The effective application of digital printing techniques for fine artists in the South African context.

a
Dissertation

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PROMOTERS

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DEDICATION

To my family who gave me the opportunity to do this.

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Chapter One

1 Introduction

1.1 Background

Traditionally, fine artists have shown innovative use of new technology and new media for their own artistic expression, this is illustrated by the number of artists, who are at present making use of computers to extend their image making techniques (Katz, 1994, pp. 38 - 45, Steinberg, 1998, pp. 2 - 5). The final artefacts created on a computer can range from screen images, to files, to images incorporated into interactive compact discs (CDs), to images placed on web pages. However many artists still feel the need to print their digital images for presentation to the public. Although some fine artists are at home with computer-based media, others are hesitant to use the new technology to produce prints. The artist, Karen Guzak, who uses digital prints combined with lithographic techniques, states, "I was sceptical about whether the computer could serve me in making art, largely because of the problem of transforming the monitor image into something that I could display in a studio gallery or art museum" (1997, p. 20). The issue that she mentions here, that of transforming an image into a print is for many artists the largest stumbling block in creating an exhibition of digital work.

For artists working in the fine art medium, digital prints are often found wanting in terms of retaining a fine art print’s 'feel', texture, quality, detail and colour. Steinberg's article on the artist Dorothy Simpson Krause alludes to this, but she goes on to describe a digitallymastered print by Krause as follows, “this print is characterized both by lush color and texture and by allegorical, spiritual content” (1997, p. 2). One of the main issues is whether digital prints might offer artists a viable method of producing limited editions of their work. Considering that short runs of digital prints are relatively inexpensive, print sizes are almost limitless, a wide range of substrates exist and turnaround times are short.

Digital prints are printed primarily at digital print bureaux, which have been set up to cater for the ever-growing commercial imaging market. There were approximately 42 bureaux in the province of Gauteng, South Africa in 1998 (Bate, 1998, pp. 30 - 31). This number had increased to 50 by early 1999 (Bate, 1999, p. 28 - 29). The bureaux supply limited edition prints from digital files, the prints are often of a large scale (from around 21 x 28 cm to spectacular billboard sizes of 5,000 x 20,000 cm) and image quality ranges from low quality electrostatic images to high quality prints on digital enlargers. A number of printing devices are available, the most popular being laser printers, inkjet printers, colour copiers, film recorders and electrostatic printers (Bate, 1998, pp. 7 - 9). The industry is characterised by quick turnaround times and prints are often used for 'one-off' display purposes. Steven Strooh, manager of the USA based Beeline Color Center, classifies their important customers as advertising agencies, tradeshow exhibitors, architects and law firms. Applications can vary from backlit displays for fast food vendors, floor displays in school gymnasiums, billboards, posters to illustrate evidence at trials, and backlit advertisements in airport concourses (S.C. Strooh, personal communication, May 16, 1998). Johannesburg bureau manager Steve Majewski does not consider fine artists significant clients and states quite honestly that they cannot interrupt commercial production to do extensive testing for a fine art client, unless the artist is prepared to pay commercial rates (S. Majewski, personal communication, May 22, 1998).

Most bureaux in South Africa lack an extensive range of equipment and their personnel have very limited expertise, especially of fine art applications, compared to the USA where certain vendors market directly to fine artists. Katz describes the mission of fine art printers Nash Editions of Manhattan Beach near Los Angeles. It "is to create an environment where artists feel comfortable experimenting with new technology" (1994, p. 38).

Bureaux and printer manufacturers face issues of colour accuracy on a daily basis and solve these problems in their own unique way, but often cannot guarantee 100 percent accurate results. Correct monitor calibration and colour management software can assist in obtaining more accurate results, but a thorough understanding of the strengths and weaknesses of the printing processes is essential. At present there do not appear to be any books, manuals or any form of comprehensive assistance, that a fine artist could consult, to help them with the complexities of getting digital prints made. A promotional advertisement for the Bowens bureau emphasises the importance of co-operation with the person who does the actual printing. "Even with the most powerful technology around, problems still creep in.… We know that communication amongst print, repro, design and client is the key to successful publishing" (Bowens, 1999, p. 11).

In addition to these issues there are a number of practical problems encountered when printing digital images. Image manipulation software can often produce large files. An 80 to 100 Mb (megabyte) file can be required when producing a full colour, photographic quality 76 x 102 cm image. Storage of large files and sending them to a bureau by modem or e-mail can become problematic and artists need to be sure that they have the expertise, correct equipment and software to successfully do this. Mistakes made in this area can be costly as bureaux charge additional fees for above average output time.

A number of the digital printers make use of inks that are not stable and the substrates printed on are often fragile, this influences how the images can be finished and exhibited, and whether clients will purchase them, or galleries consider them for permanent collections. The prints are often large, which makes them difficult to transport and exhibit. Diana Wall curator of the Museum Africa in Johannesburg, South Africa has indicated that although they have exhibited digital prints in the past, they have as yet not formulated a policy for the purchasing, storage or acquiring of such prints. This is primarily because they do not have sufficient information or experience of the problems presented by the new medium (D. Wall, personal communication, May 29, 1998).

In some South African tertiary educational institutions such as technikons and universities, students are trained on a range of computer-based image manipulation and image generation software. Many graphic design, photography, journalism and fine art courses have integrated computer training into their syllabi. Traditionally the final evaluation of student work has been the presentation of a portfolio or an exhibition of the work. Academic institutions seldom have the funding to buy a range of printers and so students, although skilled in creating computer images, are not always familiar with the range of print processes that are available. With the prohibitive cost of commercial digital printing, students are often unable to experiment and if the commercial print does not match their pre-visualised image, they cannot afford to have re-prints made.

1.2 Formulation of the Problem

The question to be answered by this research is how would a fine artist working in South Africa, identify and use the correct digital printing techniques to accurately print their work? This problem may be broken down into the following subproblems.

1.3 Subproblems

1.3.1 First Subproblem

What types of digital print techniques are available in South Africa and what are their characteristics?

1.3.2 Second Subproblem

What printing anomalies are encountered when making digital prints?

1.3.3 Third Subproblem

In what way do fine art applications differ from commercial applications?

1.3.4 Fourth Subproblem

Can digital print characteristics be matched to the original artwork?

1.4 Delimitations of the Research

The digital printing field is obviously an extensive one. In this document, the emphasis is on printing in a South African environment, and only print techniques that are available in South Africa will be discussed. Where possible every digital print process available in South Africa will be used, the success of this will depend in part on the co-operation of the bureaux that own the more expensive types of equipment.

The major print reproduction techniques of offset lithography, gravure, flexography and screen printing will not be seen as digital print techniques. As is defined in section 1.5 the first three processes are not seen as digital printing processes, as they do not lend themselves to printing short runs of prints, quickly and directly from the computer, and are generally considered to be traditional reproduction processes.

In order to print full colour using screen printing, the image has to be separated and halftone screens created. These are then used for each ink colour. Only one colour can be printed at a time and each ink layer must dry before the next one can be printed. Once again this means that no print can be made directly from the computer and that turnaround times are long even for low print quantities. It must be added to this, that the processes of generating film positives and negatives, to be used for printing onto photographic materials, will be considered to be part of digital printing. These processes, because of the relatively low cost of photographic materials are used quite successfully to print low volumes of prints in short time frames, even though the image is not printed directly from the computer.

As it is both financially as well as physically impossible to test every ink and substrate on the market in South Africa, one fine art print for each available process will be made, using the most common inks and substrates. On the same principle it is not possible to use every type of artwork or type of computer-based image to print from. A selection of the more common types of images will therefore be made. These images will be chosen for their potential to challenge the digital printing techniques, and should range from black and white line images to full colour images.

There are an extensive number of manufacturers for almost every printer type. Whichever brand of printer is available to the researcher will be taken as being a typical example of that printer type.

The assessment of prints will be a subjective visual assessment conducted by visually literate individuals, in a controlled situation, using a standard method of assessment. No assessment of images making use of colour measuring devices such as densitometers will be made, as the visual tests are more relevant to the fine art application of the prints. This is discussed in more detail in the research methodology.

Longevity is not something that can be tested within a limited time period and without specialised equipment, the researcher will not attempt to test prints for longevity. The findings of recognised groups, plus the experiences of digital print operators will be considered. As these are rather contentious issues, with statistics and opinions varying vastly, the current situation will be outlined as will opinions on future trends and changes.

As this is a technological field that is constantly developing, the information will be as up-to-date as possible, but it is possible that some of the very latest technology will not be included in the final document.

Numerous sources in this document are American, the use of such words as color (colour) and program (programme) will be taken as correct.

All the test and fine art images that are reproduced in this document as figures are low-resolution files derived from the original digital images. The high-resolution originals of these figures are included in the CD packaged with this document.

1.5 Definition of Concepts

The digital printing industry is a rapidly changing and evolving industry, as is the terminology that is used. Digital printing to those working in the reprographics industry, generally means "printing from digitally produced plates" as defined by Bruno in *The Focal Encyclopedia of Photography* (1993, p. 218). Schildgen further defines digital printing to be limited to short run colour printing (1998, p. 172). In some cases bureaux consider inkjets, colour copiers and traditional proofing devices to be part of digital printing. The book *Photographic Imaging and Electronic Photography*, gives the following definition of digital printing systems.

> Digital printing systems: Besides digital plates, a number of other digital imaging processes can produce prints directly from digital data without the use of intermediate films or plates. These include high-speed copiers, electrophotographic, magnetographic, and ion-deposition printers, and inkjet printing (Ray, 1994, p. 199).

It does not include the hybrid photographic processes such as digital enlargers. Mortimer places inkjet, thermal wax transfers, thermal dye sublimation, photography and electrophotography into the proofing category and calls them “digital data colour proofing devices” (1991, p. 148).

The terminology is therefore rather confusing, as there is no agreement on a definition of proofing, print on-demand, digital printing, electronic printing and on-demand printing. As fine art applications can make use of digital printing, large format printing and print on-demand, the general term, digital printing will be used in this document. Throughout this document the term digital printing will be taken to mean any limited run printing process, with a short turnaround time, that uses digital data as its source. This excludes offset lithography, gravure, flexography, screen printing and the cromalin process, which is in principle an analogue process.

Within digital printing categories, such as inkjet printers, there is some confusion regarding the categorization of these devices. The magazine *Digital Output* lists thermal, phase-change and piezo inkjet printers in their article on large-format printing ("The Big," 1999, p. 22). Le puts inkjet printers into two main categories, continuous and drop-on-demand. He further categorizes them as follows "the drop-on-demand ink-jet [sic] printers on the market today are using either the thermal or piezoelectric [sic] principle" (Le, 1998). Anderson mentions the six colour inkjet printer (Anderson, 1998) and the Wide Format Digital Imaging Council (WFDIC) mentions superwide printers including airbrush inkjet printers (WFDIC, 1998). In some cases combinations of technologies are used. For this document's purposes inkjet printers will be divided into thermal, piezo-electric, extended gamut (six colours or more), continuous flow, airbrush and phase-change inkjet printers.

The term art and fine art have been written about extensively and many attempts have been made to define both. In the context of this document the defining aspect is the application of the artwork, and this is seen as images created for sale, exhibition and display, but with no commercial message. Fine art applications would include prints made for exhibition, sale, promotion and display, but not for mass production or images created with the intention of selling commercial products and services. Any digital print produced with the intention of selling products and services would be considered to have a commercial application.
The definition for bureau or bureaux (plural) given in the *1998 Creative Directory* is: "service center for transforming electronic publishing into required form of reproduction, such as scanning and film playout" (Bate, 1998, p. 5). In the USA they are often referred to as print-for-pay companies (S. Strooh, personal communication, October 24, 1999).

The following forms of currency will be used, $ to indicate United States dollars and R for South Africa rands. Where conversions have been made, the exchange rate (1999) for dollars to rands is fixed at six rand and twenty cents for one US dollar.

1.6 Assumptions of the Research

There are a number of factors that indirectly influence print anomalies. These can include input, the setting up of the image on the computer, the accuracy of the printer itself and the expertise of the print operator. These aspects do not form part of the research, but will be dealt with in chapter two, which aims to point out what is common knowledge, as it forms an important part of the assumptions of the research.

It is obvious that finishing techniques effect the appearance and longevity characteristics of digital prints. Finishing is also seen as an indirect influence and so will be explained, but not tested.

The digital images, used to print the test images and fine art images, have been correctly set up for digital printing. The influencing factors of input, image manipulation and operator expertise will not be taken into account when assessing the prints.

Digital printers that are used for commercial applications can also be used for fine art applications.

It will be assumed that printing devices have all been correctly calibrated and that colour management systems, colour correction techniques, as well as profiles for specific printing devices might be used by the bureaux print operator. This implies that the printers used are printing at their optimum quality.

1.7 Significance of the Research

The information contained in this document could be beneficial to a number of groups and individuals. Firstly, a relatively cheap and accurate way to reproduce limited editions of photographs, paintings, drawings and prints might be of benefit to many fine artists. A document describing a working method and offering practical assistance in matching print techniques to images, as well as outlining where to find the necessary equipment and expertise, should be of use to artists working in this field. Secondly, digital print bureaux do not have a significant number of fine artists as clients. This document could identify a new market for the bureaux, as well as help them to assist existing and new fine art clients (S. Majewski, personal communication, May 22, 1998). Thirdly, technikons and universities in South Africa teach a number of courses where students learn to create images and designs by making use of computers and the appropriate software. Historically students have had more problems with printing images than with creating them (J.M. Mathee, personal communication, May 25, 1998). This document will be invaluable to lecturers teaching digital imaging courses and in assisting students to efficiently and economically print their work. Finally, information on longevity and presentation techniques for digital prints will be of assistance to museum and gallery policy makers (D. Wall, personal communication, May 29, 1998).

1.8 Review of Related Literature

There is, to my knowledge, no literature or registered research into the use of digital printing for fine art application in South Africa. In 1995, Adam Lowe, in conjunction with Permaprint, Senici Press and the Print Research Unit at the University of the West of England conducted tests on a number of printing processes. Some of this information is published on the *Exolart* web site in an article titled “Hard Copy” (Lowe, 1996). This information and some of the illustrations published on the *Exolart* site are relevant to this research in terms of the tests conducted on a range of printing techniques. Unfortunately the detailed information contained in Lowe's 64 page book with accompanying print portfolio, is largely inaccessible to the average artist in South Africa, as it has a prohibitive price of a few hundred British pounds. The information on the web site was published in 1996. Since then a number of new processes and improvements to old processes have taken place. The research project by James M. Reilly and Franziska S. Frey on “Recommendations for the Evaluation of Digital Images Produced from Photographic, Microphotographic, and Various Paper Formats” has elements that contribute to the methodology of this research.

A few books on printing include sections on digital printing, the most comprehensive, although slightly dated, of these is *Digital Imaging for Visual Artists* by Weiner Grotta and Grotta (1994). It does identify some print anomalies, but these are usually in very general terms. The Schildgen (1998) *Pocket Guide to Color with Digital Applications* is primarily concerned with how to achieve correct colour, when printing from digital files and the emphasis is on offset printing rather than digital printing. A particularly relevant book published by the International Reprographics Association (IRGA, 1998), is *The Digital Color Graphics Certification Program. Training and Reference Guide*. The book is written as a training manual for the large format printing industry and provides essential information regarding inkjet printing, substrates, inks and finishing. The book by Golding (1997), *Photomontage a Step-by-Step Guide to Building Pictures* covers both digital and traditional methods for creating images and has a section on preparing files for output to film. Burkholder’s (1999) book, *Making Digital Negatives for Contact Printing* addresses many technical aspects of creating files and playing them out on imagesetters. It provides useful information about terminology and the predictability of results. *Photographic Imaging and Electronic Photography* by Sidney Ray (1994) covers terminology in both the digital and photographic fields. A number of books have been written about digital imaging in general and they contain small sections on printing. These books are *Basic Digital Photography* by Breslow (1991) and *Understanding Electronic Photography* by Larish (1990) they do not provide very relevant or detailed information for this research.

Certain manuals on equipment and computer software are good sources of technical information. The Adobe (1998) *Adobe Photoshop 5.0 Users Guide* contributes to the understanding of specific terms, how image manipulation software can be used to correct colour and tonal range, colour management software and scanning. The Phase One (1996) *Phase One User Guide* for the Phase One digital back outlines how to use this equipment and how to achieve accurate captures, this is essential information for the practical tests conducted in this research.

Because of the rapid advances in digital technology, books on many library shelves are out of date and therefore the most accurate technical information can be gathered from periodicals, brochures, instruction manuals and electronic networks. Periodicals, in particular *Advanced Imaging, The British Journal of Photography, Design Graphics and Step-by-Step Graphics* contain a number of useful technical articles and are generally concerned with commercial applications. Some South African magazines touch on digital printing, the article by Karney and Stone (1998) on "Network Printers" in *PC Magazine SA*, offers some comparative evaluations and tests on a limited range of laser and phase-change inkjet printers. *Photo Lab Management* offers technical information as well as examples of work done by bureaux for commercial clients. *Aperture, Art in America, Contemporary Visual Arts, Flash Art* and *Leonardo* contain articles on specific fine artists who use digital printing techniques, review and critique exhibitions and look at the aesthetic and philosophical implications of this new technology. *Artbyte* contains both technical and philosophical articles.

Some photographic manufacturers have published excellent manuals and brochures on digital photography and printing. Agfa-Gevaert (1994, 1995, 1996) have published a range of books on digital imaging, digital printing, colour, scanning and pre-press. These booklets are a good source of information on aspects that impact on digital printing, such as scanning and image manipulation. Eastman Kodak's (1999) on-line *Digital Dictionary* has simple explanations and illustrations of a number of digital printing techniques.

The more philosophical aspects of image manipulation are addressed in a number of books, which do not contribute directly to this research, but are of general interest. These are: *The Computer Revolution and the Arts* edited by R. Loveless (1989), *The Reconfigured Eye: Visual Truth in the Post-Photographic Age* by William J. Mitchell (1994), *Pedro Meyer Truths and Fiction* (1995), and Fred Ritchin's (1990) *In Our Own Image: The Coming Revolution in Photography*.

There are a number of sites on the World Wide Web (www) relating to digital printing, such as, printers and digital bureaux promoting their products and services. In addition to these, on-line magazines such as the *PC Technology Guide* by Anderson (1998) give good explanations of different types of printers and how they work. This site does not cover the full range of digital printers, but is limited to inkjet, laser and colour copiers, dye sublimation and thermal wax printers.

The digital printmaking on-line magazine, *Digital Fine Art,* contains relevant articles on techniques and processes, fine art print bureau and individual artists. It is basically concerned with the digital printmaking industry in the USA. A number of fine art printmaker groups have on line sites, such as the International Association for Fine Art Digital Printing (IAFADP, 1998) and the Digital Atelier (Digital Atelier, 1999). General information on some products can be found at many of the manufacturers sites, such as Xerox (1998), Tektronix (1997), Scitex (1998), and many others. Aesthetic aspects are addressed and portfolios presented at the *Zone Zero* (1999) magazine site, though these are orientated to photographic based images.

1.9 Methodological justification

1.9.1 Methodological Justification of the First Subproblem

In order to answer the questions posed in the first section of this introduction, a certain methodology should be followed. The initial subproblem of what types of digital printers are available will be established by consulting various books and periodicals to identify the broad categories of digital printers on the market. Bureau and print mangers will be interviewed so as to identify which of the available printers are operated in South Africa.

A technical explanation of how each digital printer works is essential to provide a better understanding of how images are formed by each printer. This will help in the identification of print anomalies (the second subproblem). The type of information needed should describe how the printer lays down colour, what substrates are available and what type of work the printer is designed to do. By consulting appropriate books and magazine articles, as well as the web sites of manufacturers, these technical aspects can be compiled.

In addition to this, the following characteristics should be identified for each printer, resolution, longevity, speed, scale limitations, cost per square meter and the cost of the machine. This will further help to identify the potential of each printer for fine art applications. It will also provide information for the practical tests and assessments to be conducted. The information will be gathered from manufacturers brochures (printed and on-line), interviews with suppliers and bureau managers, bureau price lists, the published results of relevant archival testing organisations and the published results of recognised sources, such as the WFDIC and the *Big Picture Magazine.*

Technical information on what common inks and substrates consist of must be identified. This is an area that covers a number of disciplines. The variety of inks and substrates is vast and therefore books that address issues concerning ink, paper and printing would be consulted to gather specific information. In addition to this any specialised information regarding certain fields of digital printing will be used as examples of how ink and substrate combinations can effect images. This information will be gathered from magazine articles and training manuals.

1.9.2 Methodological Justification of the Second Subproblem

In order to identify print anomalies three different approaches will be taken. Firstly, previous research such as Lowe's tests conducted from 1995 to 1997 will be evaluated (Lowe, 1996). Secondly, South African and foreign bureau managers will be asked to identify print anomalies in the machines that their companies run. Where possible these interviews will be conducted in person if this is not possible electronic mail (e-mail) will be used. Thirdly, a number of practical tests will be devised to identify print anomalies.

The methodology used for testing the digital prints in this research is based on the research of Lowe and of Reilly and Frey, as well as comparative studies such as that published in the *PC Magazine SA* (1998) on network printers. The Reilly and Frey project was designed to establish tests for the evaluation of scanners. The scanners would be used to digitize photographic images, prints and microfilm images for the Library of Congress in the USA. There are a number of similarities with this research, in that existing images are to be digitised and that the digital copies should retain the intrinsic qualities of the originals. The originals vary from photographs, to documents to microfilm images. According to Reilly and Frey, testing of printed material can be made, by using two different approaches. "*Objective* image quality is evaluated through physical measurements of image properties. In the case of digital imaging this is achieved with special software evaluating the digital file. *Subjective* image quality is evaluated through judgment [sic] by human observers" (Reilly & Frey, 1996, p. 19).

Adam Lowe's research was designed

> To produce a series of digital prints from one file and one image designed specifically to test the varying qualities of each process. The project was completed in 1997, and consists of 24 digital prints of the singular image in mats and boxed with an accompanying text. (Lowe, 1996, p.3)

By printing the same image using different processes Lowe standardized the input characteristics. This approach will be used in this research for the initial tests, which are designed to identify general print anomalies. The test image will contain a variety of characteristics that should reveal the printers ability to print: a range of basic colours, fine detail, a subtle range of tones, difficult or unusual colours, pure white and a solid black, and maintain shadow and highlight detail.

A form will be devised for the assessment of the digital prints. The factors to be considered will be based in part on those mentioned by Lowe. He refers to qualities of colour (subtle, saturated), surface textures, graininess, tonal qualities, three-dimensional qualities, surfaces, the colour of the paper itself and shadow detail (Lowe, 1996, pp. 5 - 6). The characteristics as defined by Reilly and Frey are " tone reproduction, …detail and edge reproduction, …noise, …color reproduction" (1996, p. 20). These will also be considered.

Although it is not stated in Lowe's article, one must assume that the evaluation of the prints is a subjective visual evaluation. This type of assessment is done on a day to day basis in bureaux specialising in fine art printing. In Duganne's article "Making the Move to Digital" he mentions this working method when he quotes Nate Dickinson of Pearl Publishing in Oregon. "For our color matching we like to have the original hanging around for a few days to look at it while we proof" (1999, pp. 60 - 61). As this approach makes more sense when considering fine art applications, than the measuring of colours in order to convert them to numbers. A visual assessment system is therefore used in this research. To ensure that the individuals who conduct the research are familiar with printing and the terminology used, visually literate individuals will make up the panel and they will each conduct the assessment in the same neutral area.

