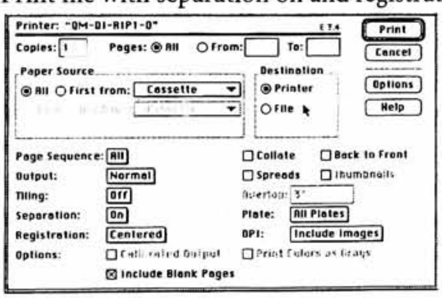
2. Check page setup and select the correct paper size in use, printer (Heidelberg PPD), resolution, and orientation



3. Select options and deselect all printer options



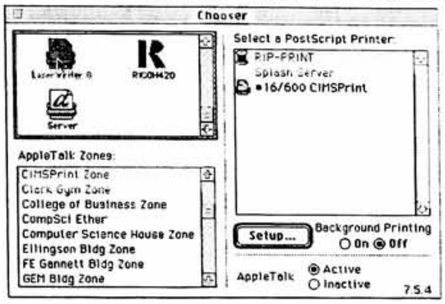
4. Print file with separation on and registration centered



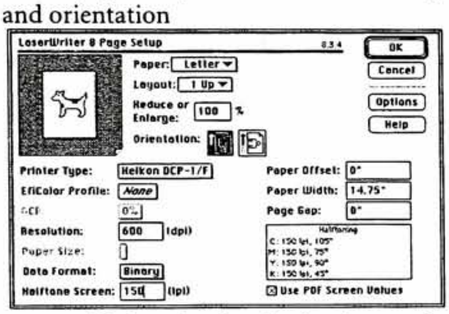
Once the job is RIPed to the Harlequin, it can be resent to Quickmaster without RIPing job again.

Xeikon DCP-32D

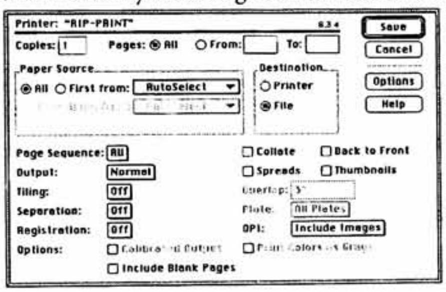
1. Convert Quark file to PDF
   - •Select LaserWriter on Chooser and select spooler RIP-PRINT for Xeikon DCP



   - •Check page setup and select the correct paper size in use, printer (Xeikon DCP-1/F), and orientation



   - •Save as file by selecting destination on the print window



2. Send PostScript file to spooler
3. Setup file to send to press
   - •paper specifications
   - •page setup
     - -simplex/duplex
     - -orientation: 0°, 90°, 180°; image position can be changed with respect to selected trim size from rip station without ripping file again
     - -tumble to backup correctly when duplexing
     - -face down to print on wide side of paper right/wrong reading
     - -data depth: two for line art/text; four for contone images
     - -dot gain: five to 35 percent in five percentincrements
     - -number of copies

Before press gets up to speed, a considerable amount of paper, up to 11 meters, must pass through machine prior to the first impression. Paper needs to become electrically charged for toner to adhere.

Appendix C: Data Collection Tables

Indigo E-Print 1000

Black

Percent dot	Sheet 3	Sheet 50	Sheet 114	Average
0	0.059	0.058	0.06	0.059
1	0.058	0.059	0.059	0.058666667
2	0.056	0.059	0.06	0.058333333
3	0.058	0.06	0.061	0.059666667
4	0.139	0.138	0.142	0.139666667
5	0.217	0.22	0.217	0.218
10	0.319	0.322	0.319	0.32
15	0.421	0.429	0.434	0.428
20	0.539	0.572	0.571	0.560666667
25	0.607	0.634	0.594	0.611666667
30	0.752	0.782	0.765	0.766333333
40	0.965	0.957	0.985	0.969
50	1.18	1.163	1.179	1.174
60	1.268	1.282	1.251	1.267
70	1.332	1.351	1.33	1.337666667
80	1.421	1.4	1.412	1.411
90	1.452	1.42	1.455	1.442333333
100	1.509	1.508	1.508	1.508333333

Cyan

Percent dot	Sheet 3	Sheet 50	Sheet 114	Average
0	0.061	0.061	0.062	0.061333333
1	0.06	0.063	0.065	0.062666667
2	0.06	0.063	0.063	0.062
3	0.088	0.08	0.093	0.087
4	0.104	0.096	0.112	0.104
5	0.179	0.176	0.187	0.180666667
10	0.233	0.223	0.244	0.233333333
15	0.283	0.278	0.285	0.282
20	0.341	0.331	0.342	0.338
25	0.397	0.383	0.401	0.393666667
30	0.491	0.474	0.484	0.483
40	0.574	0.572	0.573	0.573
50	0.749	0.711	0.736	0.732
60	0.884	0.862	0.868	0.871333333
70	1.009	0.981	0.988	0.992666667
80	1.076	1.04	1.071	1.062333333
90	1.161	1.115	1.155	1.143666667
100	1.335	1.352	1.356	1.347666667