Once the prints have been assessed, the results from each printer will be evaluated. When considered with the input from bureau managers and previous published information, it will provide the researcher with an indication of what each printers' strengths and weaknesses are and exactly in which areas print anomalies occur.

1.9.3 Methodological Justification of the Third Subproblem

In order to establish how digital printing techniques can be used by fine artists, existing commercial and fine art applications need to be identified. These will be ascertained through interviews with bureau managers and consulting relevant books and magazine articles. Where possible examples of digital print applications will be given for each type of printer. This will indicate the scope and potential of each print type.

The work of certain artists in South Africa and overseas will be identified through internet searches, books, articles, interviews with museums and galleries directors, academics, curators and print bureau managers. In some cases individual artists will be interviewed to ascertain what media they use, why they have chosen to work in that particular media and what problems and solutions they have encountered when working with digital prints. Otherwise articles describing how particular artists work in this field will be consulted for this information. This should illustrate how digital print techniques can be used for the printing of fine art images and to illustrate the potential of this new medium.

1.9.4 Methodological Justification of the Fourth Subproblem

Once the print anomalies in the second subproblem have been established, a number of fine art images will be selected and digitized using a standard procedure. The fine art images will consist of both traditional two-dimensional artwork and artwork created on computer. The images will be selected for their unique characteristics in order to test the digital print techniques to the fullest.

The artists who created the images will be asked to indicate on a form exactly what they require of a digital print. This will include what their envisaged application for the print is and what aspects of the original they feel are critical to retain.

Prints of the images will be made on the printers and substrates available to the researcher. The artist will assess the prints using their criteria established in the form. Although to some extent, these tests can either confirm the results of the initial anomaly tests or refute them, they will be taking three additional factors into account, the application of the final digital print, the cost and longevity characteristics.

1.10 Document Outline

1.10.1 Chapter One

Introduction

The introduction defines the research and its parameters and starts by providing background information about digital printing. The research problem and subproblems are stated and the parameters of the research described and definitions of concepts established. Assumptions are indicated, as is the significance of the research and related literature. In the methodological justification, each subproblem is broken down and the researcher's approach to compiling information and analysing it is established. In general, previous research, published articles and books, practical tests and personal interviews will be used to gather information and to evaluate the different techniques.

1.10.2 Chapter Two

Outside Factors that Influence Digital Print Quality

There are a number of factors that influence print quality, it is generally accepted that the input, image manipulation, output and the finishing stages all have an impact. These factors, most of which are commonly known, are outside the area of investigation of this research. However chapter two is used to provide the reader with this information, as it directly impacts on the choices made for standardizing the test procedures and establishing a working method for fine artists to digitally reproduce artwork. The influences of aspects such as scanning, monitors, image manipulation software, colour management, the print operator and finishing are addressed.

1.10.3 Chapter Three

Digital Print Techniques Available in South Africa.

Chapter three presents a brief look at how information from computers must be transformed, using a rasterizing process, in order to be printed. A list of the digital printing techniques that are available in South Africa is given, these are broken down into the broad categories of inkjet printers, dye sublimation, thermal wax, hybrid photographic processes and electrostatic systems. A technical description of how each printer lays down colour is provided. In the accompanying Table 1, aspects such as resolution, substrates, longevity figures and costs are laid out. An additional section describing the make up and influences of certain substrates and inks provides information on how results are achieved with specific printers.

1.10.4 Chapter Four

Identifying Digital Print Anomalies

This chapter sets out to identify and describe print anomalies. Three different approaches are taken, anomalies identified in previous research and publications are indicated, the opinions of bureau managers is considered and a range of tests are conducted.

The procedure used to create the test prints is described, as is the method of assessment used. The anomalies are given for each printer type.

The second section of this chapter describes the method for selecting and printing the fine art digital prints and how they are assessed. Examples of each printing type are given, accompanied by a figure illustrating the image that was printed. A table indicating the artist's degree of satisfaction with the final print is included.

1.10.5 Chapter Five

Identifying the Commercial and Fine Art Applications of Digital Prints

In this chapter, lists are given of the current commercial and fine art applications of digital printing. Examples of how a number of digital printing techniques have been used commercially are given to illustrate the diversity and potential of the medium. Some examples of how artists use digital printing are given.

The main area of divergence between fine art applications and commercial requirements, longevity, is discussed. Here the current situation regarding factors that influence image permanence and how these factors are tested are considered.

1.10.6 Conclusion

The conclusion sums up all the facts that have been gathered in the research. They are related to the four subproblems and to the methodology used, as described in chapter one. A working method for fine artists wishing to make digital prints is suggested, as are areas that provide potential for future research.

Chapter Two

2 Outside Factors that Influence Digital Print Quality

It is common knowledge that the printer is not the only factor that affects digital print quality. Scanning, colour management, operator competency and other factors will also influence print anomalies and therefore how accurately a print will match the original. These factors have, where possible, been eliminated or standardized in the digital images used for printing the practical tests described in chapter four. However as they are obviously influential parts of the digital printing process they will be addressed in this chapter, in order to further define the delimitations and assumptions of the research.

2.1 Digital Capture of the Original

2.1.1 Input

Artwork can be captured using a flatbed scanner, digital camera or a studio camera with a digital back. Another approach is for the artwork to be photographed onto film and the film scanned, using a drum or film scanner. The dimensions and surface qualities of the original artwork generally dictate how the image will be captured. As Malek describes, “for oil paintings, which might have lumps, transparencies or digital camera captures are preferred because shadow detail might be lost with a direct scan” (1999, p. 63).

Capturing an image at the correct resolution is critical. Generally the input device, the size of the original image as well as the size of the envisaged output dictates the scan or capture resolution. Basic guidelines for scanning are suggested in the Agfa booklet *An Introduction to Scanning* (Agfa-Gevaert, 1994, pp. 19 - 23). There is also an appendix on scanning for output to digital negatives in the Burkholder book (1999, pp. 279 - 295), that offers guidelines and advice on scanning.

Scanner resolution is normally quoted in terms of samples per inch (spi) (in the industry inches rather than centimetres are the standard unit of measurement). This can be directly translated into pixels per inch (ppi) which is the unit of measurement that image processing software uses. Print resolution in half tone printing is quoted in lines per inch (lpi) and in digital printers as dots per inch (dpi). The basic guidelines for scanning are to use a quality factor of 1.5 times the screen ruling of the printed image. Agfa gives the following formula for scanning for the production of halftone images: scan resolution = screen ruling x quality factor x sizing factor (Agfa-Gevaert, 1994, p. 21). The sizing factor = desired size/original size. For example a screen ruling of 133 lpi x 1.5 x a sizing factor of 2.5 (original was 20 cm and the desired size was 50 cm) would mean scanning at approximately 500 spi. When it comes to continuous tone photographic devices, such as film recorders, scans can be made at identical resolution. Scan resolution = output device resolution x sizing factor. Output device resolution = maximum addressable pixels/longest side of output film (Agfa-Gevaert, 1994, p. 23).

Burkholder points out the importance of the image capture stage by saying "just as there is no substitute for a properly exposed and developed negative, there can be no replacement for a good scan that faithfully captures shadow and highlight detail" (1999, p. 43).

Unfortunately many desktop flatbed and film scanners do not have colour calibration charts or calibration software. As bulbs age and change colour, or mirrors and lenses collect dust, no adjustments can be made to compensate for this, unless a calibration chart and the appropriate colour management software are purchased. Most scanner calibration software makes use of a colour target chart, such as an IT8 chart. This chart is scanned with the scanner set to neutral and then software is used to analyse the image created. Calibration software compares the values of the scanned image to stored standard colour values. If there are discrepancies a scanner profile for that particular device will be written. Whenever the profile is used it will automatically compensate for the unique aspects of that particular scanner. Most digital camera backs have grey balancing software that is used to calibrate the camera each time it is used (Phase One, 1996, p. 35) and profiles can also be created for camera backs.

With cheaper scanners a lack of sharpness can occur, as is pointed out in the *Agfa Guide to Color Separation* booklet. “The scanning process may cause some loss of detail and edge definition in an image” (Agfa-Gevaert, 1995, p. 6). Making use of the unsharp masking filter in Photoshop can compensate for this. Basically the mask identifies pixels that differ from the pixels around them and increases the contrast between them (Adobe, 1998, p. 128). The mask has three variables, amount, radius and threshold, which have to be set when trying to sharpen an image. The amount refers to the increase of contrast desired, radius dictates the area around the identified pixels that will be effected and threshold indicates how much of a brightness difference the pixels should have in order to be identified. If the unsharp masking is applied repeatedly a halo effect will appear around the edges of objects (Agfa-Gevaert, 1995, p. 6).

Some of the newer desktop scanning software allows for greater control over the scanning process. The operator can specify the input media, such as particular film types, and output targets, such as what printer is to be used. In addition to this there are normally adjustments for resolution, colour, brightness, contrast and sharpness. Drum scanning software offers far greater control over the process, but also requires greater expertise on the part of the operator, as is indicated in the on-line article “Making the Move to Digital”. “Capturing an image is the most critical aspect of giclée reproduction, so a great deal of focus is placed on the specialists who do this job” (Malek, 1999, p. 62).

2.2 Setting Up the Image on the Computer

2.3 Monitors

Monitors form images by shooting red, green and blue light onto a screen coated with phosphors. Monitors are red, green, blue (RGB) devices and have a resolution of about 72 ppi and cannot reproduce the range of colours that the human eye perceives.

The area of colour that can be represented by a monitor is called its colour gamut and this is represented in Figure 1 as the solid triangle. It can immediately be seen that the gamut of the monitor is substantially less than human vision, referred to as the standard observer.

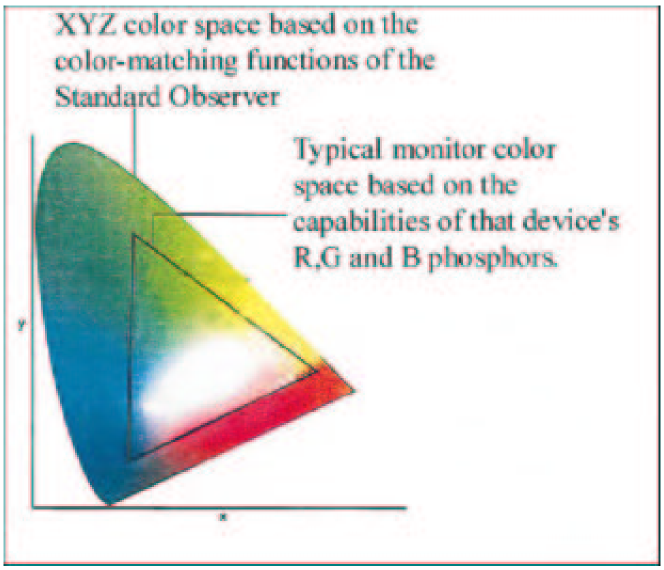

Figure 1. An RGB monitor gamut, compared to that of a standard observer. Adapted from (X-Rite, 1996, p. 15)

The *Adobe Photoshop 5.0 User Guide* stresses that proper monitor calibration leads to more predictable results.

> Whether preparing artwork for print or on-line use, you should begin by calibrating your monitor. This will ensure the closest possible match between your colors on-screen and those produced by a printer, a video display, or a different computer monitor, and also between your colors in Adobe Photoshop and in other software

programs. If your monitor isn't calibrated, the resulting colors may not even be close to what you originally saw on it. (Adobe, 1998, p. 79)

In principle, calibrating a monitor is a relatively simple step-by-step process, however accurate calibration can be more complex than this. Measuring the monitor emissions scientifically is the most accurate method of calibration. Purchasing a self-adjusting monitor, using the Adobe gamma controls, or comparing the screen image to a known printed image, are other approaches.

2.3.1 Measuring the Screen Image

Either a spectrophotometer or a colorimeter is essential to accurately measure colour off the monitor screen. A colorimeter measures the RGB emissions from a target image on the screen. The spectrophotometer measures the energy reflected from an object or transmitted by a monitor. The numbers generated by these devices can be compared to a standard set of figures and adjustments made to correct the monitor. Good spectrophotometers may cost up to $5,000, while a colorimeter can cost in the region of $300. Some bureaux are prepared to calibrate monitors for clients using their own colour measuring devices.

2.3.2 Self-adjusting Monitors

Self-calibrating monitors offer the hardware and software to adjust the image in order to guarantee an accurate colour balance at any stage of the monitor's life. They are more expensive, because they "include extra circuitry that continuously adjusts the picture-tube output to guarantee consistent white, black and grey balance" (Naudé, 1999, p. 16).

2.3.3 The Adobe Gamma Calibration

A basic method of monitor calibration is offered by the Adobe Gamma utility, which is included with Adobe Photoshop. It provides a basic step-by-step calibration procedure. The brightness, contrast, monitor phosphors, colour balance, gamma and white point of the monitor can be set, giving a reasonable amount of accuracy (Adobe, 1998, pp. 82 - 83).

2.3.4 Comparison Calibration Method

By comparing a printed image to the same image formed by the computer monitor a visual assessment of the monitor image can be made. From this point adjustments to the monitor can be made, until the printed and screen image are identical or as close as possible.

Burkholder includes the digital file of the image *Olé No Moiré,* Figure 2, on a CD, as well as a hard copy of the image, in his book *Making Digital Negatives* (Burkholder, 1999, pp. 29 - 31). These can be used to calibrate a monitor.

Figure 2. The Olé No Moiré calibration image (Burkholder, 1999)

X-Rite (manufacturers of calibration equipment and software) recommend that even when colour calibration is applied, the working conditions in the room where the monitor is placed should be consistent. This includes shielding the screen from natural light by positioning it away from windows and doors or even constructing some kind of hood to protect it. Ensuring that the on-screen pattern is a neutral grey and that walls and surrounding areas should be neutrally coloured (X-Rite, 1996, p. 29). If possible colour corrected lights should be used, for example daylight balanced fluorescent tubes.

2.3 Setting Up Images for Printing

2.4.1 Sizing Images

Images can be resized using image processing software such as Adobe Photoshop. Merely enlarging the image can result in the pixels appearing bigger and jagged edges forming around objects. If interpolation is applied this effect is avoided, but at the cost of a reduction in sharpness and edge definition (Agfa-Gevaert, 1996, p. 26). Most references recommend that sizing be done at the image capture stage.

2.4.2 Storage of Images

There is a range of file formats that images can be stored and used in. In the graphics industry tagged image file format (tiff) and encapsulated postscript (EPS) are the most common formats (Agfa-Gevaert, 1994, p. 36). Files created for digital printing are often of large size, between 5 Mb and 100 Mb. Most image compression software causes a reduction in image quality and so CDs, optical discs, Zip discs and other devices are often used for storage.

2.4.3 Colour Modes

File formats offer the options of storing images in a particular mode. Image processing software can transform images from one colour mode to another. Common modes are RGB, cyan, magenta, yellow and black (CMYK), Lab colour and greyscale. It seems to be accepted that the best option is to leave the file in its original scan format and to allow the operator or raster image processor (RIP) software to do the conversion to CMYK or any of the extended gamut modes (T. Carstens, personal communication, September 17, 1999).

Bureaux generally give clients detailed information regarding all of these aspects. Stonehouse Graphics gives clients a hand out on “File Preparation for Digital Printing” which covers media, file formats supported, application programs supported, file preparation, scanning, colour, orders and deadlines (Stonehouse Graphics, 1999, pp. 1 - 2).

2.4.4 Image Manipulation Software

Making colour, brightness and contrast corrections using image processing software, is standard practice. The *Adobe Photoshop 5.0 Users Guide* contains a chapter on “Reproducing Color Accurately” (Adobe, 1998, pp. 79 - 101) and correcting the colour and tonal range of an image (Adobe, 1998, pp. 105 - 130). Within the image manipulation software, images can be changed from one mode to another. This can be a highly influential factor, when it comes to both colour accuracy and tonal range. In some colour copier machines, if an image is sent to the RIP in RGB mode instead of CMYK, the print can appear to be washed out, with de-saturated colours and the black areas will print as greys (M. Swanepoel, personal communication, March 18, 1999).

Another type of software can assist in achieving colour accuracy, this is colour management software. This is an extensive field on its own, what follows is a brief explanation.

2.4.5 Colour Management

These days colour management includes software and hardware that can adjust the colour of images when they are captured, designed or processed by computer software or RIPs, viewed on monitors, and when images are printed. Very simply what colour management does is to relate each device's colour gamut to a standard colour space (Agfa-Gevaert, 1994, p. 34). It can assist in achieving certain results, as DiCosola writes, "the goal of color management is to reduce waste and increase productivity. This is achieved by giving you more consistent, automated, predicable color results – in other words, getting the color correct the first time" (1998, p. 71). O'Leary however emphasises the technological side of colour management. " 'Color management' as we are currently hearing about it really pertains to the landslide of standalone [sic] calibration and profiling software (generally classified as Color Management Systems or CMS), along with color-measurement instruments with which they interface" (1998, p. 77).

2.4.6 Colour Models

There are a number of models used for representing colour values, such as the CIE (Commision Internationale de l'Eclairage) and Munsell systems. The CIE LAB system has been the standard model since 1976 (Agfa-Gevaert, 1994, p. 33). LAB colour is device independent and based on the colour range that a standard observer can distinguish. The goal of such a model is to provide a universally recognised system for colour matching or "to develop a repeatable system for color communication standards for manufacturers of paints, inks, dyes, and other colorants" (X-Rite, 1996, p. 16).

In Figure 3, this model is represented, with L,A,B axes. A denotes the green/red value, B the yellow/blue value and L the lightness of the colour. When colours are allocated LAB values they can be moved from one colour space to another and will retain their accuracy.

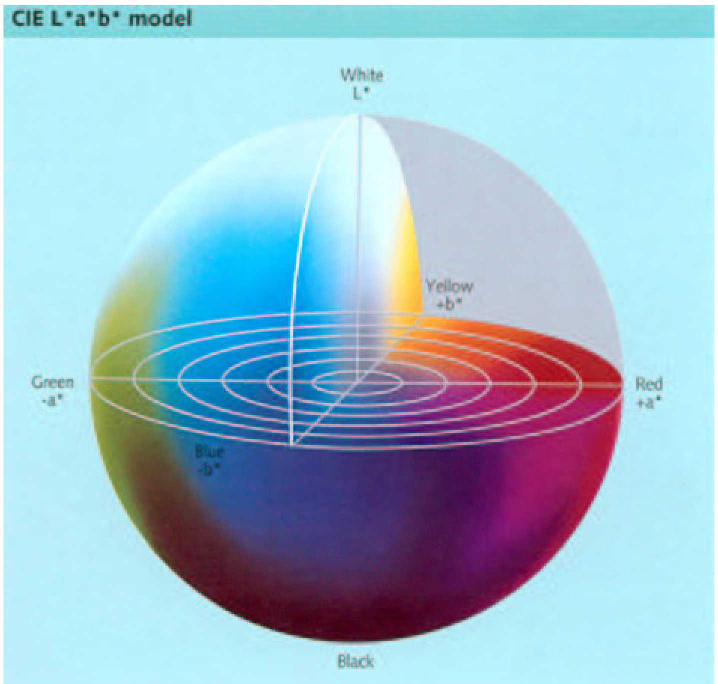

Figure 3. The CIE lab model for representing colours.
(Agfa-Gevaert, 1994, p. 33)

2.4.7 Colour Space

A bitmapped image represents all its areas (pixels) as numbers or a series of numbers. In order to represent a coloured area the numbers need to specify very precisely, what tone of what colour is in a particular area.

Each piece of hardware in the image capture, processing and reproduction process has what is termed its own colour space. Aaland and Burger give a simple explanation of this, " a 'color space' is just a mathematical model used to describe the colors of an image" (1992, p. 84). Most scanners, digital cameras and monitors operate in the RGB space while digital printers often use the CMYK space.

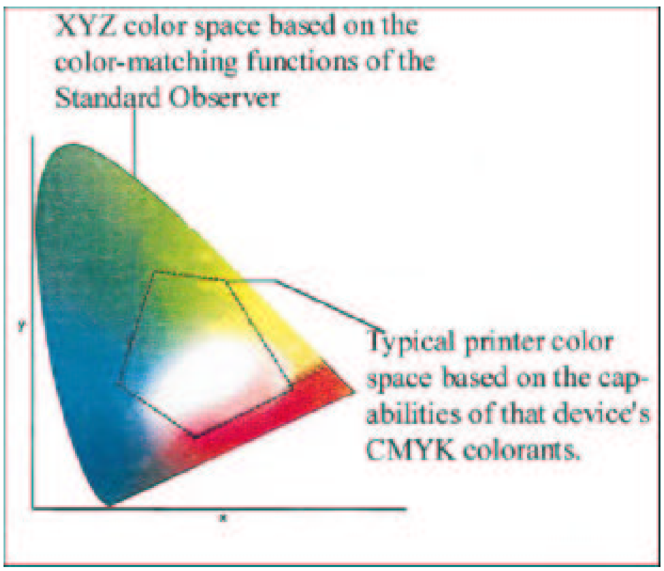

Figure 4. Colour gamut of a typical CMYK colour printer. Adapted from (X-Rite, 1996, p. 15)

Unlike the human eye, which can recognise millions of colours, scanners and digital printers can only capture and reproduce a limited range or gamut of colours. A typical CMYK printer gamut is illustrated in Figure 4. Because of gamut limitations, compression of colour information from the original artwork occurs at each stage. When a scan is made the gamut limitations of the scanner will cause compression, as will the gamut limitations of the monitor or the printing device. In most cases out-of-gamut colours are replaced by colours that approximate the original colours.

To ensure that colour information received from the input device, viewed on the monitor and then output to the printer, remains accurate colour management software is essential. To this end a number of companies have brought out appropriate software, the aim being to bridge the gaps caused by moving information from one colour space into another.

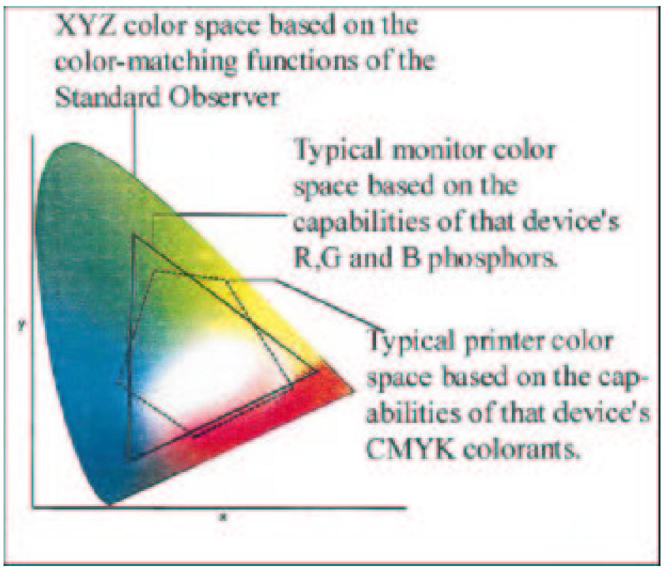

Figure 5. Comparison of the gamut seen by a standard observer and that reproduced by a monitor and a CMYK printer. Adapted from (X-Rite, 1996, p. 15)

An example of colour management software that is relatively freely available to artists is ColorSync. In principle what ColorSync is designed to do is to tag information onto a file, that will stay with it from scan to output stage. At the scan stage an International Colour Consortium (ICC) profile of the image is tagged onto the file. This profile can contain information regarding the original source, the scanner characteristics and the final output device and its characteristics. If the output device has a colour management system that can read ICC profiles it will be able to read the tagged information and make the appropriate adjustments (Green, 1997, pp. 12 - 14). Theoretically this will result in better colour and tonal results, however there has been some criticism of the system. As O'Leary points out, embedding profiles at the scan stage leads to compression of the colour gamut, limiting the final output (1998, p. 78).