INDIGO E-PRINT 1000

MAGENTA

PERCENT DOT	SHEET 3	SHEET 50	SHEET 114	AVERAGE
0	0.056	0.056	0.058	0.056666667
1	0.056	0.059	0.059	0.058
2	0.058	0.059	0.062	0.059666667
3	0.078	0.073	0.082	0.077666667
4	0.106	0.095	0.106	0.102333333
5	0.155	0.144	0.156	0.151666667
10	0.205	0.193	0.201	0.199666667
15	0.264	0.253	0.26	0.259
20	0.32	0.31	0.318	0.316
25	0.365	0.369	0.371	0.368333333
30	0.449	0.449	0.449	0.449
40	0.543	0.536	0.535	0.538
50	0.668	0.67	0.659	0.665666667
60	0.85	0.822	0.802	0.824666667
70	0.954	0.961	0.922	0.945666667
80	1.067	1.069	1.063	1.066333333
90	1.178	1.152	1.144	1.158
100	1.365	1.183	1.35	1.299333333

YELLOW

PERCENT DOT	SHEET 3	SHEET 50	SHEET 114	AVERAGE
0	0.025	0.025	0.027	0.025666667
1	0.026	0.027	0.028	0.027
2	0.026	0.026	0.027	0.026333333
3	0.025	0.028	0.028	0.027
4	0.036	0.032	0.039	0.035666667
5	0.086	0.089	0.088	0.087666667
10	0.124	0.118	0.124	0.122
15	0.151	0.148	0.157	0.152
20	0.183	0.173	0.189	0.181666667
25	0.226	0.212	0.226	0.221333333
30	0.291	0.275	0.287	0.284333333
40	0.343	0.326	0.341	0.336666667
50	0.437	0.418	0.448	0.434333333
60	0.535	0.511	0.562	0.536
70	0.666	0.615	0.665	0.648666667
80	0.727	0.688	0.7	0.705
90	0.807	0.764	0.792	0.787666667
100	0.911	0.839	0.924	0.891333333

DocuColor 40

BLACK

PERCENT DOT	SHEET 50	SHEET 100	SHEET 150	AVERAGE
0	0.063	0.066	0.066	0.065
1	0.066	0.07	0.07	0.068666667
2	0.069	0.068	0.067	0.068
3	0.065	0.068	0.071	0.068
4	0.105	0.126	0.137	0.122666667
5	0.163	0.171	0.192	0.175333333
10	0.23	0.229	0.246	0.235
15	0.268	0.282	0.292	0.280666667
20	0.327	0.345	0.366	0.346
25	0.374	0.379	0.401	0.384666667
30	0.487	0.482	0.506	0.491666667
40	0.606	0.599	0.601	0.602
50	0.818	0.791	0.759	0.789333333
60	0.953	0.95	0.911	0.938
70	1.17	1.112	1.135	1.139
80	1.395	1.397	1.425	1.405666667
90	1.597	1.603	1.618	1.606
100	1.637	1.679	1.626	1.647333333

CYAN

PERCENT DOT	SHEET 50	SHEET 100	SHEET 150	AVERAGE
0	0.066	0.069	0.069	0.068
1	0.068	0.072	0.072	0.070666667
2	0.072	0.07	0.071	0.071
3	0.117	0.114	0.114	0.115
4	0.113	0.115	0.115	0.114333333
5	0.191	0.177	0.184	0.184
10	0.252	0.236	0.231	0.239666667
15	0.296	0.299	0.299	0.298
20	0.397	0.396	0.388	0.393666667
25	0.461	0.462	0.45	0.457666667
30	0.533	0.571	0.548	0.550666667
40	0.686	0.75	0.712	0.716
50	0.822	0.906	0.849	0.859
60	0.935	1.029	0.971	0.978333333
70	1.033	1.145	1.085	1.087666667
80	1.079	1.235	1.179	1.164333333
90	1.15	1.281	1.223	1.218
100	1.254	1.33	1.297	1.293666667