When images are sent to a printer, the RIP is instructed to treat them according to a specified profile. This will influence the appearance of the final print, some profiles will result in warmer or cooler colours, and others will increase the saturation of the colours and alter the tonal range (R.G. Mowatt, personal communication, September 17, 1999).

Even with colour management, many experts still feel that expertise on the operators part is an intrinsic aspect to achieving accurate colour (O'Leary, 1998. pp. 78 - 82). What does seem obvious is that colour management is becoming more available to the individual artist. Hopefully, in the future the use of expensive measuring devices can be eliminated and colour calibration, management and measurement could all be built into a reasonably priced and easy to use package.

2.5 Output

In order for digital printers to print colour as accurately as possible, their colour performance needs to be maintained and they need to be able to cope with unusual or out of the ordinary images and still produce accurate colour. These aspects are controlled by calibration, software systems and printer profiles. Most printers have a basic calibration process where the amount of ink or toner laid down is measured and adjustments made to compensate for this. This calibration can also take care of aspects such as head alignment and whether the substrate is feeding through the machine correctly. This type of calibration is done whenever the ink or the substrate is changed. Some devices are sensitive to humidity and temperature changes and so need to be calibrated more often.

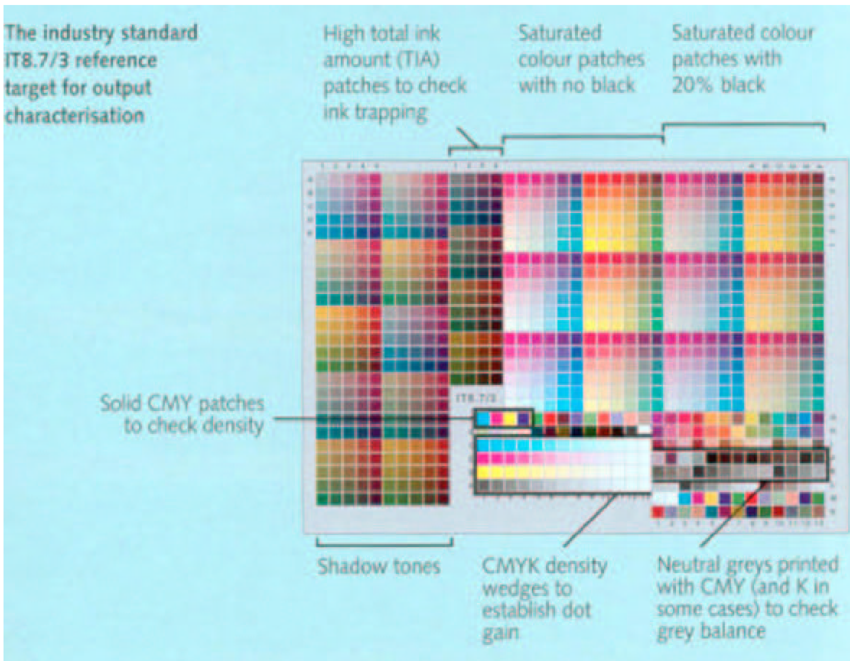

Figure 6. IT8.7/3 reference chart for output characterisation. (Agfa-Gevaert, 1994, p. 35)

When used with colour management software (CMS), calibration becomes more complicated and sophisticated. A standard reference file such as the IT8.7/3 seen in Figure 6, consisting of a range of different colours, black, white and tones of grey is printed. A colorimeter or spectrophotometer is then used to measure the densities achieved in the various colours. This information is fed back to the CMS and a profile is created (Agfa-Gevaert, 1994, p. 35). A profile for each ink or substrate combination can be generated.

2.6 The Print Operator

In an ideal situation " studios still need to have a fine art printmaker on staff, otherwise they are going to lose contact with artists" (Duganne, 1999, p. 52). In South Africa bureaux print mostly for commercial clients with fine art clients providing less than 1% of their business (T. Maio, personal communication, February 9, 1999). Very few commercial bureaux have operators that understand fine art printing. Operators are often skilled at printing images if an accurate proof, material swatches, or the original artwork is provided. This is even the case at some fine art print companies in the USA as Malek points out, “even when working from transparencies, most printmakers still prefer having originals in-house” (1999, p. 60).

2.7 Finishing

Digital prints are often of large scale and exhibiting them can require them to be finished in a particular way. This is in order to ensure that they can be transported and displayed easily, that they are not easily damaged, that they will not fade quickly and to enhance their appearance. In the commercial world, lamination, mounting and liquid clear coats are standard finishing techniques applied to digital prints, especially inkjets. For the fine artists, framing and other finishing techniques might also be applicable.

Lenticular prints are fashionable printing and finishing techniques at present. The technique, which uses a variation of the old lenticular colour process devised by Lippmann, creates an "illusion of movement, depth, animation, morphing, or three-dimensional space" (Krause, 1999, p. 46). The print can be made up of a number of different images which are broken up and printed as thin strips next to each other. Strip plastic lenses, angled at different pitches, are placed in front of the image. This enables the viewer to only see one image at a time, but if he or she moves a new image is revealed.

2.7.1 Lamination

Most lamination material consists of a layer of film onto which adhesive is coated. Laminates can be applied to the front side only or to both sides (encapsulation) of a print. There are four main types of laminates:

- cold, which uses pressure only,
- hot or thermal, making use of heat only and
- multi-heat or heat-assist laminates, which make use of heat and pressure.
- Wet transfer laminates allows the colour of a digital print to be embedded into the laminate, after which the paper substrate is peeled off. This system has very specific applications and is more geared for sign making that continuous toned images.

Cold laminates are made up of plastic film, a layer of clear adhesive and a release sheet. The release sheet is peeled of and under pressure the laminate adheres to the print. Thermal laminates consist of an outside layer of polyester film, combined with an inside layer of polyethylene. They require temperatures of between 200 and 300 degrees Fahrenheit to bond with the print (Edlund, 1996, p. 50).

The laminating film is classified according to the process, the thickness and the surface or application. Some of the surface types that are available are glossy, matt, black, white, magnetic backing, dry erase for writing on, pebbling, leather and embossed. Although the method of quoting thickness varies, they generally range between 3 and 10 mm (IRGA, 1998, ch. 5, p. 7).

Figure 7. A laminating machine, with laminate on the top and bottom rollers. (Lamination Station, 1999)

Laminating prints can vastly influence their longevity. Edlund points out that "a laminates ability to protect an image from UV light varies greatly between standard laminates and specifically formulated UV laminates. The differences between them can translate into a vastly extended life of the graphic" (1996, p. 84). Professional laminating is a complex process requiring the operator to feed the film and print through a machine while ensuring that the temperature, pressure and speed are all correctly set. Matching lamination material to the print and image type is also critical, as thermal wax and some piezo inkjets, cannot withstand heat laminating and would be damaged by the process. The visual appearance of an image can also be enhanced or degraded by lamination. Glossy films tend to enhance brilliant colours, while a matt surface will reduce contrast and subdue colours. The fact that the print can be sealed off from the environment, will also protect it from chemicals, water, scratching, graffiti and many other damaging factors.

Liquid coatings are easier for the individual to apply to prints, as they require no specialised equipment. They are either sprayed on, or spread over the surface using a roller. They do offer some protection to moisture, UV wavelengths and scratching, and give a reasonably high gloss finish.

2.7.2 Mounting

Through mounting, graphics are attached with adhesive to a rigid substrate, once again adhesives that are activated by pressure alone or heat and pressure may be used. For commercial applications, polystyrene and polyvinyl chloride (PVC) foam sheets are the most popular, but prints can be stuck to almost any support (IRGA, 1998, ch. 5, p. 17). Once again great care has to be taken to use the correct materials combination to match the final application of the print.

Figure 8 shows a photograph of an inkjet print that was laminated on the front, then attached to a porous plastic substrate. When it rained the water passed through the plastic backing and the water-soluble ink leached out of the print (T. Land, personal communication, June 9, 1999).

Figure 8. Photograph of the discoloration caused by ink leaching out of a thermal inkjet poster. (Giloi, 1999)

It can be seen from the scope of factors addressed in this chapter, that to achieve perfect print quality is the goal of numerous manufacturers of materials, hardware and software, as well as groups of experts in the fields of colour standardization. The input stage is critical as it is highly influential in determining the colour balance, tonal range, highlight and shadow detail, sharpness, resolution and the size of the final print. Additional aspects, such as corrections made by the print operator, or automatically by colour management software will also effect print quality. If the artist wants to achieve print accuracy, this chapter emphasises that all the equipment used must be correctly calibrated. The first section of the following chapter describes how some of these aspects, such as colour management, impact on the preparation of an image for printing, the rest of chapter three is dedicated to identifying and describing the digital printers that are available in South Africa.

Chapter Three

3 Digital Printing Techniques Available in South Africa

After a brief outline of how images are prepared for digital printing, this chapter deals with the types of printers that are available to a fine artist working in South Africa. Gathering technical information about the various digital printers is relatively easy, with most companies publishing comprehensive brochures both on paper and on-line. However detailed technical information about how some printers print images is not as easy to find. Many companies are not prepared to publish detailed descriptions of the technology or the materials used. There are a number of good sources of information on the inkjet processes, but information on for instance the Fuji Pictrography process is not readily available. Some processes therefore, are discussed in more detail than others are.

Where possible the technique each printer uses to lay down colour will be described in detail and in Table 1 aspects such as dpi, maximum print size, available substrates and other aspects will be listed.

A separate section on inks and substrates is included in this chapter, as these are technical aspects that effect print quality.

Table 1.
Printers Characteristics

Printer	Thermal Inkjet	Piezo-electric Inkjet	Extended Gamut Inkjet	Continuous flow Inkjet	Airbrush Inkjet	Phase-change Inkjet	Dye Sublimation	Thermal Wax	Digital Enlarger	Film Recorder	Imagesetter	Fuji Pictrography	Laser Printer	Colour Copier	Large Scale Electrostatic
Maximum DPI	600	1400	1440	300	6	1200	300	300	400	2,032	3,000	400	1200	400	400
Maximum print size	152 cm	137 cm wide	132 cm wide	55 x 76 cm	5 m wide	21 x 29 cm	29 x39 cm	36 x 66 cm	124 x 246 cm	20 cm x 25 cm	60 cm wide	31 x 46 cm	32 x 45 cm	29 x 42 cm	137 cm wide
Print speed	14.3 to 5.789 m per hr	3.72 to 15 square m per hr	2.5 to 5 square m per hr	1.01 square m per hr	66 square m per hr	2 pages per minute	1 page per minute	4 pages per minute	18.6 to 241.8 square m per hr	20 cm x 25 cm print per minute	40 cm per minute	29 x 40 cm print in 93sec	four 21 x 29 cm pages per minute	six 21 x 19 cm pages per minute	37.2 to 241.8 square m per hr
Cost per meter square	R284	R 450.00	R 360	R453	NA	19 x 29 cm print R 12	29 x 39 cm print R 110	29 x 42 cm R 32	R 167.65	10 x 12 cm sheet of film R285	29 x 42cm sheet of film R32	21 x 29 cm print R45	21 x 29 cm print R20	21 x 19 cm pages R15	R 390
Substrates	Coated paper, gloss photo paper, film, clear imaging media, translucent, opaque, cloth, vinyl, vellum	Paper, film, polyester, polycarbonate, canvas and vinyl.	Coated paper, synthetic paper, PET film, PVC, backlit imaging film, canvas, cloth	Canvas, gloss, semi-matte, hi-color matte, watercolour, cotton, film,transparent and translucent.	Paper, vinyl, fabric, others	Paper, vinyl, canvas	Paper, transparency film	Paper, vinyl, polyester	Photographic paper, negative and positive, black and white, backlit.	Black & white, colour negative, colour transparency film	RC paper, film, polyester Contact printed onto black and white or colour photographic paper.	Standard paper, light weight paper, overhead transparency	Laser paper, copier paper, labels, recycled paper, glossy paper, transparency, fabric transfer	Paper, glossy paper, light card, transparency, T shirt transfer.	Vinyl, canvas, banner, transfer materials
Size of equipment	H 122 cm D 73 cm W 156 cm W 115 kg	H 116 cm D 61cm W 190 cm W 169 kg	H 125 cm D 73 cm W 224 cm W 90 kg	H 107 cm D 768 cm W 174 cm W 314 kg	H 137 cm D 107 cm W 671 cm W 1365 kg	H 36 cm D 60 cm W 43 cm W 35 kg	H 34 cm D 57cm W 52 cm W 38 kg	H 21cm D 37 cm W 43 cm W 19 kg	H 127 cm D 235 cm W 205 cm W 1650 kg	H 46 cm D 77cm W 63 cm W 100 kg	H 100 cm D 30 cm W106 cm W 200 kg	H 93 cm D 63 cm W 90 cm W 110 kg	H 64 cm D 49 cm W 728 cm W 68 kg	H 58 cm D 59 cm W 61 W 82 kg	H 99 cm D 76 cm W 182 cm W 344 kg
Longevity	2 to 3 years. (Wilhelm, 1999)	2 to 3 years outdoors. (Wilhelm, 1999)	Images fade 2/3rd faster than other inkjets with same ink type. (Wilhelm, 1999)	Varies from 5 to 150 years depending on ink and paper combinations. (Wilhelm, 1999)	NA	18 to 28 years depending on ink and paper combinations. (Wilhelm, 1999)	6 months (T. Maio, personal communication, February 9, 1999)	3 to 5 years. (T. Maio, personal communication, February 9, 1999)	12 to 60 years depending on the paper type (Wilhelm, 1999)	12 to 60 years depending on the paper type (Wilhelm, 1999)	29 years or more. (Wilhelm, 1999)	Still being tested	Indefinite	Indefinite	With lamination up to 5 years outdoor applications (T. Jordaan, personal communication, February 13, 1999)
Cost of Machine	R 68,000 to R 136,000	R 2147,000 to R 2,000	R 2.300 to	R 600,000	NA	R 25,000	R48,000	R37,000 to R929,000	R886,000 to R1420,000	R17400	R 325 000 to R 395 000	R125 000 to R 220 000	R49,000	R136,000	R557,000 to R359,000
Manufacturers	ColorSpan, Hewlett-Packard, Encad, Selex	Epson, Xerox, NUR, Raster Graphics	Lexmark, LaserMaster, Roland, ColorSpan, Raster Graphics, Mimaki	Iris, ColorSpan	Vutek	Tektronix	Mitsubishi, Tektronix, Fargo, Kodak	Kodak, Fargo, Tektronix	Durst-Dice, Gretag, Cymbolic Science	Management Graphics, Laser-graphics	Screen, ECRM,	Fuji	Tektronix, Xerox, Canon, Apple, Nashua	Canon, Xerox, Hewlett-Packard	Xerox, Raster Graphics, 3M
Reference	("The big," 1999, WFDIC)	("The big," 1999, WFDIC)	(Roland, 1998)	(Scitex, 1997)	(Vutek, 1998)	(Tektronix, 1997)	(Eastman Kodak, 1998)	(Eastman Kodak, 1998)	(Cymbolic, 1997)	(Cymbolic, 1997)	(Dainippon, 1998)	(Fuji, 1996)	(Tektonix, 1997)	(Xerox, 1998, Gestetner, 1999)	(Xerox, 1998)

3.1 Preparation for Printing

An image viewed by an artist on a computer screen goes through a number of stages before it can be printed. There are many software programmes available to the artist who can use them to create images or to manipulate existing images. A small sample of the software programmes that are available, are Adobe Photoshop, Adobe Illustrator, Macromedia Freehand, QuarkXpress, Adobe Pagemaker, Fractal Design Painter and Corel Draw.

Some programmes create images as vector graphics where each point on a line or curve would be defined by a mathematical description. Printers are not capable of understanding or printing this type of information and so all vector images must be converted to bitmapped or raster images in order to be printed. A bitmap image consists of a grid made up of pixels, each pixel has a location and can be assigned a colour value. Bitmap images are very commonly used to produce imagery, because they can represent subtleties of tone and gradations of colour accurately. A RIP is needed to process all vector images into a bitmapped images. Some RIPs are built into the printers themselves as print controllers, others are purchased separately and can act as document server RIPs, or stand-alone RIP software can be installed into an existing workstation. The workstation can also be used to run other applications.

3.1.1 Raster Image Processors

RIPs have four main functions: rasterizing images for output, scaling images, controlling colour and driving one or more output devices. The first step in the process is to separate the image into the appropriate colour values. These can be CMYK for most inkjets, RGB for digital enlargers and other variations for extended gamut inkjets.

Unlike traditional printing processes most digital printing does not require images to be screened, however because most digital printers build up an image by laying down minute dots, images are broken up into dot patterns. The system used to control this is called dithering. The most common form of dithering is stochastic screening, it can also be called frequency modulated (FM) screening. The stochastic screening system relies on using very small dots of the same size to build up an image and varying the spaces in-between the dots, thereby producing a seemingly random pattern. Second order FM screens vary both the dot sizes and the spaces between the dots in a random pattern (Somerville, 1999, p. 1).

RIPSs have colour management software built in to them and can adapt images to match the ink limitations of specific devices. When a dot is printed onto a substrate, the substrate's absorbency will significantly effect the size and density of the dot achieved, dot gain or dot loss will occur. When processing images, RIPs can be instructed to take the final output media into account and will therefore make adjustments regarding dot gain. This will be described in more detail in section 3.9 when substrates are discussed. RIPs control how solid black is printed, using pure black ink or building it up as a combination of black and the other inks, the later takes less time to print and improves drying times and finishing capabilities. Specific image characteristics can also be taken into consideration when images are processed, for instance if the image is photographic or contains process colours, the RIP will make appropriate adjustments to achieve the best results.

3.2 Digital Printers

The following printing devices were identified as operating in the South African digital printing industry: thermal inkjet, piezo-electric inkjet (piezo inkjet), continuous flow inkjet, airbrush/aerosol inkjet (airbrush inkjet), extended gamut inkjet and phase-change/solid ink inkjet (phase-change inkjet), thermal wax, dye sublimation, digital enlargers, film recorders, imagesetters, Fuji Pictrography, laser, colour copiers and large format electrostatic.

3.3 Inkjet Printers

Inkjet printers come in a variety of sizes from desktop models that take 21 x 29 cm wide paper sheets, to super large format devices that print on 6,400 cm wide rolls of media. Most wide format digital printing originated from the reprographics industry and today it is an extensive growth market.

The company IT Strategies predicts a continuing growth in the number of wide format inkjets, from 62,895 machines in the USA in 1998 to 259,386 by the year 2003 (IT Strategies, 1999, p. 16). Otsuki predicts that the display models in Europe will increase from 2,000 in 1994 to 70,000 by the year 2000 (1996, p. 4). It is generally accepted that this type of printer will dominate the commercial wide format digital printing market for some time to come.

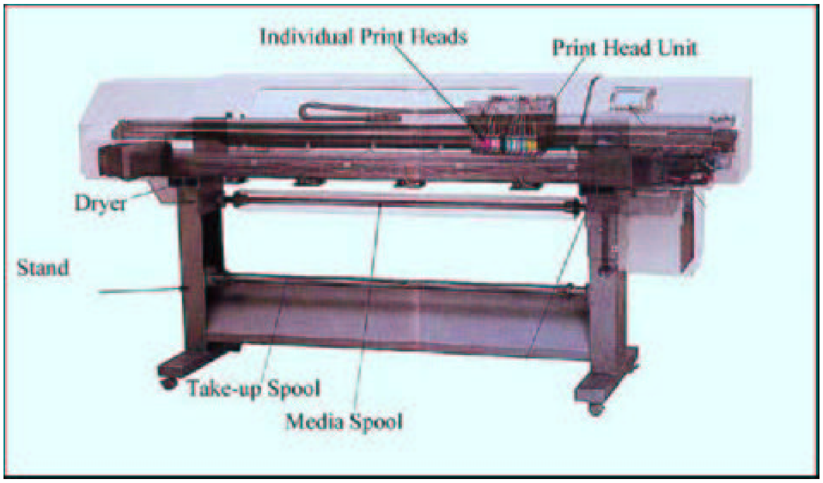

Figure 9. An example of a large format inkjet printer.
Adapted from (ColorSpan, 1999, pp. 6 - 7)

Large format printers usually consist of a sturdy stand onto which the print head, paper rolls and paper advance machinery is attached, Figure 9. There have been some recent developments of flat bed inkjets, where the inkjet heads can be positioned above a rigid substrate. In both systems the print head unit contains print heads for each colour (CMYK), the unit runs above the surface of the substrate, while spraying on the inks. Some inkjet heads only spray while the unit moves in one direction, the faster models spray on ink while the head runs in both directions, these are called bi-directional machines.

Figure 10. The refillable CMYK ink containers.
(Kanitone, 1998, p. 8)

Each print head may be a sealed unit, which has to be replaced when the ink is used up, or the head may be refilled, these heads are usually attached to refillable ink containers by thin tubes. Figure 10 shows the four ink bottles which can be refilled.

In the vertical units, the print head unit moves across the substrate horizontally, the substrate is fed through the machine vertically, thus a line (or many lines) of ink are sprayed, the substrate advances and the next line of ink is sprayed. The inkjet heads spraying ink onto the substrate are illustrated in Figure 11.

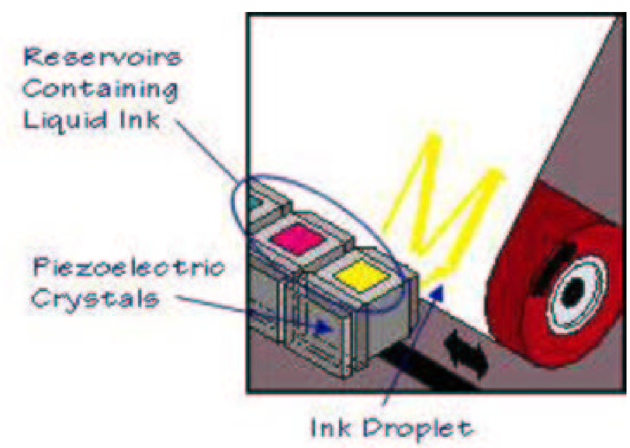

Figure 11. Inkjet heads moving over the substrate while spraying on ink droplets. (Eastman Kodak, 1999)

Figure 12. A large format thermal inkjet printer.
(Encad, 1998)

Take-up spools and fans for drying the printed section are options that some manufacturers offer. Other than the superwide (5 to 6.4 m) devices, most can be placed into an average sized room and do not require any special ventilation. Inkjets can be divided into two broad categories, continuous flow and drop on-demand inkjets (Le, 1998). Within these categories are further refinements as to how the technology is used. The following list of inkjets is divided into general categories using the commercially recognised names.

3.3.1 Thermal Inkjet

Although the thermal inkjet technology had been invented by Canon scientists in 1979 (Le, 1998), it was only in 1993-94 that Vivigraf, Encad, Hewlett Packard and Lasermaster applied it to large scale printing (Otsuki, 1998, p. 2). In the print head a resistor heats the water-based ink until it expands, creating a micro-bubble of air, which forces out a droplet of ink onto the substrate. This is illustrated in Figure 13. Once the ink droplet is released the temperature of the ink in the head drops and the cycle begins again, a complete cycle can take as little as 5,000 MHz (cycles per second) (IRGA, 1998, ch. 1, p. 3). The resulting printed droplets are tiny, between 50 and 60 microns in diameter (Anderson, 1998).

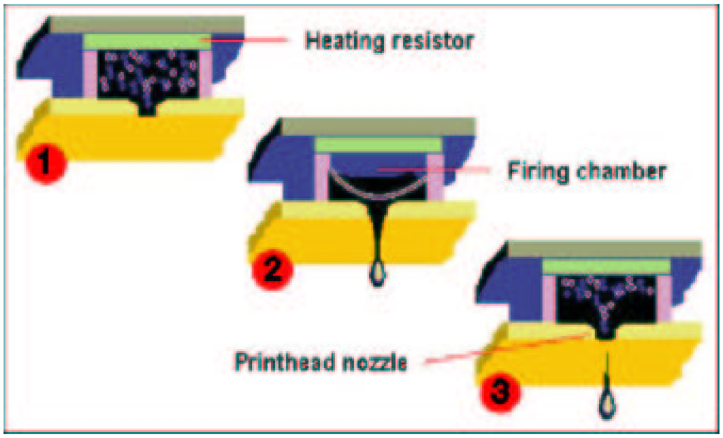

Figure 13. The heating and firing cycle of a thermal inkjet head. (Anderson, 1998)

The thermal inkjet printer is relatively maintenance free and reliable, it can deliver a wide range of colours, but tends to print rather slowly. In early models only dye-based inks could be used because of the heating of the ink. Today some manufacturers provide pigment inks. The high temperatures that are required to heat the ink may cause problems such as kogation. Kogation, which is the accumulation of deposits at the nozzle of the print head, will cause the nozzle to clog up resulting in uneven printing. A further drawback is pointed out by the IRGA "thermal inks … are extremely dependent upon the receptor coating of the printable media for everything from basic adhesion to print characteristics" (1998, ch. 1, p. 4).

Because of these drawbacks, thermal machines appear to be reaching the end of their usefulness. Tilla Jordaan of Xerox SA has indicated that the company has already started phasing out thermal printers and replacing them with piezo machines (personal communication, February 13, 1999).

3.3.2 Piezo-electric Inkjet

Piezo inkjet technology, which was developed by Epson was introduced into the large format market in 1997 (Otsuki, 1998, p. 2). It is the system that Epson and other manufacturers continue to use in their desktop printers. The print head has a number of piezo crystals placed behind the inkwells, an electrical charge is applied to the crystal causing it to oscillate, thereby forcing the ink out of the nozzle. Figure 14 provides an illustration of this process.

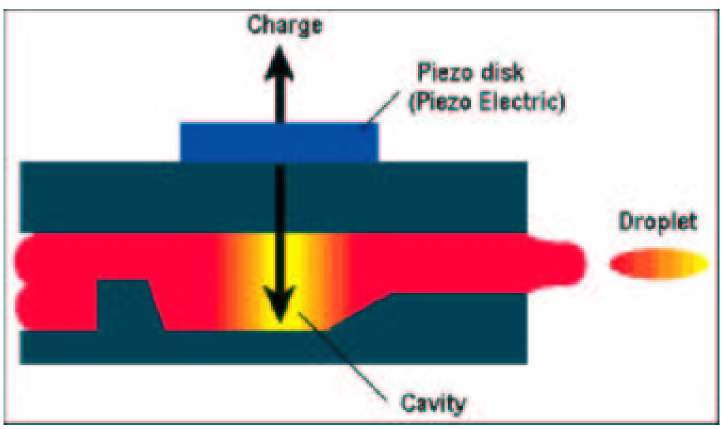

Figure 14. A droplet of ink fired out of the ink chamber by a piezo crystal. (Anderson, 1998)

This system allows for smaller droplets and control over the shape, size and position of the ink droplets. The inks do not have to withstand heat and so can be designed with fast drying and longevity qualities in mind and pigment and solvent inks can be used (Anderson, 1998). Print heads for these machines are semi-permanent, which makes them more reliable, and brings down running costs. The piezo inkjet machines are becoming more and more popular, offering excellent image quality. This applies to the desktop models and the superwide printers with widths of up to 6,400 cm and the ability to print onto a variety of substrates, including carpets, fabric and floor covering.

3.3.3 Extended Gamut Inkjet

Recently a number of companies have introduced extended gamut printers, once again some desktop models offer this option, as do some large-scale printers. There are a number of approaches used by manufacturers to extend the printing gamut. ColorSpan brought out an eight-head machine that has three cyan and three magenta densities, plus the usual yellow and black, this falls into the Super CMYK category. Lexmark and Roland have taken the option of including two cartridges, one containing CMY and the second containing black, (G) green and (O) orange, the hi-fi option.

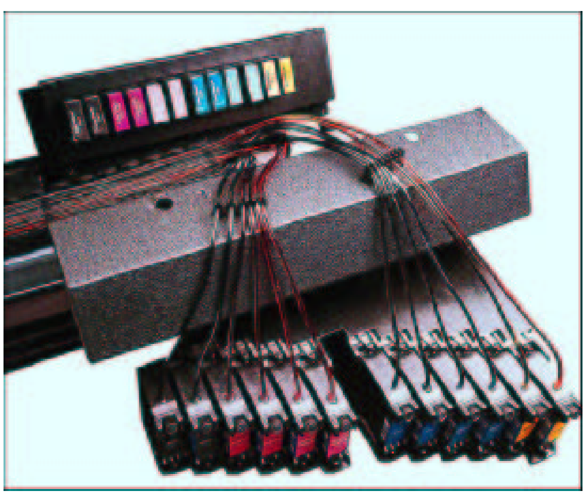

Figure 15. Twelve print heads on an extended gamut inkjet. (CololSpan, 1999, p. 4)

More recently ColorSpan introduced a twelve head machine, which is illustrated in Figure 15, that offers the options of mixing a number of ink colours. They offer a hi-fi set with CMYKOG, a red and blue set with CMYKRB and an orange, blue, set with CMYKOB. In addition to this are high-resolution variations, which would include light and medium cyan and magenta, as well as the other standard inks (ColorSpan, 1999, p. 7).

Manufacturers claim that the additional inks enable the printer to truthfully reproduce a far greater range of colours and to render subtle gradations as well as vibrant colours far more effectively. The hi-fi inkjets were designed primarily to produce proofs for the traditional Pantone six colour HexaChrome printing system that also makes use of additional colour plates and inks. The heads used in these printers often use piezo technology.

Figure 16. A continuous flow inkjet printer. (Scitex, 1999)

3.3.4 Continuous Flow Inkjet

Iris Graphics developed a version of continuous flow technology in which ink is forced at high pressure through nozzles made of glass. In the nozzle a micro-crystal oscillates, breaking the stream of ink and so separating the flow of ink into millions of droplets. Some droplets are allowed to exit the nozzles and other not, this is achieved by applying an electrical charge to selected droplets, uncharged droplets are expelled and charged ones are diverted back into the ink stream. This is illustrated in Figure 17. The software controls the selection of the droplets and where they fall on the substrate.

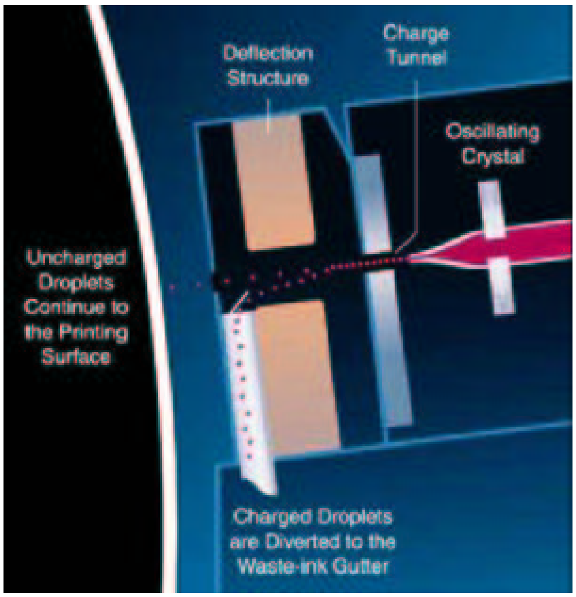

Figure 17. Illustration of a continuous flow inkjet firing system. ("Understanding Digital," 1999)

In most continuous flow machines the media is taped onto a drum which spins while the print head traverses it. The distance between the head and the media in some machines is adjustable, meaning that a wide variety of substrates can be used, even for instance, hand made paper. When prints using specific inks and substrates are printed using this technology they are referred to as giclée prints.

These machines, with an effective dpi of about 1,800 can print exceptionally high quality images. "This is because each dot is a mixture of CMYK and dot size can be varied"

(IRGA, 1998, ch. 1, p. 5). This overlapping dot is illustrated in Figure 18. Continuous flow inkjet machines are generally used as proofing devices, but Iris have brought out a modified machine, the IrisGPRINT, designed specifically for fine art applications.

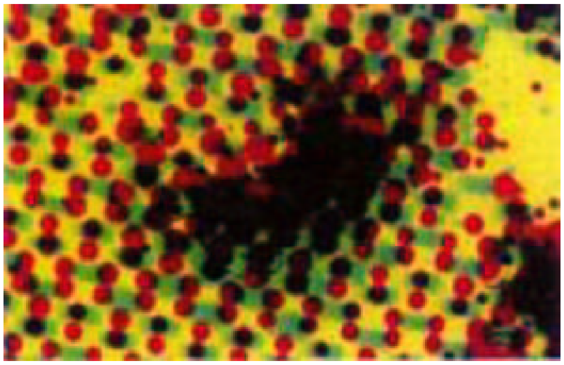

Figure 18. Close-up photograph of dots printed by the Iris continuous flow inkjet printer. (Lowe, 1996, p.3)

Unfortunately there are no IrisGPRINT machines in Africa (K. Solomon, personal communication, February 11, 1999). There is one bureau in South Africa that does offer the option of printing on more permanent inks and substrates, though not with an IrisGPRINT machine (R. Streak, personal communication, November 11, 1999). The Iris machines are expensive, rather slow and need to be well maintained. The manufacturers claim an extended greyscale and smoother tonal gradations. Prints have been tested at the Wilhelm Imaging Research Inc. (Grinnell, IA) and with the right combination of inks and substrate are predicted to have an indoor display life of up to 150 years (Wilhelm, 1999).

3.3.5 Airbrush/ aerosol Inkjet

These systems are used for very large-scale printing such as billboards and truck sidings. A variety of substrates are available for indoor and outdoor use, some machines are even designed to print onto fabric and carpets. Once again it seems that piezo machines are gradually replacing these printers. An example of an airbrush machine is illustrated in Figure 19.

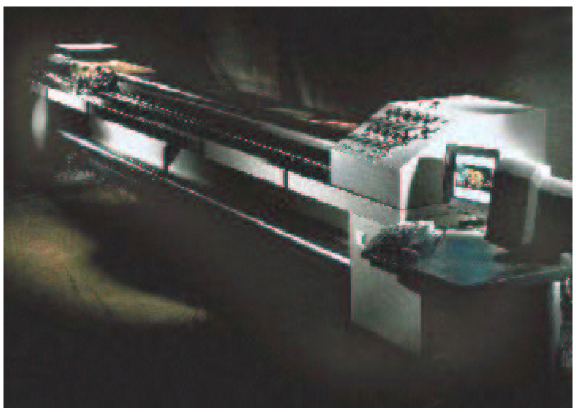

Figure 19. An airbrush inkjet printer. (WFDIC, 1998)

3.3.6 Phase-change/Solid Ink inkjet

Solid ink technology is available in a number of machines today. Phase-change relates to the change that takes place when a substance changes from one form to another, such as liquid to solid or vapour to liquid. During the printing process, solid ink sticks, made up of fatty amide waxes, rosin ester and dye, are melted and the warm liquid is squirted onto the substrate where it solidifies (Tektronix, 1997). To produce a good surface texture the material is then run between two rollers cold-fusing it onto the paper. Some of the advantages of this system are that the inks can be printed on to virtually any substrate that can be handled by the printer.

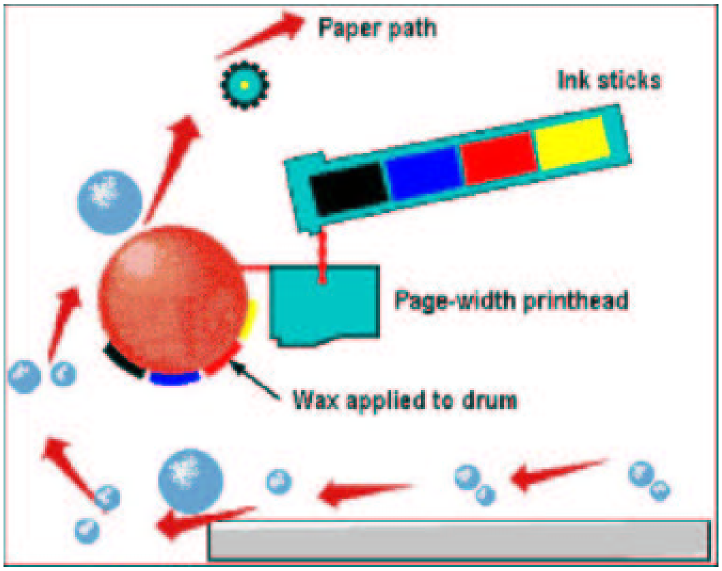

Figure 20. An illustration of the phase-change inkjet process. (Anderson, 1998)

Le describes the process slightly differently, more in keeping with the illustration in Figure 20.

> Basically, the printing process starts with coating a thin silicon oil film onto a warm rotating aluminum [sic] drum. Ink is then jetted onto this intermediate drum. Once an entire image is printed, it is then transferred from the drum onto a preheated media via a pressure nip (Le, 1998).

3.4 Dye Sublimation

Dye sublimation printers were originally developed for textile printing and they rely on the melting of one material in order to transfer its colour onto a substrate. The printers usually have four sheets of plastic film, sometimes in continuous transfer rolls. Each sheet is coated with either cyan, magenta, yellow or black dye. The sheets are fed across a print head, which contains over 2,000 heating elements, these heat the solid ink, changing it into gas which diffuses onto the paper surface, as is illustrated in Figure 21.

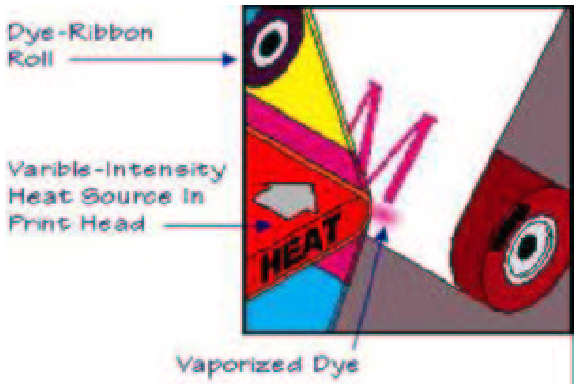

Figure 21. Heating element of dye sublimation printer vaporising ink. (Eastman Kodak, 1999)

The temperature achieved by each element can be varied thereby influencing how much ink is melted and the colour density of each dot transferred onto the paper. This process results in an image, which is almost continuous tone with a photographic appearance. As opposed to a dithered dot appearance, the dyes blend together giving a softer more evenly toned look, as can be seen in Figure 22.

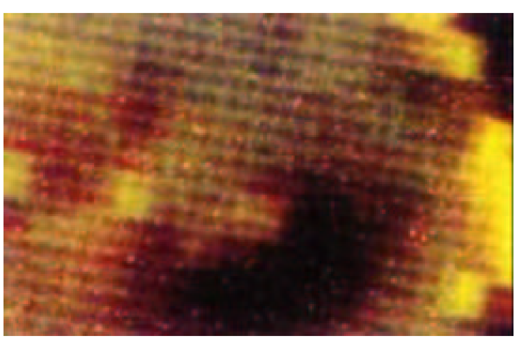

Figure 22. Close-up photograph of the diffused ink pattern from a dye sublimation printer. (Lowe, 1996, p. 2)

Because the four sheets have to be brought into contact with the heads and the substrate at different stages, registration problems can occur, consumables are expensive, only specially prepared paper may be used, the printers are relatively slow and print size is limited.

3.5 Thermal Wax Process

A similar process to dye sublimation is used in the thermal wax process, in fact some manufacturers offer both processes in one machine. The difference in the thermal wax process is that the ink is not vaporized, merely melted and deposited onto the substrate and in some machines the CMYK inks are coated onto ribbons rather than plastic sheets. This is illustrated in Figure 23.

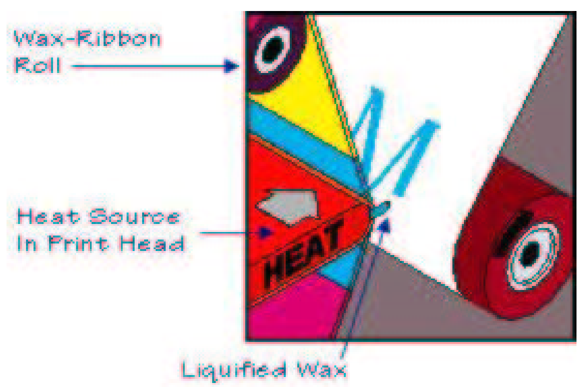

Figure 23. A thermal wax heating element melting wax onto a substrate. (Eastman Kodak, 1999)

The image is reasonably water resistant, but the inks may crack when the substrate is folded. The printing process is relatively fast and office type laser paper may be used. Colours produced are vivid and the process is reasonably cost effective. The machines are quite inexpensive. Images can be transferred onto T-shirts and ceramics and much research has gone into creating large-scale models that are designed to print onto fabric. A number of thermal wax machines are being replaced with phase-change printers.

Figure 24. An example of a combination dye sublimation and thermal wax printer. (Eastman Kodak, 1997)

3.6 Hybrid Photographic Processes

3.6.1 Digital Enlarger

Digital enlargers, introduced at Photokina in 1994 (Henshall, 1997), write information on to photosensitive materials using red, green and blue (RGB) laser beams, or cathode ray tubes (CRT), or light emitting diodes (LED). Led models are reasonably priced, small in size and use a dependable light source (Ernst, 1999). Some enlargers have to be housed in darkrooms, others can be used in a lit environment, such as the example in Figure 25. In certain models the photosensitive material is loaded into cassettes in a darkroom and the cassette is attached to the exposure unit. The material is fed into an exposure cavity, which in some cases is curved, once the material is in position in the cavity, laser beams write across its surface in microscopic lines. The exposed material is fed into a take up cassette and taken to a processing unit. The material is processed in standard photographic chemicals.

Figure 25. An example of a digital enlarger. (Henshall, 1997)

This system produces high quality images on almost any kind of photographic material, colour negative paper, positive material, backlit material and even black and white resin coated papers. Prints from digital enlargers have all the advantages of photographic materials, which are relatively fade resistant. For instance Wilhelm Imaging Research (1999) has tested the Ilford Ilfochrome Classic Deluxe polyester-base material, and found that it showed no noticeable fading within 29 years, while Fujicolor Crystal Archive colour negative paper is quoted to last for 60 years (Wilhelm & Meehan, 1999). It is predicted that the number of digital enlargers in the USA, will increase from 483 in 1998 to 3,082 by the year 2003 (IT Strategies, 1999, p. 16).

3.6.2 Film Recorder

Figure 26. A film recorder unit. (Cymbolic, 1997)

The film recorder writes digital information onto photosensitive material, such as black and white film, colour negative material or colour transparency material. This can be 35 mm, medium format or large format film. The film image can then be used as the final artwork, or can be used to make contact prints or enlargements onto the appropriate photosensitive material. There are two basic types of film recorders, (CRT) devices and direct-light imaging devices. The film writer usually consists of a camera body in which the shutter remains open while the film is exposed to lines of light. The direct-light imaging device produces higher quality images, with higher resolution and faster speeds than CRT devices.

3.6.3 Imagesetter

These devices are designed to produce black and white film positives for the production of plates for traditional four colour printing process. On high-end imagesetters digital information can be written onto resin coated paper, black and white film or flexible polyester plates. The film negatives or positives produced by imagesetters can be created on lithographic film, which produces high contrast images, areas are either black or clear, there are no tones of grey. As the positive is usually to be used in four colour printing, the image is screened, meaning that the image is broken up into minute dots which vary in size. On a positive the highlight areas will have small dots while shadow areas will have larger dots. The frequency of the dots is dictated by the screen settings of the device, most devices give options of high medium or low-resolution screens, with lines per inch (lpi) of 100 to 425 being common. Some imagesetters offer a stochastic dot pattern, these produces a much higher quality image.

There are two basic types of imagesetters: capstan and drum. Imagesetters generally use a helium-neon laser as a light source and the beam is focussed and directed by lenses and mirrors to expose the light-sensitive material. In drum imagesetters the light-sensitive material is taped onto a drum and a rotating mirror exposes the surface. Manufacturers claim that this assists uniform exposure, achieving sharp dots and simplifies the registration process. Registration is of prime importance for later printing and so in capstan imagesetters great attention is given to the design and manufacture of a roller transport system that advances the film consistently during exposure. The capstan transport system is illustrated in Figure 27. An internal punch of the appropriate format assists operators with later registration. Film processing units can be attached to the exposure unit.

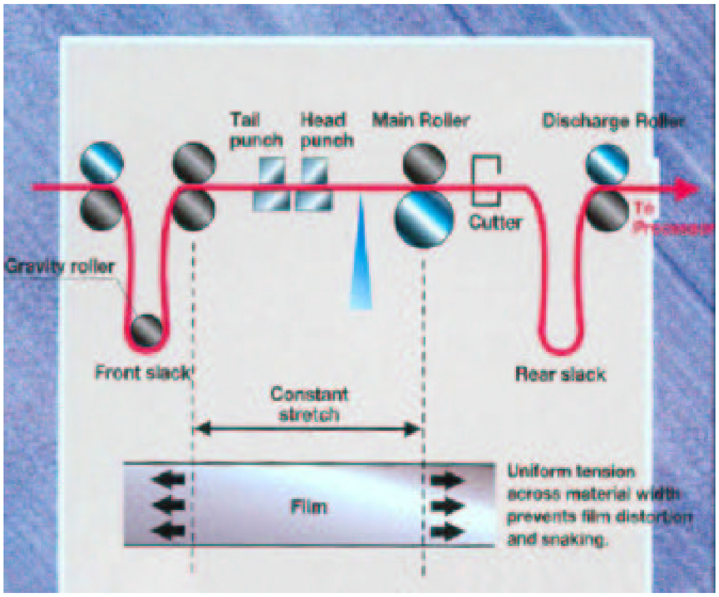

Figure 27. The transport system of a capstan imagesetter. (Dainippon, 1998, p. 4)

An acceptably high quality negative or positive can be made from a digital file using this process. This can then be used in a conventional darkroom to make prints onto black and white or colour photographic paper. The large negatives can also be used to make contact prints using alternate processes such as albumen, platinum, cyanotype, carbon, gum bichromate and pigment transfer printing.

For all photographic based processes there are certain obvious complexities. The materials produced by film recorders, imagesetters and digital enlargers require sophisticated photographic processing. And so a complete processing unit, big enough to handle the large paper or film sizes is needed. In addition to this all the usual intricacies of chemical processing need to be taken care of, mixing and disposal of chemicals, cleaning and maintenance of the machine and running and measuring of control strips to maintain quality standards. This requires expertise on the part of the operator. Processing machines are expensive to purchase and not cheap to run or maintain, high volumes have to be processed to make the equipment economically viable. Because of chemical emissions they have to be housed in a specific isolated environment with appropriate ventilation.

3.6.4 Fuji Pictrography

Fuji introduced the unique peel-apart thermal dye transfer process and these printers produce photo-quality images on a small scale. The machines are small and relatively easy to operate, as they merely require water and cassettes of donor and receiver material.