DocuColor 40

MAGENTA

PERCENT DOT	SHEET 50	SHEET 100	SHEET 150	AVERAGE
0	0.06	0.063	0.063	0.062
1	0.059	0.067	0.066	0.064
2	0.066	0.074	0.07	0.07
3	0.068	0.087	0.076	0.077
4	0.108	0.1	0.097	0.101666667
5	0.185	0.183	0.173	0.180333333
10	0.268	0.245	0.24	0.251
15	0.318	0.301	0.298	0.305666667
20	0.374	0.375	0.354	0.367666667
25	0.423	0.438	0.403	0.421333333
30	0.501	0.516	0.509	0.508666667
40	0.613	0.637	0.606	0.618666667
50	0.703	0.764	0.731	0.732666667
60	0.825	0.893	0.848	0.855333333
70	0.953	1.021	0.978	0.984
80	1.012	1.086	1.061	1.053
90	1.066	1.154	1.088	1.102666667
100	1.188	1.258	1.179	1.208333333

YELLOW

PERCENT DOT	SHEET 50	SHEET 100	SHEET 150	AVERAGE
0	0.028	0.033	0.03	0.030333333
1	0.03	0.037	0.037	0.034666667
2	0.031	0.036	0.036	0.034333333
3	0.028	0.035	0.035	0.032666667
4	0.039	0.055	0.041	0.045
5	0.119	0.127	0.121	0.122333333
10	0.172	0.166	0.169	0.169
15	0.208	0.215	0.197	0.206666667
20	0.253	0.277	0.256	0.262
25	0.29	0.316	0.298	0.301333333
30	0.383	0.405	0.391	0.393
40	0.45	0.484	0.464	0.466
50	0.539	0.571	0.546	0.552
60	0.623	0.677	0.627	0.642333333
70	0.706	0.743	0.723	0.724
80	0.806	0.833	0.814	0.817666667
90	0.878	0.892	0.837	0.869
100	0.933	0.962	0.887	0.927333333

Quickmaster DI

BLACK

PERCENT DOT	SHEET 50	SHEET 100	SHEET 150	AVERAGE
0	0.057	0.053	0.056	0.055333333
1	0.053	0.056	0.058	0.055666667
2	0.092	0.068	0.084	0.081333333
3	0.109	0.107	0.108	0.108
4	0.117	0.113	0.114	0.114666667
5	0.151	0.147	0.145	0.147666667
10	0.192	0.183	0.182	0.185666667
15	0.235	0.226	0.229	0.23
20	0.286	0.273	0.273	0.277333333
25	0.338	0.325	0.323	0.328666667
30	0.445	0.422	0.421	0.429333333
40	0.548	0.53	0.522	0.533333333
50	0.71	0.684	0.689	0.694333333
60	0.821	0.786	0.786	0.797666667
70	0.961	0.934	0.941	0.945333333
80	1.059	1.044	1.056	1.053
90	1.089	1.085	1.087	1.087
100	1.094	1.081	1.103	1.092666667

CYAN

PERCENT DOT	SHEET 50	SHEET 100	SHEET 150	AVERAGE
0	0.059	0.055	0.058	0.057333333
1	0.058	0.057	0.058	0.057666667
2	0.056	0.057	0.057	0.056666667
3	0.073	0.071	0.074	0.072666667
4	0.077	0.077	0.077	0.077
5	0.089	0.088	0.088	0.088333333
10	0.113	0.112	0.114	0.113
15	0.145	0.143	0.145	0.144333333
20	0.176	0.175	0.175	0.175333333
25	0.212	0.209	0.209	0.21
30	0.296	0.296	0.294	0.295333333
40	0.376	0.373	0.373	0.374
50	0.49	0.482	0.485	0.485666667
60	0.568	0.563	0.558	0.563
70	0.691	0.676	0.681	0.682666667
80	0.863	0.845	0.838	0.848666667
90	0.931	0.907	0.909	0.915666667
100	0.938	0.929	0.91	0.925666667

Quickmaster DI

MAGENTA

PERCENT DOT	SHEET 50	SHEET 100	SHEET 150	AVERAGE
0	0.055	0.051	0.054	0.053333333
1	0.051	0.053	0.056	0.053333333
2	0.051	0.053	0.054	0.052666667
3	0.057	0.062	0.062	0.060333333
4	0.056	0.061	0.059	0.058666667
5	0.074	0.077	0.083	0.078
10	0.099	0.102	0.115	0.105333333
15	0.122	0.126	0.148	0.132
20	0.15	0.154	0.185	0.163
25	0.176	0.181	0.212	0.189666667
30	0.258	0.263	0.314	0.278333333
40	0.311	0.316	0.364	0.330333333
50	0.389	0.396	0.468	0.417666667
60	0.489	0.492	0.59	0.523666667
70	0.593	0.596	0.716	0.635
80	0.767	0.774	0.903	0.814666667
90	0.837	0.86	1	0.899
100	0.907	0.923	1.062	0.964