Figure 28. A Fuji Pictrography 4000 printer. (Fuji, 1996, p.2)

Laser diodes are used to expose the photosensitive donor material and water and heat are introduced to activate the dye image. The dye image on the donor paper is brought into contact with the receiver paper and the image is transferred using heat and pressure. The receiver paper is peeled apart and the donor paper disposed of.

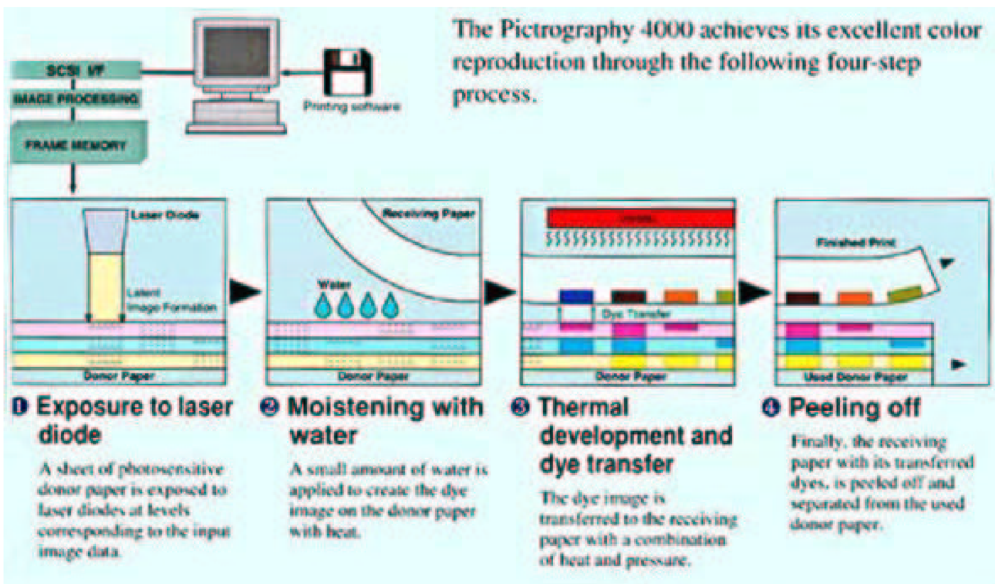

Figure 29. A diagram of the thermal dye transfer process used in the Pictrography 4000. (Fuji, 1996, p.5)

3.7 Electrostatic Systems

3.7.1 Colour Laser

The laser printer has at its center an organo-photoconductor (OPC) or drum that has a light-sensitive surface. While the drum is rotated past an array of electrodes its surface is electrically charged. A laser beam is directed by a set of mirrors and lenses at the drum. Where the original image is to be black the laser beam exposes the drum. Areas that are exposed change polarity and unexposed areas maintain the drum's charge. Toner powder is introduced and is attracted to the exposed areas and repelled by the drum that has the same charge. The toner is transferred onto a sheet of paper that has the opposite charge, heated rollers fuse the toner by melting it onto the paper. The drum is scraped clean and ready to go through the next cycle.

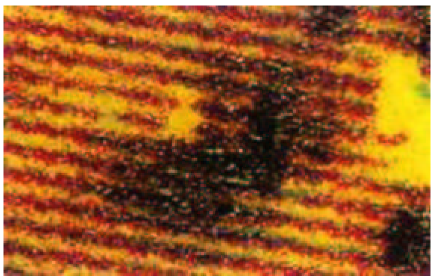

Figure 30. Close-up photograph of toner fused into the paper during laser printing. (Lowe, 1996, p. 4)

Colour laser printers go through this process four times with the appropriate CMYK toner being introduced. Some cheaper laser printers use LEDs instead of lasers. They tend to have a lower resolution.

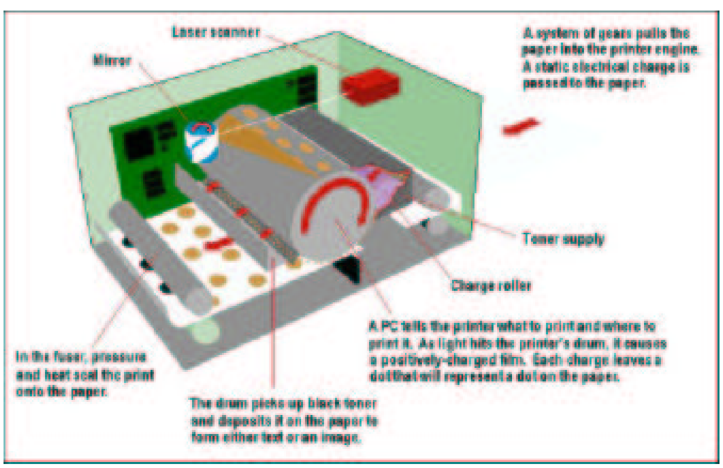

Figure 31. The main components of a laser printer. (Anderson, 1998, p. 2)

Colour laser printers produce good quality images and they cannot be matched in terms of speed of output. The chemically inert toners are stable and enhance the longevity of the prints. A small variety of papers and surfaces can be printed on, but size is limited.

3.7.2 Colour Copier

Colour copiers work in much the same way as laser printers do and can be connected via a RIP to a computer or computers. They often offer the standard copier options of direct copying of documents and images, page sorting, stapling and some machines can scan from transparency. Image longevity of colour copies is very good, in fact, in many cases they are the only accepted medium for copying legal documents (H. Van de Waters, personal communication, July 1, 1999).

3.7.3 Large Scale Electrostatic

Figure 32. Large format electrostatic printer. (WFDIC, 1998)

Large format electrostatic systems were introduced into the market in the late 1980s, costs were initially rather high and resolution low (200 dpi) but today it provides one of the cheapest forms of digital output. The electrostatic system works on the same principles as colour laser or copier machines, but prints are generally large scale. The large dot pattern is illustrated in Figure 33.

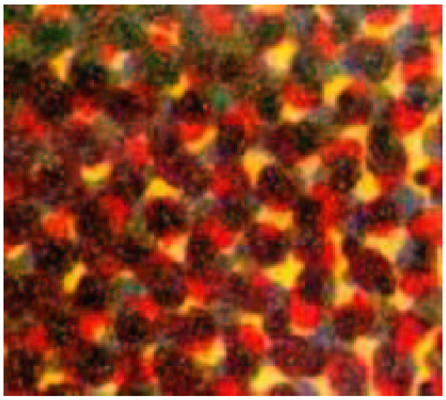

Figure 33. Close-up of dots of toner printed with the electrostatic process. (Lowe, 1996, p. 4)

The process gives a durable product and print speeds are fast. Substrates can be used for primary graphics or for use as sublimation transfers. This means that the images can be transferred onto fabric, glass, wood, metal, ceramic, plastic and other materials. This widens the applications for the process, but the process of transferring images onto secondary materials adds to material, equipment and labour costs. Jordaan points out that inks designed for sublimation transfer are dye-based, and because heat and pressure are used, they penetrate the receiver material and are then partially shielded from UV radiation (1997, p. 14).

Most electrostatic printers should be operated in a controlled environment with the temperatures maintained between 18 and 25 degrees centigrade and with a relative humidity of between 42 and 55 percent (Jordaan, 1997, p. 39). Prints in the 25 to 250 piece ranges are reasonably inexpensive, depending on the substrate selected. A growing market for electrostatic printing is the fabric printing industry, where images can be transferred onto almost any type of material. Even with the advantages that this process has to offer IT Strategies predicts that the number of electrostatic machines in the USA will decrease, from 3,271 in 1998 to 1,902 by the year 2003 (1999, p. 16).

3.8 Inks

Inks are made up of a number of different substances and have varying characteristics. It is almost impossible to discuss all the types of inks available for every type of digital printer, and so this document will concentrate primarily on inkjet printer inks. This is because inkjet printers are amongst the most accessible to fine artists and information on these inks is readily available.

Inkjet printer inks have two main components, a carrier base and a colorant. The carrier base makes up between 80 to 90% of the ink's composition. Most inkjet inks use water as a carrier base, but piezo systems can use water, oil (such as glycol ether), solvents or even UV curable carriers (IRGA, 1998, ch. 4, p. 2).

Colorants can be either dye or pigment based. The dye particles used are minute, less than 50 nm and they give excellent colour and a wide tonal range but are not particularly light fast. Dye particles are soluble in water and they pass through print nozzles easily. They tend to be absorbed into uncoated substrates and so an optimum colour gamut is achieved on coated substrates. Pigments, which are bigger (between 50 and 100 nm), are insoluble and more fade resistant, but do not offer the same colour range. As they are large they tend to clog the print nozzles and are not easily absorbed by the substrate, instead they remain on the surface (IRGA, 1998, ch. 4, p. 3).

Water based inks can cause a number of problems. Inks can take some time to dry and while damp they are prone to smudge and run. Often machines have a built in fan that blows directly onto recently printed paper enabling it to be rolled up moments after it has been printed.

Environmental issues regarding inks and toners are to a large extent still being studied. Jones (1999) from the Graphic Arts Technical Foundation points this out in his presentation at the 1999 DIMA (Digital Imaging and Marketing Association) conference. However there are a number of hazardous substances used in inkjet inks such as cyclohexanone, methoxyl - 2 - propanol acetate and diethylene glycol, plus the resins, pigments and dyes. In electrostatic systems some use naphthol spirits, arsenic alloys, selenium and cadmium salts, as well as pigments and resins (Jones, 1999). While it seems that the inks and toners have to be used in large quantities to attract official notice, care has to be taken with ventilation when machines are placed in working environments. As environmental regulations are tightened, these could become major issues for printers.

3.8 Substrates/Media

There are a wide variety of substrates available for use with different types of digital printers, these include paper, vinyl, canvas, polyester, cotton, carpeting, silk, mesh, polymer and clear film, polyethylene, static cling, nylon, and vellum. In addition to these almost any photographic material can be used as a substrate with the appropriate photographic process. Materials are available for reflection prints or for transparent or translucent films.

Paper remains the most common substrate for inkjets and certainly the most popular output media (IRGA, 1998, ch. 4, p. 7). Otsuki estimates the media split for inkjet material is as follows " photo papers 41%, premium coated papers 31%, photo film 15%, backlit film 5%, vinyl 3%, clear film 2%, canvas 1%, others 2%" (1996, p. 11). Papers can be coated or uncoated, generally inkjets achieve better results with coated papers. "The coated sheet holds the dye or pigment high on the surface, unprotected from the effects of light, while allowing the full color gamut to show (Boulter & Ingraham, 1999, p. 64).

Inkjet media generally consists of a base substrate, a top receptor coating and sometimes a base or barrier coating. As inkjet printers put down large amounts of ink, when the ink is absorbed into uncoated paper the dots spread and are not well defined, resulting in poor image quality. The receptor coating also influences drying time, which is further influenced by temperature, humidity and ink coverage. Drying times have an impact on dot gain, throughput rate and finishing. The receptor coatings of substrates are often designed by manufacturers to be used with specific inks. If the substrate and ink are not matched, dot gain, colour gamut, dry times, reaction to laminates and longevity characteristics can be adversely effected.

For inkjet printing the other materials such as film, vinyl and canvas all have their own unique characteristics. Generally the film materials, which can either be white or opaque (for backlit applications), are made out of polyester. Film is often coated on both sides and has the characteristic of remaining very flat. The high gloss finish assists in achieving saturated colours. As the film does not absorb the inks there is little image bleed or dot gain, drying times are short and the polyester material is very durable. Vinyl material is both durable and flexible, it can be made with an adhesive backing and it too gives good colour and definition. Artist's canvas is treated with a special embedded protective pre-coating, giving it a very white gloss finish and eliminating fiber peaks. This has the advantage of increasing colour intensity and reducing dot gain. The material can be stretched across frames and is very flexible. Other materials that are available for inkjet printing are satin fabric, metallic silver and gold foils, which can be manufactured with adhesive backing.

With the specialised fine art Iris machines the range of substrates that can be printed on is extended. Smolen quotes Jamie Cook of Cook Editions in Atlanta, GA. "What's so beautiful about Iris and digital printing are the substrates you can print on: board paper, rice paper, garlic paper, paper with bugs or flower petals in it, or newsprint" (1999, p. 43).

Laser copiers and colour copiers offer some options when it comes to using a variety of substrates. "In theory any uncoated paper of a suitable weight (usually around 80 gms) can be used on plain paper copiers" (Turner, 1991, p. 98). Generally paper that is of similar weight to the mass-produced paper used in copiers should work, lightweight tissue paper, flecked and fibrous papers, thin card, handmade paper, foil and tracing paper can be used. As colour copiers feed the paper through thin channels and electricity and heat are applied to the media, care has to be taken not to damage the machine itself. Some substrates will produce excessive dust while others might feed unevenly and cause jams. Prints made on laser and colour copiers can be transferred onto receiver materials using acetone, this expands the options in terms of substrates.

The digital printers identified in this chapter can be roughly categorized into printers that spray on ink, printers that use heat to melt inks (dye sublimation and thermal wax), printers that use hybrid photographic processes and those that use charged toner particles to form a colour image. The printers all have their specific limitations for instance the laser, colour copier, phase-change inkjet, dye sublimation and thermal wax printers are all limited, in the size of print that can be made, to approximately 29 x 42 cm. Other inkjet printers range from small desktop models to huge super wide models that are over 6.5 m wide. The technique that each printer uses to create colour, influences the quality or resolution of the image, what inks can be used on what substrates, what colour gamut and tonal range can be achieved and the permanence of the image. The actual appearance and qualities of the prints made by these machines are tested and discussed in the next chapter, where print anomalies are identified.

Chapter Four

4 Identifying Digital Print Anomalies

As is outlined in the research methodology in chapter one, three different approaches are taken in this chapter to identify digital print anomalies. They are to consider the results of previous research and the literature that has been published on this topic. Plus to conduct a range of practical tests and asses the results.

4.1 Previous Research and Literature

As is mentioned in section 1.9.2, Lowe conducted a range of tests on digital print processes from 1995 to 1997. His tests covered a broad range of printing techniques, including traditional processes, some photographic processes and others that are not easy to categorize.

> The conventionally accepted print processes have been included (intaglio, relief, planographic, and screenprint) as are the processes more commonly associated with digital output (inkjet, thermal transfer, and electrostatic). There are a selection of 19th-century processes (collotype, pigment transfer, photogravure), several associated with photography (dye transfer, C-type, and cibachrome), a genuinely hybrid process (indigo electrophotographic), and the odd maverick like the cromalin (introduced in the late 60s as a oneoff [sic] proofing system) (Lowe, 1996, p. 3).

Although there is no description of how the prints were evaluated, the tests revealed many print anomalies, and are mentioned in the article, "New Technology, New Painting".

> The resulting portfolio is a demonstration of how radically some of these processes transform the original. On one level this demonstration surveys the qualities of different print technologies and processes. On another level it raises important philosophical questions which can be seen in terms of the varying material results produced by the mediation of each process (Finch, 1997, p. 63).

There are a few books, which have commented, even if only briefly, on digital print anomalies. One of these is *Digital Imaging for Visual Artists* (1994). The printers discussed are inkjet, phase-change inkjet, dye sublimation, electrostatic, colour laser, imagesetters and dot matrix (Weiner Grotta & Grotta, 1994, pp. 210 - 243). In terms of commentary on print anomalies they are quite general, such as "the colors are more vibrant, the image usually more realistic" (Weiner Grotta & Grotta, 1994, p. 216). This is the description of dye sublimation prints.

Burkholder's *Making Digital Negatives for Contact Printing* (1999) is only concerned with the print anomalies encountered when creating digital negatives or positives, to be printed on a variety of materials. Burkholder gives the following criteria for successful negatives: they should retain the tonal range and detail of the original and they should not be too dense (as they are used for light transmission). The archival qualities and sturdiness of the materials are not seen as critical issues. (1999, pp. 114 - 115) He goes on to list the advantages and disadvantages of using laser printers, dry resin printers, dye sublimation printers and inkjet printers for producing digital negatives (Burkholder, 1999, pp. 116 - 123).

Some computer magazines publish the results of comparative tests on printers. Unfortunately these are generally performance tests and are more concerned with office type printers than large format models. The article "Network Printers" that appears in *PC Magazine SA June 1998*, does have a section on colour printers which includes tests done on laser and phase-change inkjet printers (Karney & Stone, 1998, pp. 70 - 71). The conclusions regarding print anomalies are minimal.

4.2 Bureau Managers

The following digital print managers at well known digital bureaux in South Africa were interviewed, Tony Maio of Beith Digital cc, Johannesburg and Nolan Weight of Stonehouse Graphics, Johannesburg. These two companies are amongst the most prominent in South Africa, Beith not only provides digital printing facilities, but also offers a professional photo-laboratory service, scanning, proofing, traditional printing and finishing facilities. Stonehouse Graphics concentrates on large-scale inkjet output, up to billboard size, electrostatic, screen printing, vinyl cutting and scanning. Two print managers in America were asked a number of questions via e-mail regarding print anomalies. John Otsuki of Capitol Color Santa Clara CA and Jon Cone of Cone Editions are both recognised as knowledgeable individuals in the digital printing industry. Otsuki has presented a number of courses and seminars on large format digital printing (T. Jordaan, personal communication, February 13, 1999). Cone Editions have gained a reputation for providing fine artists with an excellent digital printing service and are involved with research into manufacturing and testing inks for the fine art market. Only Jon Cone answered the e-mail questions.

4.3 The Initial Practical Test

This test was devised to identify print anomalies in a variety of digital print techniques. In order to create the test image a number of variables, some of which are mentioned in chapter one and in chapter two, were eliminated. A Phase One PhotoPhase digital camera system on a Sinar P large format camera was used to record the image, this meant that any colour variations caused by film and processing could be avoided. Obviously the Phase One back has its own inherent characteristics, but manufacturers claim that it offers a number of advantages over film, namely that the image is "cleaner, does not contain film grain, has more exact colors, and has a better dynamic range" (Phase One, 1999). This technique is also recommended by Hunter Editions a company in Maine USA that prints fine art images (Malek, 1999, p. 60).

4.3.1 Procedure for Capturing and Setting up the Digital Image

A still life was set up containing a standard colour chart, grey patches, a dense black, a pure white, problematic colours, natural objects, metallic objects, text and a skin tone, this is illustrated in Figure 34. This approach extends the test done by *PC Magazine SA* (Karney & Stone, 1998, p. 70 - 71).

Standard lighting was applied and the recommended filter used, the lens was set on F11 and an exposure of 1/40th of a second given. The exposure marker fell well within the green area, just above the one setting, as recommended in the *Phase One User Guide* (Phase One, 1996, p. 24). This indicates that the image is correctly exposed. A gamut warning check was made, only the extremely strong highlights on the silver bangles in the image were out of gamut. The image produced was 21 x 30 cm at 300 ppi and a resulting file size of 25.8 Mb. A grey balance was done, in accordance with the instructions in the *Phase One User Guide* (Phase One, 1996, p. 24). The colour management software (ColorSync) was applied, RGB capture mode set and camera matched to monitor, all other settings were default settings.

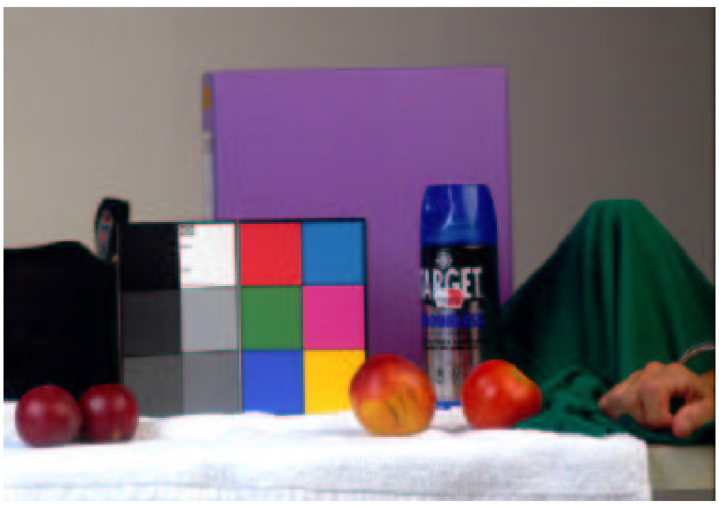

Figure 34. Test image recorded on the Phase One digital back. (Giloi, 1998)

The resulting file was opened in Adobe Photoshop 5.0 and measured using the 3 by 3 average eyedropper. The original image was assessed using this method and seen to have a contrast that was too low. Using the system recommended in the *Adobe Photoshop 5.0 User Guide* the white and black target values were adjusted to white R 244, G 244, B 244 and black R 10, G 10, B 10 (Adobe, 1998, pp. 114 - 116). The black and white areas were chosen off the chart, rather than off the solid black and white objects. This was done so that the black and white areas (the bag and the towel) would print as very dense blacks and clear whites. The image was saved as high, medium and low-resolution images of 100, 200 and 300 ppi tiff files onto an optical disc and then written onto compact discs (CD). Either the high or medium resolution image was used, depending on the printer's requirements. No finishing techniques were applied to the prints.

4.3.2 Range of Prints

The following tests were made: thermal inkjet (Walker A.A. Hing, Port Elizabeth and First Graphics, Johannesburg), piezo inkjet (Xerox, Johannesburg), continuous flow inkjet (Beith Digital, Johannesburg), airbrush inkjet (Omni Graphics, Johannesburg), phase-change inkjet (Square One, Johannesburg), thermal wax on paper (Vaal Technikon, Vanderbijlpark) and on transparency material (Walker A.A. Hing, Port Elizabeth), dye sublimation (Walker A.A. Hing, Port Elizabeth), Fuji Pictrography (Teltron, Johannesburg), colour laser (Square One, Johannesburg), large format electrostatic (Omni Graphics, Johannesburg) and colour copier (Port Elizabeth Technikon, Port Elizabeth). Tests were not made on a digital enlarger, film recorder, extended gamut inkjet or imagesetter.

4.3.3 Assessment of Test Prints

A group of eight art educators from Port Elizabeth Technikon Faculty of Art and Design were asked to individually assess the prints. The prints were placed on a neutral background in an exhibition area and lit by diffused daylight. The panel was given additional information on size limitations, substrates and longevity, based on the information in Table 1. In order to focus their attention on critical aspects of each print, the evaluation was broken down as follows: 1. colour accuracy, 2. tonal range, 3. ability to render highlight and shadow detail, 4. sharpness (ability to render fine detail), 5. visibility of dot/line/screen pattern, 6. surface texture, 7. size limitations and 8. variety of substrates.

This breakdown is based in part on Lowe's perceptual qualities discussed in chapter one (Lowe, 1996, pp. 5 - 6), the criteria used in the *PC Magazine SA* article (Karney & Stone, 1998, pp. 70 - 71), and the criteria described by Reilly and Frey (1996, p. 19). The form used for the evaluations appears as Appendix A and a statistical analysis of each factor can be seen in Appendix B.

In addition to the evaluation, the individuals were asked to comment on possible fine art applications for the various print media. Some saw some the potential for the more acceptable media to be used for making copies of original art works or for proofing. Many thought that all the media offered creative potential in terms of exploiting the particular characteristics of the prints for fine art and craft applications. Some suggested applications such as large-scale outdoor installations, printmaking, painting, digital illustration and photography**.** Asked to comment on the limitations of the media, some expressed concerns regarding sharpness, longevity and size limitations.

4.4 Identified Print Anomalies

The identified print anomalies are discussed under headings for each printer. The evaluation figures (between 0 and 5) referred to in these sections relate to those in Table 2 and the statistical analysis in Appendix B.

Table 2

Ranked Evaluations of Printers in Terms of the Identified Characteristics

	1	2	3	4	5	6	7	8	Ave
Piezo-electric Inkjet	4	4	3.8	4.4	3.4	4	4.5	4.6	4.1
Thermal Wax	3.8	4.4	4.4	4.4	4.1	3.8	2.5	3.7	3.9
Fuji Pictrography	4.2	4	3.7	4.3	4.2	4	2.2	2.2	3.6
Continuous Flow	3.2	3.5	3.5	3.8	3.9	3.5	3.5	4.5	3.4
Colour Laser	3.4	3.5	3.7	3.3	3	3.6	2.2	3.6	3.4
Dye Sublimation	3.4	3.7	3.5	3.6	3.7	3.4	2.7	1.9	3.2
Colour Copy	3.2	3.2	3.2	3.4	2.8	2.9	2.5	2.4	2.4
Electrostatic	2.2	2.5	2	1.7	1.4	2.5	3.2	4	2.4
Phase-change	2.2	2.5	2.2	2.5	2.5	2.7	2.2	2.5	2.3
Thermal Inkjet	2	2	1.5	1.5	1.7	2.4	3.3	3.2	2.2
Aerosol Inkjet	1.2	1.6	1.2	1.4	1.2	1.5	3.8	2.2	1.7

Note. The characteristics used to evaluate the printer types are:

1. Colour accuracy, 2. Tonal range, 3. Ability to render highlight and shadow detail, 4. Sharpness (ability to render fine detail), 5. Visibility of dot/line/screen patterns, 6. Surface texture, 7. Size limitations, 8. Variety of substrates, Ave is the average evaluation achieved by that particular printer. The maximum evaluation possible is 5.

4.4.1 Thermal Inkjets

Thermal inkjets offer large media sizes and a variety of substrates, UV resistant inks and indoor inks are available, though inks must be matched to the appropriate media or problems can arise, such as rapid fading and uneven drying (T. Maio, personal communication, February 9, 1999). These machines produce saturated colour with high colour density, going for “maximum visual impact” (White, 1998, p. 6), but lack subtlety of tone and in some machines the rather large dot pattern can be quite disturbing.

The initial print seen in Figure 35, made on the thermal inkjet, gave a disappointing results with an average assessment of 2.2 out of a maximum of 5. In Appendix B the thermal inkjet is the second worst printer in terms of colour accuracy, tonal range, retaining highlight and shadow detail, sharpness and surface texture.

Figure 35. Comparison of original image (L) and copy of thermal inkjet print (R). (Giloi, 1999)

4.4.2 Piezo Inkjet

In general the piezo inkjet was assessed as producing the best overall output, on average rated at 4.1 out of a possible perfect score of 5. In Appendix B the printer was rated at number one or two in the following properties, colour accuracy, tonal range, sharpness, texture, size limitations and substrates. From a bureau manager’s point of view these inkjet printers are low maintenance, user-friendly machines that are easy to calibrate. Definite advantages are that they offer very large print sizes and they can print onto almost any material (N. Weight, personal communication, February 10, 1999). The fineness of the dot achieved by this machine is a positive factor, giving a good tonal range and sharp image (T. Carstens, personal communication, September 17, 1999).

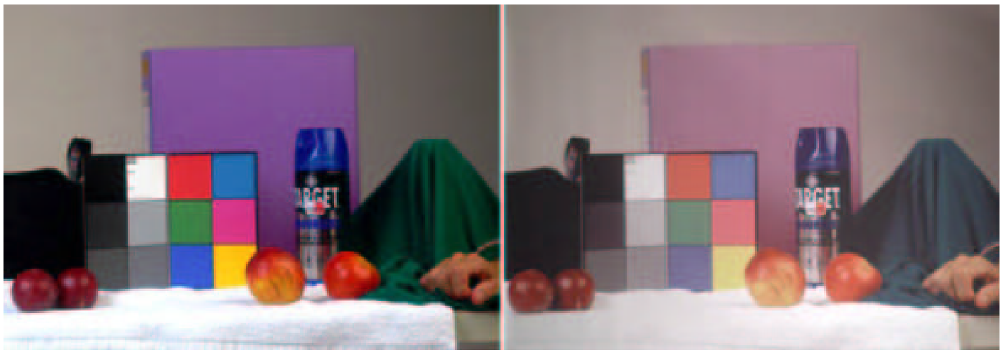

Figure 36. Comparison of original image (L) and copy of piezo inkjet print (R). (Giloi, 1999)

4.4.3 Extended Gamut Inkjet

No initial test was made on this machine, as there are a very limited number of them available in South Africa. The machines are expected to give excellent colour and tonal rendition. However there are queries regarding longevity, especially with the Super CMYK models (Wilhelm, 1999).

4.4.4 Continuous Flow Inkjet

The continuous flow inkjet prints give accurate colour, a good tonal range, high resolution and the ability to render fine detail. The inks are not waterproof, the printer is slow as it can only print a 42 x 59 cm print in 30 minutes and costs per print are high. Cone Editions only produce continuous flow inkjet prints (Iris giclée prints). Jon Cone feels that they offer great colour accuracy and longevity (J. Cone, personal communication, April 26, 1999). This does depend very much on the type of inks and substrates used.

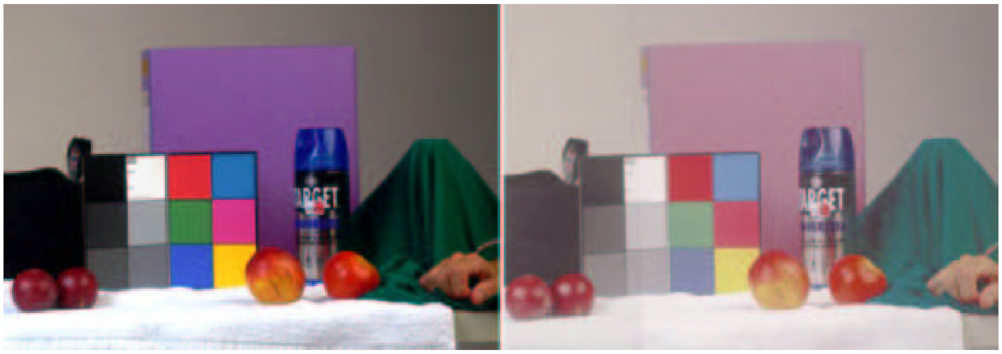

Figure 37. Comparison of original image (L) and copy of continuous flow inkjet print (R). (Giloi, 1999)

The initial test print made on the continuous flow inkjet (not a giclée system) was seen to be successful in all properties, with an average of 3.4. The print, seen in Figure 37, was evaluated as one of the best in terms of sharpness and lack of a dot, line or screen pattern. Although limited in terms of print sizes, the potential to print on a wide range of substrates was seen as a definite advantage. The printer offers some obvious advantages to the fine artists in terms of longevity, though not all bureau offer the inks and substrates designed to achieve this.

4.4.5 Airbrush Inkjet

The process is designed to print images on a very large scale and so the assessment of a 30 x 40 cm sized image, is not ideal. In general the appearance of the print is poor, the dot pattern is very large and noticeable, to the extent that it breaks up the reading of the image. This printer was rated in Appendix B to be the worst at achieving colour accuracy, a good tonal range, highlight and shadow detail, sharpness and surface texture. Because of its low quality appearance, illustrated in Figure 38, and the low assessment of 1.7, this medium is not seen as a fine art print option and no further tests were made using this process.

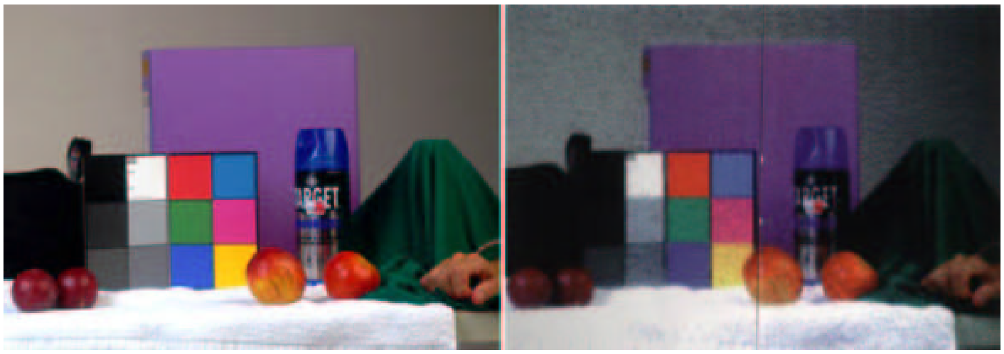

Figure 38. Comparison of original image (L) and copy of airbrush inkjet print (R). (Giloi, 1999)

4.4.6 Phase-change Inkjet

As the inks in this process are not absorbed by the substrate, this process can be used to print onto paper, vinyl, film or card stock. Another advantage is that the inks cannot spread out and be absorbed into adjacent areas, this results in increased image sharpness, and crisp lines. However because the wax sits on top of the substrate surface, prints can be easily damaged and may crack when folded. Printers can print onto both sides of the substrates. The printers are relatively slow and expensive, but produce vivid colours (personal communication, D. Johnstone, September 14, 1999).

The evaluation of the test print for this process was not very positive with its average evaluation being 2.3. It was particularly poor in terms of achieving colour accuracy, highlight and shadow detail and a good tonal range with its best characteristic the rendering of surface texture. The print is seen in Figure 39.

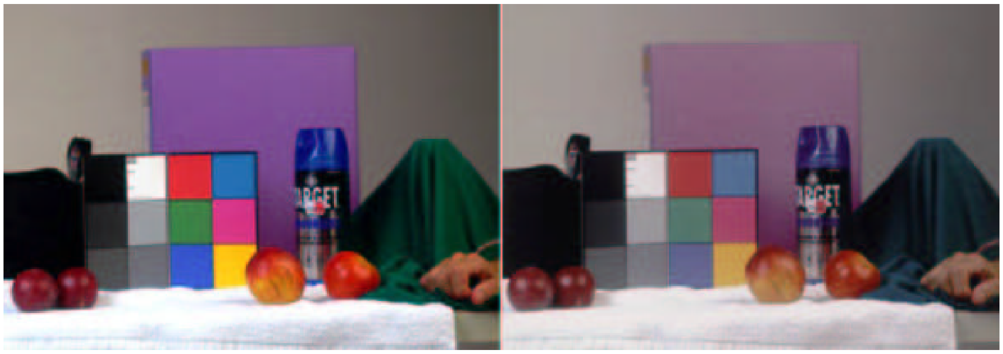

Figure 39. Comparison of original image (L) and copy of phase-change inkjet print (R). (Giloi, 1999)

4.4.7 Dye Sublimation

Dye sublimation prints offer colours that are not particularly vibrant. They give a high-resolution image with a good tonal range but the prints are not very light resistant. Maximum print size is 29 x 42 cm and opaque and clear substrates are available. (T. Maio, personal communication, February 9, 1999) White considers them to offer "photographic quality prints" (1998, p. 6).

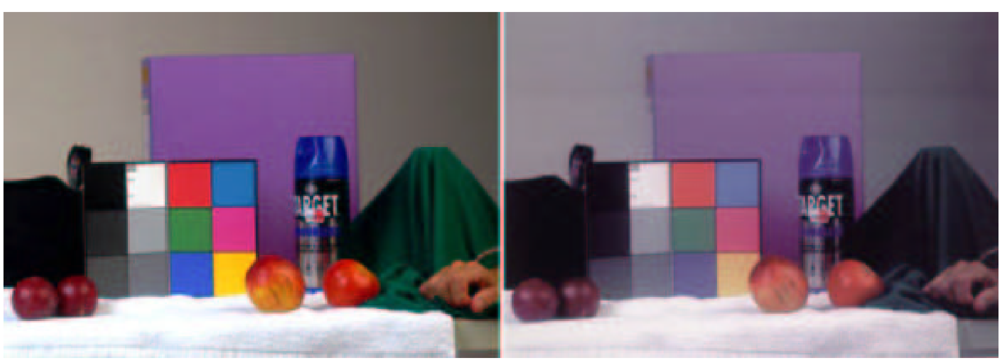

Figure 40. Comparison of original image (L) and copy of dye sublimation print (R). (Giloi, 1999)

The dye sublimation print was given an above average rating of 3.2 in the initial test, with only the size limitations and limited range substrates seen as disadvantages. The other properties as illustrated in Appendix B, are consistently well above average.

4.4.8 Thermal Wax

Although the thermal wax process is rather limited in terms of scale and substrate selection, it can be used for display and promotional purposes. Colours are saturated, image quality is good though costs are high. The limited life span of prints means that its applications are limited (White, 1998, p. 6). The initial test was rated highly in most aspects, especially in terms of ability to render tonal range, maintain highlight and shadow detail, sharpness and the lack of a visible dot, screen or line pattern. See Appendix B and Figure 41. On average the thermal wax print was rated at 3.9.

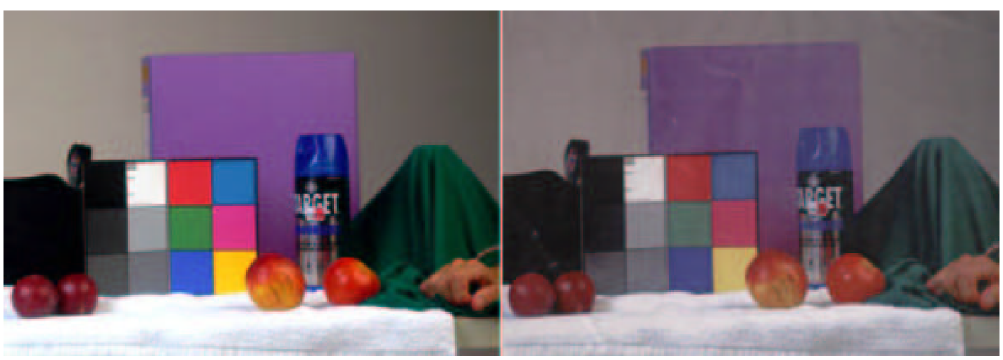

Figure 41. Comparison of original image (L) and copy of thermal wax print (R). (Giloi, 1999)

4.4.9 Digital Enlargers

Photographic prints made on digital enlargers have certain intrinsic qualities. The technique of exposing materials with laser beams produces very high quality prints. This is enhanced by the resolving power of photographic materials. Excellent colour saturation can be achieved, but the ability to render some specific colours is not good. The rendition of text is not always sharp and there can be some fall off towards the edges of prints and dimensional changes of the image. “One of the disadvantages of ultra-wide laser printers is that the laser spot varies from being circular at the center of the print to being increasingly elliptical towards the corners, resulting in distortion and reduced image quality” (Henshall, 1997).

It proved impossible to access one of these printers in South Africa. Although a file was taken to a company in Pretoria which runs one of these machines, they were unwilling to interrupt their commercial output to make a test print or the fine art print.

4.4.10 Film Recorders

With photographic material, the longevity and quality of the digital images is enhanced. From the initial slide, enlargements can be made, a large format transparency (10.2 x 12.7 cm) will enable the artists to print up to approximately 1.5 meters square without losing image quality (White, 1998, p. 8). "The spatial and color resolution of many of today's film writers is good enough to produce transparencies that are difficult to distinguish from a photographically derived original" (Aaland &

Burger, 1992, p. 96). Ilfochrome print materials in particular, offer vibrant colours partially created by the highly reflective base and the glossy surface. The two step process however has obvious drawbacks as the final print is a second-generation product, dust and the usual problems associated with enlargement of photographic images can degrade the image. The process is relatively expensive.

No initial test was made using this technique.

4.4.11 Imagesetter

There are a number of aspects that can be problematic when creating digital negatives or positives on an imagesetter, Burkholder names two problem areas, grain and streaks that are often caused by software problems or incorrect resolution settings (1999, p. 176). If multiple negatives are to be used for contact printing, registration problems can also be encountered. Achieving accurate contrast and an appropriate tonal range for a particular process can also be problematic, this aspect has more to do with setting up files than printing. Once again the negative or positive is used as an in-between step and so dust and scratches on the film can be problematic.

No initial test was made using this process.

4.4.12 Fuji Pictrography

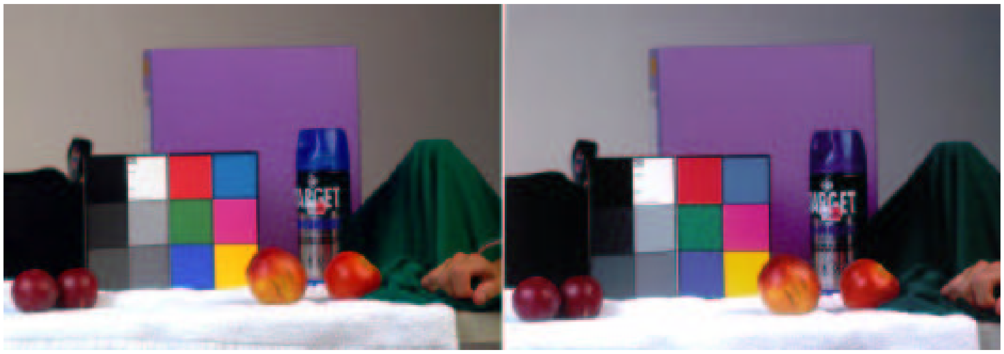

Figure 42. Comparison of original image (L) and copy of Fuji Pictrography print (R). (Giloi, 1999)

The Fuji Pictrography printer gives an almost photographic quality print. Appendix B illustrates that this printer achieves excellent colour accuracy, good tonal range, and the image generally has little or no dot, line or screen pattern. This process received a good overall evaluation of 3.6. Figure 42 shows the Fuji Pictrography print.

4.4.13 Colour Laser

Figure 43. Comparison of original image (L) and copy of colour laser print (R). (Giloi, 1999)

The colour laser offers a stable print, but the size is limited to 29 x 42 cm. Most laser printers reproduce colour relatively well and they have the advantage of being able to print on both sides of the paper, as well as accept a reasonably wide variety of substrates (R.G. Mowatt, personal communication, September 17, 1999). Prints last indefinitely and can render solid blacks very well, when the appropriate substrate is used.

The initial print received a rating of 3.4, which is above average, with the best aspect being its ability to render highlight and shadow detail, the only poor property being the limited size of prints.

4.4.14 Colour Copiers

Colour copiers offer much the same advantages and disadvantages as colour laser printers. They are generally quite accessible to most fine artists and prints are very reasonably priced. Scale is limited to 29 x 42 cm. The images generally have a halftone screen pattern and this can lead to a reduction in image sharpness.

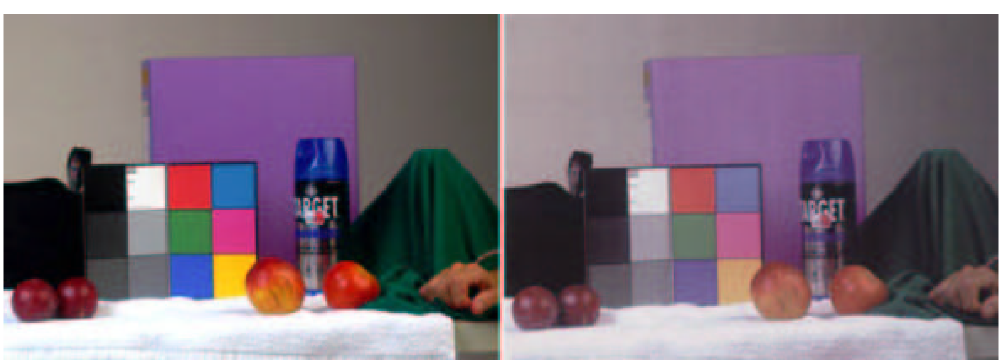

Figure 44. Comparison of original image (L) and copy of colour copier print (R). (Giloi, 1999)

The initial test evaluation given to this media was poor with an average of 2.4, although its best properties are colour accuracy, tonal range, highlight and shadow detail and sharpness. As print quality can vary quite substantially between printers, it was decided to print a fine art image. The test print is illustrated in Figure 44.

4.4.15 Large Scale Electrostatic

Electrostatic prints are often not of very high quality and sometimes suffer from poor coverage, flare spots and streaks. The electrostatic process does however offer a stable outdoor image. In terms of operation, toners must be replaced monthly or inconsistent colours will result, printers are known to be temperamental and complicated to operate (N. Weight, personal communication, February 10, 1999). The toner problems make it impossible for the printer to print precisely the same every time.

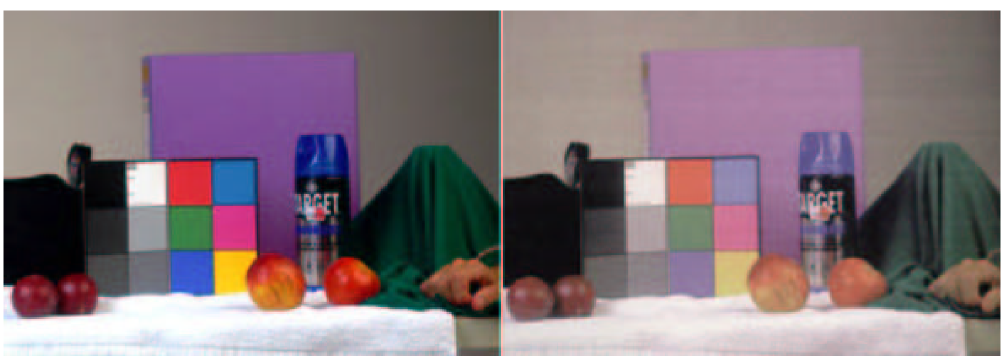

Figure 45. Comparison of original image (L) and copy of electrostatic print (R). (Giloi, 1999)

The initial test image (Figure 45) received one of the lowest assessments, with an average of 2.4 on a scale of zero to five. The poor tonal range, lack of sharpness, very visible dot pattern and poor surface texture were assessed as serious drawbacks. A number of companies that previously offered electrostatic prints have put their machines into storage and replaced them with piezo inkjet machines (R. Henry, personal communication, September 16, 1999). Taking these factors into consideration it was decided that no fine art print would be made using this print technique.

4.5 Fine Art Prints

4.5.1 Range of Prints

Thermal inkjet (Beith Digital, Johannesburg), piezo inkjet (MIPS Technologies), Johannesburg, extended gamut inkjet (Tone Graphics, Cape Town), continuous flow inkjet (City Graphics, Johannesburg), phase-change inkjet (Square One, Johannesburg), dye sublimation, (Beith Digital, Johannesburg), thermal wax (Walker A.A. Hing, Port Elizabeth), film recorder (Beith Digital, Johannesburg), imagesetter (CMYK, Port Elizabeth), Fuji Pictrography (Universal Image, Johannesburg), colour laser (Square One, Johannesburg) and colour copy (Downtown Copy Center, Port Elizabeth). No print could be made on a digital enlarger.

4.6 Evaluation of Fine Art Digital Prints

In order to make the print anomalies identified in sections 4.4.1 to 4.4.15 relevant to the fine artist it was essential to try to match print techniques to specific fine art images and applications. This would either substantiate or refute the initial test results. A number of artists were asked to submit finished works of art or files of computer-based art. The artwork was copied using the Phase One digital back, this time on a Hasselblad camera. Unsharp masking was applied in Adobe Photoshop, as is standard practice with any scanning or capturing of images (Holland, 1999). The images were kept as RGB tiff files. Otherwise all the parameters used in the initial test were maintained.

The artists were asked to give input regarding possible applications for the digital prints and to list their criteria regarding the print characteristics. An example of this form appears as Appendix C. Using this information and the anomalies of the various print techniques, certain images were matched to certain print processes. In some cases the same image was used for two different printing techniques.