YELLOW

PERCENT DOT	SHEET 50	SHEET 100	SHEET 150	AVERAGE
0	0.023	0.019	0.029	0.023666667
1	0.019	0.023	0.031	0.024333333
2	0.021	0.033	0.032	0.028666667
3	0.058	0.059	0.072	0.063
4	0.07	0.072	0.08	0.074
5	0.094	0.097	0.104	0.098333333
10	0.113	0.111	0.123	0.115666667
15	0.146	0.144	0.156	0.148666667
20	0.17	0.169	0.179	0.172666667
25	0.198	0.198	0.207	0.201
30	0.251	0.247	0.259	0.252333333
40	0.32	0.318	0.324	0.320666667
50	0.409	0.415	0.413	0.412333333
60	0.505	0.508	0.503	0.505333333
70	0.599	0.599	0.596	0.598
80	0.677	0.684	0.671	0.677333333
90	0.783	0.771	0.771	0.775
100	0.83	0.829	0.827	0.828666667

XEIKON DCP-32D

BLACK

PERCENT DOT	SHEET 50	SHEET 100	SHEET 150	AVERAGE
0	0.068	0.071	0.066	0.068333333
1	0.067	0.071	0.068	0.068666667
2	0.071	0.067	0.066	0.068
3	0.065	0.068	0.068	0.067
4	0.101	0.1	0.105	0.102
5	0.138	0.145	0.142	0.141666667
10	0.166	0.173	0.166	0.168333333
15	0.195	0.211	0.197	0.201
20	0.231	0.237	0.227	0.231666667
25	0.258	0.261	0.256	0.258333333
30	0.34	0.338	0.327	0.335
40	0.401	0.395	0.394	0.396666667
50	0.488	0.499	0.476	0.487666667
60	0.586	0.615	0.571	0.590666667
70	0.715	0.712	0.689	0.705333333
80	0.927	0.905	0.852	0.894666667
90	1.015	1.027	0.978	1.006666667
100	1.183	1.202	1.188	1.191

CYAN

PERCENT DOT	SHEET 50	SHEET 100	SHEET 150	AVERAGE
0	0.069	0.073	0.068	0.07
1	0.066	0.072	0.068	0.068666667
2	0.07	0.069	0.067	0.068666667
3	0.08	0.077	0.081	0.079333333
4	0.083	0.096	0.084	0.087666667
5	0.122	0.122	0.13	0.124666667
10	0.144	0.147	0.151	0.147333333
15	0.187	0.183	0.186	0.185333333
20	0.216	0.218	0.221	0.218333333
25	0.254	0.254	0.252	0.253333333
30	0.338	0.335	0.333	0.335333333
40	0.411	0.415	0.412	0.412666667
50	0.525	0.509	0.514	0.516
60	0.636	0.626	0.63	0.630666667
70	0.757	0.745	0.759	0.753666667
80	0.898	0.906	0.89	0.898
90	0.989	0.986	0.988	0.987666667
100	1.129	1.062	1.071	1.087333333

Xeikon DCP-32D

MAGENTA

PERCENT DOT	SHEET 50	SHEET 100	SHEET 150	AVERAGE
0	0.065	0.068	0.063	0.065333333
1	0.067	0.058	0.063	0.062666667
2	0.067	0.063	0.069	0.066333333
3	0.075	0.083	0.074	0.077333333
4	0.081	0.086	0.08	0.082333333
5	0.131	0.13	0.128	0.129666667
10	0.164	0.16	0.163	0.162333333
15	0.194	0.196	0.201	0.197
20	0.232	0.237	0.228	0.232333333
25	0.269	0.271	0.263	0.267666667
30	0.343	0.353	0.351	0.349
40	0.425	0.422	0.425	0.424
50	0.523	0.527	0.507	0.519
60	0.632	0.63	0.617	0.626333333
70	0.768	0.735	0.747	0.75
80	0.902	0.901	0.899	0.900666667
90	1.002	1.04	0.996	1.012666667
100	1.095	1.102	1.107	1.101333333

YELLOW

PERCENT DOT	SHEET 50	SHEET 100	SHEET 150	AVERAGE
0	0.036	0.038	0.035	0.036333333
1	0.035	0.032	0.034	0.033666667
2	0.035	0.032	0.033	0.033333333
3	0.035	0.033	0.038	0.035333333
4	0.046	0.035	0.034	0.038333333
5	0.092	0.096	0.098	0.095333333
10	0.119	0.117	0.118	0.118
15	0.157	0.147	0.158	0.154
20	0.197	0.192	0.195	0.194666667
25	0.221	0.22	0.221	0.220666667
30	0.291	0.289	0.293	0.291
40	0.351	0.354	0.351	0.352
50	0.442	0.433	0.447	0.440666667
60	0.535	0.533	0.533	0.533666667
70	0.659	0.646	0.651	0.652
80	0.788	0.785	0.785	0.786
90	0.852	0.836	0.846	0.844666667
100	0.9	0.895	0.902	0.899