The final digital prints were returned to the appropriate artist and they assessed them in terms of the categories on the form that appears as Appendix D. These categories were based on the initial test, with a few necessary additions. The criteria are, colour accuracy, tonal range, rendering of highlight and shadow detail, sharpness, lack of visible dot, line or screen, surface texture, cost, archival longevity. The artists were invited to add any other areas of criticism. Each prints assessment form appears in appendices E to P.

4.6.1 Thermal Inkjet

In spite of the fact that the thermal inkjet, was identified to have numerous print anomalies, a print of the image seen in Figure 46 was printed using this method. This decision was made after consultation with bureaux that successfully use this type of printer for commercial and fine art applications (R. Streak, personal communication, August 5, 1999). The artist's application for this image was for a limited edition print on canvas. Retaining the bright colours and tonality of the original painting was essential and longevity was a reasonably critical issue.

Figure 46. Digital copy of oil painting (L), thermal inkjet print (R). (Cull, 1999)

The digital print on canvas using a thermal inkjet printer did not match the original oil painting accurately. In terms of printing a number of limited edition prints for exhibition and sale this process was unsuccessful. The colour accuracy, sharpness, highlight and shadow detail, and tonal range were lacking in the final print. The overall feel of the print was of de-saturated colour and a flattened or compressed tonal range. Many subtleties in the painting had been lost and the original blues in the image were shifted towards the magenta/purple area of the spectrum and greens had become blues. The fact that this particular ink and substrate combination, has a permanence of one to two years (Wilhem, 1998) was unacceptable. In terms of the other factors, the print was quite adequate and the reasonable price of R130.00 was a positive factor (C. Cull, personal communication, November 4, 1999). This image was certainly a failure in terms of successfully matching a digital printing process to the original image. The anomalies of this printer were however indicated by the initial test and in retrospect, the process should not have been considered for the second round of testing.

Table 3

<u>Thermal Inkjet Assessment Based on Appendix E</u>

Properties	Importance	Achieved	%
Colour accuracy	7	2.2	31
Tonal range	7	1.2	17
Rendering of highlight and shadow detail	7	2	29
Sharpness	7	2	29
Lack of visible dot, line or screen pattern	7	7	100
Surface texture	5.6	1.5	27
Cost	5.6	5.6	100
Archival longevity	7	1.8	26
Average	6.6	2.9	44

4.6.2 Piezo Inkjet

Figure 47. Digital copy of oil painting (L), piezo inkjet print (R). (Cull, 1999)

The fine art image printed on this system, Figure 47 was chosen because of the subtleties of colour and tone. The piezo system is well suited to the artist's chosen application of a poster to advertise or promote her work. The printed image did not produce the expected subtleties of tone. The colour was inaccurate with the darker reds and blues not retaining tonal variations. Shadow detail was particularly poor. The image was seen to be slightly unsharp and did not recreate the hard-edged effect of the original, although the lack of visible dot was seen as a positive factor. Cost was rather high at R225.00 per print and for the poster application an expected life of more than 1 year was acceptable (C. Cull, personal communication, November 4, 1999).

Table 4

Piezo Inkjet Assessment Based on Appendix F

Properties	Importance	Achieved	%
Colour accuracy	7	3.2	46
Tonal range	7	3.2	46
Rendering of highlight and shadow detail	7	3.2	46
Sharpness	7	4.5	64
Lack of visible dot, line or screen pattern	7	7	100
Surface texture	5.7	3.2	46
Cost	5.7	2	29
Archival longevity	6.3	6.3	100
Average	6.5	4	61

4.6.3 Extended Gamut Inkjet.

Figure 48. Digital copy of oil painting (L), extended gamut inkjet print (R). (Cilliers, 1999)

Figure 48 was printed on an extended gamut machine, a hi-fi inkjet printer for use as a promotional poster. The print did not achieve perfect colour accuracy. The neutral tones and warmer tones reproduced well, but the blues did not print accurately. The only other criticism of the printing system was that there was quite a distinctive grid like pattern that was possibly from the misalignment of print heads. The cost of R 60 per print was seen to be quite a reasonable price for this size of print.

Table 5 Extended Gamut Inkjet Assessment Based on Appendix G

Properties	Importance	Achieved	%
Colour accuracy	7	4.8	69
Tonal range	7	7	100
Rendering of highlight and shadow detail	7	7	100
Sharpness	7	7	100
Lack of visible dot, line or screen pattern	7	6.2	88
Surface texture			
Cost	3.3	3.3	100
Archival longevity			
Average	6.4	5.9	92

Note. A blank cell denotes that this aspect was not seen as relevant criteria for this particular image and application.

4.6.4 Continuous Flow Inkjet

An initial fine art print of the image Figure 49 was made. It proved to be unacceptable, as the digital image had not been set up correctly. The white areas were not clean, measuring under 220 R,G,B and the black areas measuring around 60 R,G,B in Photoshop. This relates to the aspect mentioned in 2.4.4 and is a clear example of an outside factor influencing image quality.

Figure 49. Uncorrected digital image of etching.
(Frankenfeld, 1998)

A second image, Figure 50, was printed using this process. This print was very successful. It achieved every critical aspect that the artists had prescribed perfectly. The tonal range of the black and white image reproduced very well. The inks had been absorbed into the substrate, giving the print a particularly good textural quality (M. Duker, personal communication, November 8, 1999).

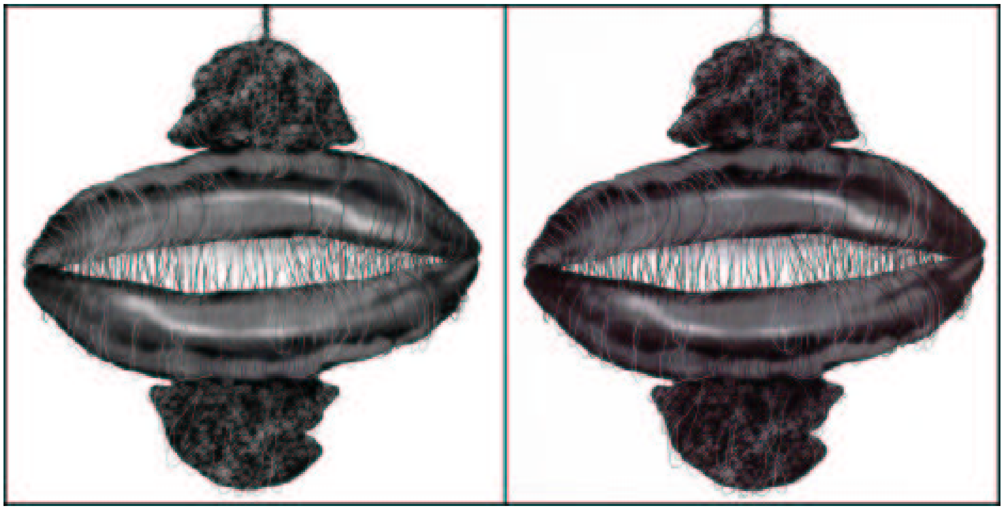

Figure 50. Painter image (L), continuous flow inkjet print (R). (Duker, 1999)

Table 6

Continuous Flow Inkjet Assessment Based on Appendix H

Properties	Importance	Achieved	%
Colour accuracy			
Tonal range	7	7	100
Rendering of highlight and shadow detail	7	7	100
Sharpness	7	7	100
Lack of visible dot, line or screen pattern	7	7	100
Surface texture	7	7	100
Cost	2	2	100
Archival longevity	5.3	5.3	5.3
Average	6	6	100

4.6.5 Phase-change Inkjet

In spite of the poor evaluation and because these machines are supposed to represent bright colours well, a fine art image was printed using this process. The application for the print was for use as a reasonable quality postcard that would advertise and promote the artwork.

Therefore a heavy card paper was needed and a process whereby both sides of the paper could be printed on. Feedback from the artists on the print made from Figure 51, onto card stock using the phase-change inkjet machine was very positive. The artist was particularly impressed with the surface texture that retained the feel of the original silkscreen. The only criticism was of a slight reduction in contrast (E. Frankenfeld, personal communication, October 6, 1999).

Figure 51. Digital copy of silkscreen print (L), phase-change inkjet print (R). (Frankenfeld, 1987)

Table 7

Phase-change Inkjet Assessment Based on Appendix I

Properties	Importance	Achieved	%
Colour accuracy	7	7	100
Tonal range	6	4	67
Rendering of highlight and shadow detail	6.1	6.1	100
Sharpness	7	7	100
Lack of visible dot, line or screen pattern	6.1	6.1	100
Surface texture			
Cost	6.1	6.1	100
Archival longevity	0.5	0.5	100
Average	5.5	5.2	95

Note. A blank cell denotes that this aspect was not seen as relevant criteria for this particular image and application.

4.6.6 Dye Sublimation

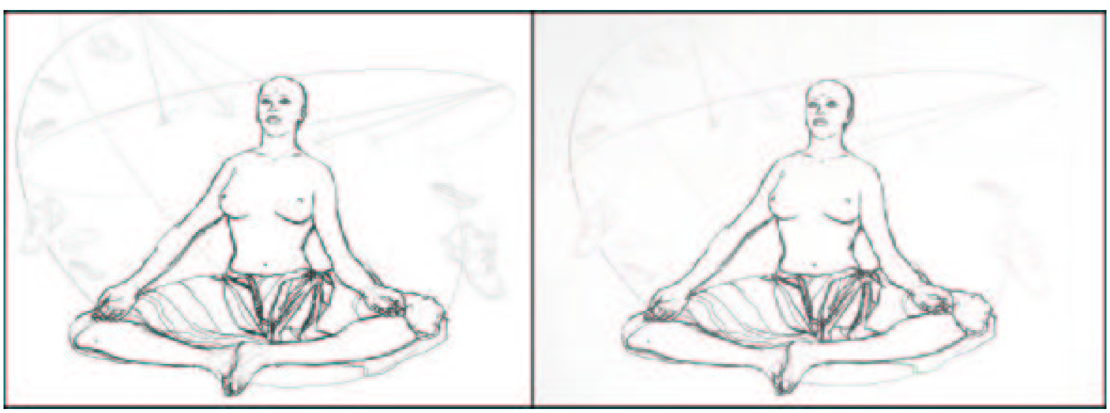

Figure 52. Painter image (L), dye sublimation print (R).
(Duker 1999)

The image chosen for this type of print was a black and white line drawing created on computer, Figure 52 to be used as an exhibition quality print. The print was assessed as being adequate in all areas other than the limited permanence of six months. The glossy surface was good, as was the heavy weight of the substrate. The tonal range of the image was maintained and the lines appear crisp.

The only criticism was regarding an area in the lower right-hand corner, where a solid black line printed as a green line, as the magenta ribbon had not printed dye in this area. (M. Duker, personal communication, October 7, 1999). This failure in registration was due to a fault in the materials used in the printer and can be seen as an outside factor influencing print quality, falling under factor 2.5, in that the machine was obviously not running at its optimum quality.

Table 8

Dye Sublimation Assessment Based on Appendix J

Properties	Importance	Achieved	%
Colour accuracy			
Tonal range			
Rendering of highlight and shadow detail			
Sharpness	7	7	100
Lack of visible dot, line or screen pattern	5.8	5.8	100
Surface texture	0.5	0.5	100
Cost	3.5	3.5	100
Archival longevity	3.5	0	0
Average	4	4.66	80

Note. A blank cell denotes that this aspect was not seen as relevant criteria for this particular image and application.

4.6.7 Thermal Wax

This process was used to reproduce a landscape created in Painter and converted to Photoshop, Figure 53, to be used as an exhibition quality print. The colours achieved by the thermal wax print were not accurate having a browner appearance than the original. The tonal range was also more compressed and the image was slightly light. The lightweight paper was seen to be problematic, as it would most likely become wavy and warp under exhibition conditions (M. Duker, personal communication, October 7, 1999). In principal the print could not be offered for sale or for inclusion in collections because of the poor longevity characteristics.

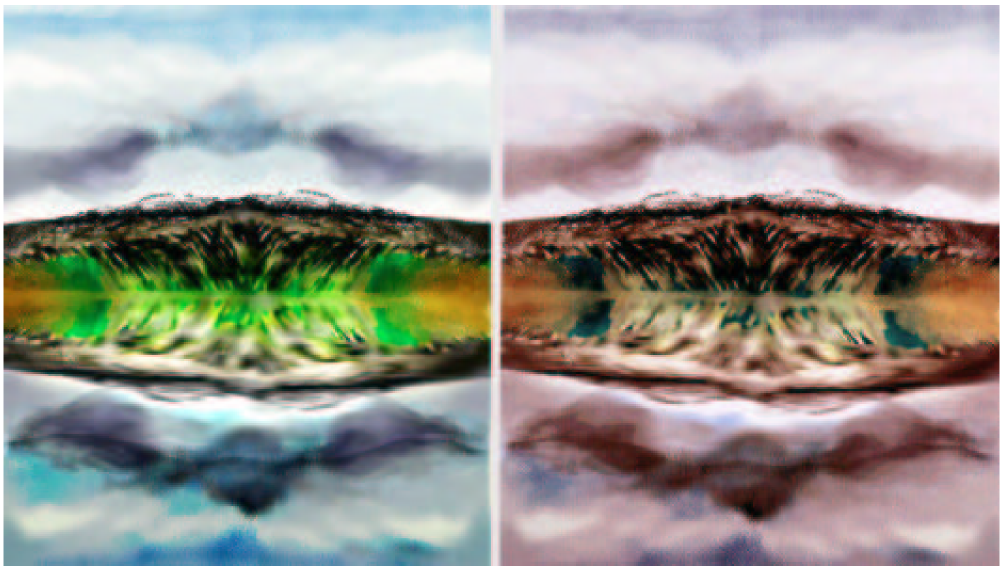

Figure 53. Painter image (L), thermal wax print (R).
(Duker, 1998)

Table 9

Thermal Wax Assessment Based on Appendix K

Properties	Importance	Achieved	%
Colour accuracy	7	1	14
Tonal range	7	1.2	17
Rendering of highlight and shadow detail	3.5	3.5	100
Sharpness	7	7	100
Lack of visible dot, line or screen pattern	7	7	100
Surface texture	7	7	100
Cost	3.5	3.5	100
Archival longevity	5.5	0.9	16
Average	5.9	3.8	68

4.6.8 Film Recorder

The image Figure 54 was used to create a 35 mm transparency and this was enlarged onto Ilfochrome material. The resulting image was to be used for promotional purposes. Other than producing inaccurate colour, especially in the green tones, and appearing to be slightly unsharp, this print was quite successful. It retained subtleties of colour well, reproduced blues well and was accurate enough to submit to clients, museums and galleries for promotional purposes. (C. Cull, personal communication, October 8, 1999)

Figure 54. Digital copy of oil painting (L), Ilfochrome print from film recorder transparency (R). (Cull, 1999)

Table 10

Film Recorder to Ilfochrome Print Assessment Based on Appendix L

Properties	Importance	Achieved	%
Colour accuracy	7	3.6	51
Tonal range	7	6	86
Rendering of highlight and shadow detail	7	6.3	90
Sharpness	7	1.3	18
Lack of visible dot, line or screen pattern	7	7	100
Surface texture	5.6	5.6	100
Cost	5.6	5.1	91
Archival longevity	6.2	6.2	100
Average	6.3	5.1	80

4.6.9 Imagesetter

A 35 mm negative was scanned and then adjusted in Adobe Photoshop to create the digital image, Figure 55. The final print was to be used for exhibition purposes. A digital negative was played out and a contact print made from it onto photographic colour negative paper. It was critical that the photographic look of the image be retained and that there be no visible line or dot pattern. As the image is monochromatic, achieving accurate colour relates more to the contact printing stage, but it was essential to retain a good tonal range and shadow and highlight detail.

The final print by was assessed to be very successful, all the important characteristics of good tonal range and retaining highlight and shadow detail were achieved. The issue of longevity, as the photographer had chosen to use colour negative paper, was a drawback. However additional prints from the negatives could be made on black and white fibre-based paper and toned at a later stage (E. Pienaar, personal communication, October 6, 1999).

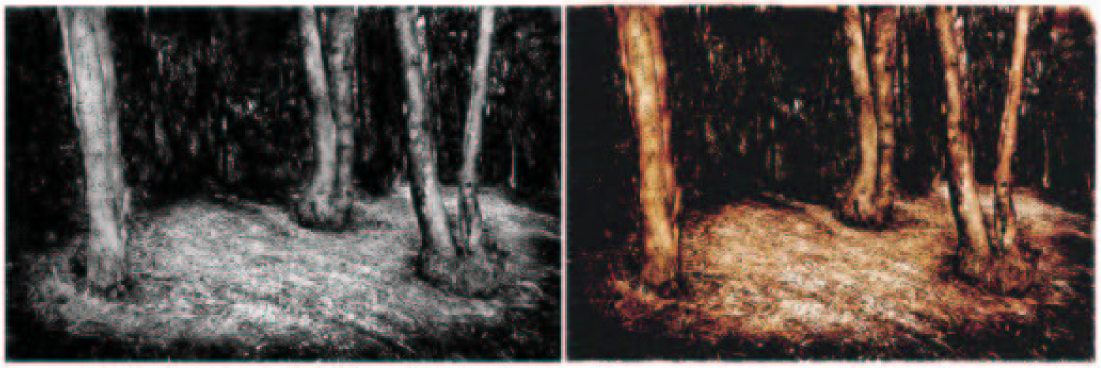

Figure 55. PhotoShop image (L), imagesetter negative printed onto photographic colour negative paper. (Pienaar, 1999)

Table 11

Imagesetter to Colour Negative Print Assessment Based on Appendix M

Properties	Importance	Achieved	%
Colour accuracy	6	6	100
Tonal range	7	7	100
Rendering of highlight and shadow detail	7	7	100
Sharpness	4.7	2.6	55
Lack of visible dot, line or screen pattern	5.5	5.5	100
Surface texture	4.8	4.8	100
Cost	6.4	6.4	100
Archival longevity	1.5	1.5	100
Average	5.3	5.1	94

4.6.10 Fuji Pictrography

An oil painting was copied to create the digital image in Figure 56 and printed using this process. The artist required accurate prints that could be sent to museums and galleries for promotional use. The Pictrography's ability to render colour and tonal range well was taken into consideration. The Fuji Pictrography print was lacking in a number of areas. The colour was not accurate, certain of the warmer tones had been lost and the print had an overall blue cast. The areas that should have been a neutral grey were blue. The tonal range was also lacking and the textural qualities of the original were not well represented. The cost of R 45 for a 19 x 21 cm print was seen as being too high for the purpose of promotional handouts.

Figure 56. Digital copy of oil painting (L), Fuji Pictrography print (R). (Cilliers, 1999)

When this print was made, the researcher was invited to observe the setting up of the image and to give input regarding colour and tonal range. Unfortunately the print operator was not particularly skilled in making the necessary colour adjustments needed for this machine and so three prints were finally made. The print that was the most accurate was assessed.

Table 12

Fuji Pictrography Print Assessment Based on Appendix N

Properties	Importance	Achieved	%
Colour accuracy	7	4	57
Tonal range	7	5.9	84
Rendering of highlight and shadow detail	7	7	100
Sharpness	7	7	100
Lack of visible dot, line or screen pattern	7	7	100
Surface texture			
Cost	3.3	1.6	48
Archival longevity			
Average	6.3	5.5	82

Note. A blank cell denotes that this aspect was not seen as relevant criteria for this particular image and application.

4.6.11 Colour Laser

A print of the image in Figure 57 was made for exhibition purposes. The print was seen to be adequate in all aspects other than achieving a saturated, solid black. The lightweight paper that was used was also criticised in terms of it staying flat when exhibited. The low cost and good archival qualities were seen as positive factors. (M. Duker, personal communication, October 7, 1999) It must be stated that these printers do offer the option of printing on heavier and more glossy papers, which would probably solve both the lack of flatness and the poor black.

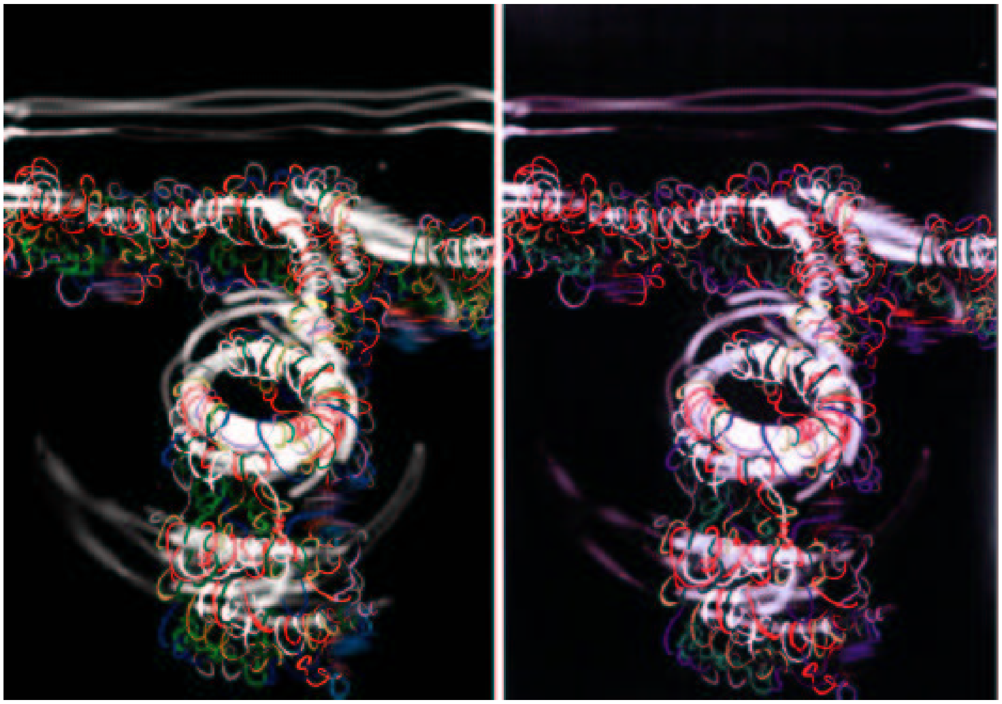

Figure 57. Painter image (L), laser print (R). (Duker, 1998)

Table 13

Colour Laser Print Assessment Based on Appendix O

Properties	Importance	Achieved	%
Colour accuracy	6	6	100
Tonal range	7	7	100
Rendering of highlight and shadow detail	7	1.5	21
Sharpness	7	7	100
Lack of visible dot, line or screen pattern	7	7	100
Surface texture	7	7	100
Cost	3.5	3.5	100
Archival longevity	5.5	7	100
Average	6.2	5.7	90

4.6.12 Colour Copier

The black and white etching, featured in Figure 58, was chosen and its application would be for use as a promotional print. The retention of the tones of dark grey and a solid black were of great importance. The colour copy made of this print was successful in terms of tonal range, good highlight and shadow detail, surface texture, low price and excellent archival qualities. Even fine detail in the very dark areas was achieved. The process enables the artist to print on both sides of the paper and to write or draw on it. The only negative feedback was the fact that a screen pattern was visible in the highlight area of the hands. (E. Frankenfeld, personal communication, October 6, 1999)

Figure 58. Digital copy of etching (L), colour copy print (R). (Frankenfeld, 1998)

As can be seen in sections 4.1 to 4.4, each digital print type produced a number of print anomalies. Appendix B, which is derived from the initial tests, illustrates how each printer performs according to the specific properties. While there is some disagreement from other sources, as to exact characteristics, the initial test revealed that the piezo inkjet, thermal wax, Fuji Pictrography, colour laser, continuous flow inkjet and dye sublimation printers all produced acceptable results. The thermal inkjet, phase-change, electrostatic and aerosol inkjet printers produced poor results. The aerosol inkjet and electrostatic printer were eliminated from the second round of tests. Some of the aspects identified in the first test were confirmed and others refuted by the second round of tests.

Table 14

<u>Colour Copy Print Assessment Based on Appendix P</u>

Properties	Importance	Achieved	%
Colour accuracy			
Tonal range	7	7	100
Rendering of highlight and shadow detail	7	7	100
Sharpness	7	7	100
Lack of visible dot, line or screen pattern	7	1.5	21
Surface texture	3.9	1.6	41
Cost	5.5	5.5	100
Archival longevity	1.1	1.1	100
Average	5.6	5.4	80

<u>Note.</u> A blank cell denotes that this aspect was not seen as relevant criteria for this particular image and application.

Table 15

Ranking of digital prints from fine art images

	Printer Type	Artwork	Application	Percentage
1	Continuous flow inkjet	Computer-based	Exhibition print	100
2	Phase-change injket	Silkscreen print	Promotional postcard	95
3	Imagesetter	Photographic manipulation	Exhibition print	94
4	Extended gamut inkjet	Oil painting	Promotional poster	92
5	Colour laser	Computer-based	Exhibition print	90
6	Dye sublimation	Computer-based	Exhibition print	84
7	Fuji Pictrography	Oil painting	Promotional hand-out	82
8	Film recorder	Oil painting	Promotional hand-out	81
9	Colour copier	Etching	Promotional hand-out	80
10	Thermal wax	Computer-based	Exhibition print	68
11	Piezo inkjet	Oil painting	Promotional poster	61
12	Thermal inkjet	Oil painting	Limited edition print	44

The fine art prints were matched to the print characteristics, according to the artist's criteria and their choice of application. In this second round of tests all printers other than the thermal inkjet printer scored over 50%, proving that the fine art images could be matched quite efficiently. The continuous flow inkjet was the only printer that totally satisfied the criteria described for that particular application. In spite of the fact that this continuous flow inkjet printer was not a giclée machine, it confirms why many international artists use this method to print exhibition prints. How artists and commercial clients use different types of digital prints will be described in the following chapter.

Chapter Five

5 Identifying the Commercial and Fine Art Applications of Digital Prints

For fine artists to make intelligent choices when choosing a digital print medium, an existing range of applications need to be identified. As both commercial and fine art applications offer potentially useful information, both these areas will be investigated in this chapter. Some commercial applications of digital prints will be identified and specific examples of applications will be given to illustrate how different print products have been used. In order to ascertain how fine artists have used digital prints, a number of artists work will be discussed. Where possible, an explanation will be given as to why they made particular choices in terms of printing processes. Finally specific mention will be made of archival issues, which has particular relevance to fine art applications.

5.1 Commercial Applications of Digital Printing

The commercial application of digital prints is a constantly evolving market, as new processes, substrates and inks enter the arena, new applications are found for them. Up to this stage a number of commercial uses for digital prints have evolved. Jordaan lists them as follows:

> Uses: retail merchandising, trade show exhibits, service firms/utilities, public spaces/event promotion, corporate spaces/exhibits, point-of-purchase advertising, recreation and entertainment, automotive,

architecture/construction, convention displays, presentations/seminars, grocery, restaurants/fast food, shopping mall/centers, [sic], medical/scientific/eng., museums/galleries. (Jordaan, 1997, p. 2)

Other uses include photographic prints and enlargements, business-, greeting- and post cards, proofing, publishing, printing on to fabric, and film positives for traditional printing processes. Prints serve a wide range of applications, from prints used to decorate snowboards, to prints on mesh, which can be used to cover buildings or construction sites.

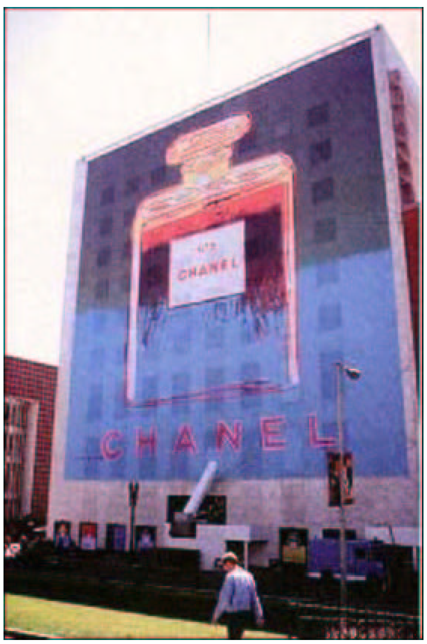

Figure 59. Vinyl mesh panels used to cover a building.
(WFDIC, 1998)

Because of the wide range of applications and printing processes, most digital print bureaux accept work from a broad range of clients. These can include advertising agencies, architects, trade show designers, corporate and retail graphic design departments, photographers and publishing print shops. These clients design posters, displays, billboards, murals, stage sets, vehicle markings, signage, postcards, brochures and many other images. Their designs generally include text, renderings or illustrations and photographs. In terms of computer software a huge range of design products can be used. This range of input formats, images and display criteria constantly challenge the bureau to offer unique solutions for each designers' needs.

Figure 60. Aeroplane with digital prints used as branding. (WFDIC, 1998)

5.1.1 Examples of Some Commercial Applications

Commercial applications of hybrid photographic processes such as imagesetter to print, film recorder to print and digital enlargers are vast. Photographers for instance can make use of these facilities for retouching and the restoration of photographic images. However this type of retouching is, for the bureau, a labour intensive and not very profitable area, as print quantities are generally small. Far more profitable for both bureau and client is using the digital negative or positive to print quantities of between 10 to 1,000. These images are then used as postcards, business cards, posters or catalogue sheets. This route is a lot cheaper than traditional printing methods, especially if print quantities are low (Berg, 1997, pp. 28 – 32). Film recorders writing to transparency film are used extensively to produce slides for presentations. Once again clients often combine graphics, text and photographic images and these designs are sometimes printed to colour copy machines for handouts, as well as being used to generate the slides. Some companies such as RB Images of Hollywood print 1,700 – 2,500 slides per month, with a turnaround time of three hours (Brown, 1997, p. 39).

Figure 61. Backlit displays. (WFDIC, 1998)

Digital enlargers offer the option of printing onto any type of photographic material, from backlit transparency film to black and white resin coated paper. Material such as Ilford's Ilfochrome, colour reversal, translucent material or a RA-4 translucent material is ideal for the display of photographic-type images. In certain areas of the USA, it is being used quite extensively by fast food area franchises such as Macdonalds to display current products. Medium sized (101 x 127 cm) prints, in quantities of between 15 and 120 can be printed more economically than on regular offset presses. The prints are displayed in light boxes, and so the excellent longevity qualities of the photographic materials are essential. The images are used to promote special offers on certain ranges of food and drink. Digital enlargers render the bright colours, fine text and photographic images of these pieces exceptionally well.

Digital enlargers and the Fuji Pictrography system have been used extensively by press photographers in the USA. These photographers, who shoot on digital cameras, often need prints for exhibitions, competitions and portfolios and the high quality images these machines can print are ideal for these applications.

Jody Dole was one of the first photographers to make use of digital printing for self-promotion. In 1992 he produced a number of large-scale images on the Xerox Versatec electrostatic printer. His aim was to show a prospective client a series of impressive posters that would illustrate his photographic skills. His decision to use digital printing to make the images was dictated by two aspects, firstly, that the computer offered very accurate adjustment controls and secondly the particularly attractive print characteristics of the Versatec. Davis points out that Dole chose the electrostatic machine because of its ability to "quickly turn out a large, museum-quality, four-color print - all without entering a darkroom" (Davis, 1993, p. 46).

Figure 62. Inkjet printed onto flex vinyl, for a store display. (Campbell, 1999, p. 35)

The different types of large format inkjets have a wide range of commercial applications. For instance aerosol inkjet prints have been used on promotional billboards to advertise popular TV shows. Eggers describes how

> During promotional periods in some major markets, billboards for Oprah Winfrey were being changed every day. Each afternoon, the topic for the next day went up. Only the actual topic panel was changed, but it was done daily. Making frequent changes like that before the days of digital printing, would have made such output impractical, if not impossible (1996, p. 38).

In Pretoria (South Africa) inkjet prints on billboards were used to cover three sides of a fire gutted building. The two 21 m long by 17 m high images and one 42 m long image were used to promote local TV stations (Davidson, 1999, pp. 1 - 2). Inkjet prints on the appropriate outdoor substrates are also used on bus shelters, taxis, trucks, delivery vehicles and busses.

Figure 63. Delivery vehicle with fleet branding prints.
(Omnigraphics, 1999, p. 9)

The smaller-scale digital printers such as dye sublimation, thermal wax, colour laser, colour copy, thermal dye transfer, phase-change are often used as commercial proofing devices. Some may be used to print brochures, newsletters, pamphlets and posters.

Why commercial clients use digital prints can be narrowed down to the following reasons.

- Images can be changed in the middle of a print run. For instance three posters with the same image can be printed, text changes made and further prints made at very little additional cost.
- Turnaround times are very short, in some cases a poster can be delivered to the client within a few hours.
- Scale is not a limiting factor and billboards of enormous sizes can be printed.
- Colours are vibrant and text is sharply defined.
- Images can be transferred on to almost any surface.

Jordaan lists the customer's requirements as "large format, Post Script, [sic] photographic quality, colour range, ease of use, fast production (quick turnaround), low cost, volume, media range, various substrates…" (Jordaan, 1997, p. 7).

5.2 Fine Art Applications of Digital Printing

In 1995 the magazine *Leonardo* published examples of digital images that were part of an exhibition "Art as Signal: Inside the Loop," curated for the Krannert Art Museum, University of Illinois at Urbana-Champaign. The examples depict two-dimensional computer artwork and include examples of dye sublimation, Cibachrome (Ilfochrome), from film recorder transparency, colour laser and inkjet prints (Chmelewski, Goggin, Squier, 1995, pp. 85 - 92). When looking at what artists use digital printing for, it must be noted that some artists in America have been involved with digital printing for at least the past fifteen years (Moore, 1999, p. 20). This has not been the case in South Africa, where many artists have only started to use digital media quite recently. However these artists have already exhibited work and made use of a variety of media.

Primarily, fine artists look to digital printing for the following applications: to output computer-based artwork for use as original artwork, or for use within installations and mixed media pieces. These could all be for exhibition and sale. Other applications are to produce limited editions of existing artwork, once again for sale, and to use digital prints for promotional purposes. There is another area of interest and that is the ability of the digital output to mimic traditional processes that are no longer accessible to artists. One example of this, mentioned by Cox, are large-scale negatives for use with alternate processes.

> The demise of large continuous tone film for making colour separations has left the photographer without materials to produce large negatives optically, but high resolution imagesetters and RIPs with stochastic screening have opened up the opportunity to produce negatives digitally at very high quality at a reasonable cost (Cox, 1997, p. 27).

5.2.1 Examples of Some Artists Using Digital Prints

In this section examples of artists using digital prints will be given. Where possible the type of work done will be described, as these examples will help to inform the reader of the artistic potential of digital printing.

There are a number of internationally recognised artists who have exhibited digital prints these include Frank Stella, David Hockney, Andrew Wyeth, Jim Dine, Chuck Close, Robert Rauchenberg and the Starn brothers. For example Mike and Doug Starn use an Epson 3000 printer, with Lyson inks on a 60 cm wide printer. Their installations at the Castelli Gallery, New York in 1998 showed the first digital work by these two artists. They mounted large-scale inkjet prints onto Plexiglas and illuminated them from behind. Other elements were added to produce wall like assemblages. Jones points out that the artwork does not differ vastly in appearance or concept from their previous images. However the working method, now digital, where in the past it was photographic, has radically changed the qualities of their work (Jones, 1998, p. 15).

The German artist Jenö Gindl exhibited inkjet prints, lithographs and platinum prints at the Standard Bank National Arts Festival in Grahamstown, during 1999. The artist silk-screens onto the black and white inkjet prints and works into them with charcoal. The inkjet prints shown are of large scale, in some cases as big as 76 x 106 cm.

One of the most prominent groups of American artists working in the digital print medium are the three artists who form the Digital Atelier, Dorothy Simpson Krause, Bonny Lhotka and Karin Schminke. From an initial meeting in 1994 the artists have collaborated on a number of digital projects and continue to share information (Hagan, 1999, p. 27). Their innovative use of commercial materials and mixing digital and traditional processes have ensured them the reputation of being at the forefront of this new technology. Linked to this they have received support from museums and the digital printing industry. They do research and test equipment for, amongst others, Iris Graphics, Microtek Labs, Encad, Lyson, Rexam Graphics and Tektronix.   Their work ranges from images printed on silk, to prints that are taken through a number of transforming stages. In some cases the artists transfer digital prints onto a range of surfaces such as "canvas, plywood, silk, rusty metal, rice paper, or frescoed substrate" (Hagan, 1999, p. 27). Different processes are used to transfer the images, one of them being similar to monoprinting, where an image is printed onto film and then transferred onto other substrates. In some cases further processes such as painting, abrading, tearing and collage techniques may be applied (Hagan, 1999, p. 29). Terry Towery "extends the artistic process by manipulating images with application of caustic oils and mixed media after his work has been output from the computer" (Malek, 1999, p. 17). In order to work on the surface of the print, Towery seals the inkjet print, which is glued onto canvas, with polyurethane. From this point Towery can work onto the print using traditional oil paints and sticks, as well as dry pigments, charcoal and other media. The addition of these materials allows the artists to create interesting surface textures, which he finds are often lacking in pure digital prints (Malek, 1999, p. 17).

Many artists are using the giclée system to print limited editions, these include the photographers Richard Avedon, Pedro Meyer, Olivia Parker and Joel Meyerowitz. This system offers good colours, a good range of substrates and excellent longevity qualities, plus there are many bureaux in America that are almost exclusively dedicated to their production. For limited editions, high quality scans from large format transparencies are made or the original artwork is recorded on a camera fitted with a digital back. A number of proofs are run until the artist is satisfied and from this point any number of prints can be made. One advantage of this process is that additional identical prints can be made at a later stage. Brown elaborates on this stating that "giclées have also opened new opportunities: for self-publishing an artist or group of artists; for testing the waters with works of lesser know, unproven artists; and for experimenting with small editions of works with a narrower market appeal" (Brown, 1998, p. 2).

In 1996 the Museum of Modern Art bought Peter Halley's work "Exploding Cell." The work was acquired in the form of a digital file and since its acquisition the museum has used the file to print onto sheets of newsprint. These prints were then used as wallpaper for the gallery walls. The file has also been used as part of an interactive web site, where viewers can work on a selected image, by painting onto it. They can then print the collaborative work at home. (Hagan, 1999, p. 41) This is an interesting permutation of the concept of creating digital art for printing, as the gallery might want to use the image for applications and printing processes not envisaged when the image was created.

There are a number of South African artists who have become involved in the digital printing arena. John Clarke who first used digital prints in 1996, points out the difference between artists and commercial clients.

> The point is that the artist, unlike the graphic designer, is not normally chasing the highest quality image [sic] printable image at the cheapest price in the fastest time – which is the basis of good industrial printing – but is merely trying to find another way, perhaps new and exciting, to say the same old thing (J.F.C. Clarke, personal communication, October 13, 1999).

Tony Meinjies who has a background in photography, has been involved with research in the Fine Art Faculty at Rhodes University, Grahamstown. He has exhibited digital prints for a Masters Degree evaluation and as part of the Festival of Photography held in Cape Town during September 1999.

Meintjies makes use of digital negatives and inkjet prints. The digital negatives are contact printed onto black and white photographic paper and some are hand tinted and toned. Meintjies uses commercially produced photographic materials, because they are so readily available. He also makes use of an Epson 1520 inkjet printer. As opposed to inkjet prints which are not widely used for exhibitions in South Africa, he feels that prints on photographic materials are more readily accepted by the South African public, curators and galleries (T. Meintjies, personal communication, July 13, 1999).

Figure 64. Asparagus, inkjet print. (Meintjies, 1999)

At the largest art festival in South Africa, the Standard Bank National Arts Festival 1999 Berni Searle exhibited three large inkjet prints in an installation titled "Red, Yellow, Brown". These were shown as part of the Emergence Exhibition at the Albany Museum. The three inkjet prints on paper were suspended from the wall. On the floor in front of each inkjet print, was heaped a pile of spices of the appropriate colour.

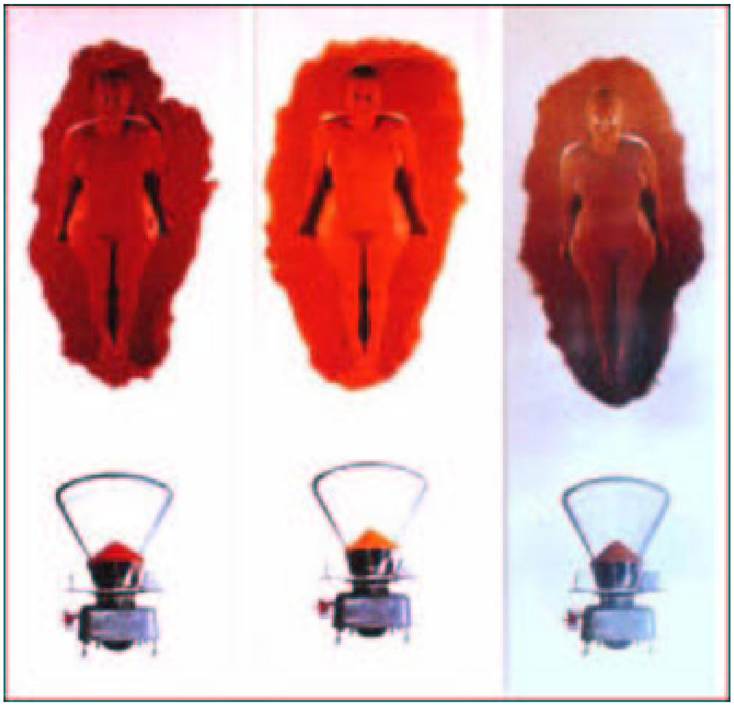

Figure 65. Red, Yellow, Brown, inkjet prints part of installation. (University of Witwatersrand, 1999)

5.3 A Comparison of Commercial and Fine Art Applications

An installation of images for promotion in a fast food restaurant does not differ vastly from an installation of a backlit fine art image. Many artists are still quite conservative in terms of how they see the application of digital prints. This is possibly linked more to cost and access than lack of ideas. Some artists push the boundaries of the digital print media then mix them with traditional fine art techniques. As Lowe points out, "artists are always pushing the parameters of what a print engine can technically achieve and are mixing aspects of different processes together to exploit the potential offered by this diversity" (1996, p. 8). They do not however have the budgets that commercial clients have and this could limit the type of applications that they would like to achieve, and the amount of experimentation that they could do.

One major factor when it comes to the application of commercial work is the fact that images are most often required to last only a few months at the most, while most fine artists would like their images to last for as long as possible. This has a limiting effect on the choices that a fine artist can make when selecting printing processes, inks and substrates.

5.4 Permanence Issues

As issues of image permanence are of major importance to artist and curator, this section is dedicated to outlining opinions on this issue, as well as explaining how longevity is assessed.

Artists using the first digital prints were dismayed at how rapidly the inks faded. This resulted in the medium acquiring a poor reputation. Recent industry efforts to improve the longevity of digital prints have substantially changed the attitudes of collectors and curators. The George Eastman House started collecting digital prints in 1993. Therese Mulligan, the curator at George Eastman House, explains that "due to the rapidly changing nature of the digital medium, entities like galleries and auction houses are moving towards a greater acceptance of the medium" (Leslie, 1998).

For the fine artist there are a number of routes that they can take when printing for permanence. Firstly the medium chosen should be suitable for the application. A dye sublimation print's longevity characteristic is vastly different to a platinum print made from a digital negative. There is also the option of offering to provide the file of an image on a relatively indestructible medium, such as a good quality CD or magneto optical disc. This means that the image could be printed again if any noticeable fading occurs, or if new and improved materials become available. There are certain drawbacks to this process. Some mediums, such as thermal wax prints, may be phased out in the future and the printers and materials will no longer be available. It might take a skilled operator to duplicate the original print when new materials, technology and software may cause subtle changes. Another issue mentioned by Henry Wilhelm is that the hardware and software for certain storage media may not be available in the future (Wilhelm, 1999).

From a curator's point of view, digital prints do not differ vastly from other art media in terms of conservation, especially with current art trends where artists incorporate natural products into their work. Cannon-Brookes refers to "the total freedom now enjoyed by the artists presents formidable problems for the museum curator and his conservator, problems which are often little understood by either the artists or the curator" (1983, p. 34). And yet there has been some substantial resistance to exhibiting and collecting digital prints. Therese Mulligan, puts this down to two factors, one that technology is constantly evolving and changing and the second that many people working at galleries and auction houses are unfamiliar with this new medium (Leslie, 1998). Fortunately informed curators like Mulligan realise that

> If you care for a digital print like you do any other work on paper, thinking in terms of preservation when storing or displaying work, understanding all

> of its physical attributes, then you can be pretty certain of its longevity (Leslie, 1998).

As more products come onto the market, it is exceptionally difficult for curators or artists to keep up with how long the images printed on the new materials will last. Fortunately a number or organisations are testing digital printing products for permanence and frequently publish these results. The following section outlines the major issues and describes some techniques used to test the longevity of prints, as well as the opinions of various experts in the field.

Considering that most digital printers were designed as proofing devices permanence was not always considered a crucial factor when it came to creating substrates and inks. Wilhelm points out that "Iris never conceived of their printer being used to produce a work of art that might hang on a wall. It was designed for digital pre-press work and industrial-design work, where permanence was not an issue" ("The man," 1998, p. 54). The situation that exists today is that some prints such as dye sublimation, thermal wax and some inkjet printers offer quick output, but are not always designed for permanence. Other machines such as the giclée machines do not have the same print speed, but can offer high quality, long lasting images.

Fortunately most manufacturers have attempted to improve the permanence of prints, largely because of demands made by their commercial clients. The permanence of inkjet inks and substrates has improved vastly over the past three years and photographic materials continue to improve in terms of longevity. Table 1 gives a rough idea of the longevity qualities of each process.

5.4.1 Factors Influencing the Permanence of Digital Prints

A number of factors appear to influence the permanence of digital prints, generally concerns are about inks fading, though realistically the influence of substrates cannot be ignored. In Browning's book *Analysis of Paper*, he points out how important the permanence of paper is when "intended for use in legal records, documents, art works, and library books of permanent value" (1977, p. 316). He goes on to say that because of paper's complex make up, the factors influencing permanence have not yet been fully established (Browning, 1977, p. 317). Not only will the paper on its own influence how long an image lasts, but the reaction of ink to substrate will also be a deciding factor. Many manufacturers will only guarantee their products when the appropriate ink is used with a specified substrate.

Other factors influencing image permanence are the finishing and presentation of images. Often images are laminated or mounted onto different surfaces and in some cases these surfaces can adversely effect the images. John Otsuki claims that

> Most color changes are due to oxidation of the dyes or pigments. This oxidation can occur due to ultra violet (U/V) radiation, a natural reaction with the paper, laminate, glue, etc., exposure to acid in the air (pollution), or just about any other cause (personal communication, February 17, 1999).

So exposure to visible and UV wavelengths, the pH balance of substrates, exposure to water, after treatment, such as lamination and mounting will all influence how quickly prints fade. When speaking to individuals at digital print bureaux in South Africa, many claim that testing done in America and Europe, has little bearing on South African outdoor conditions, where fading appears to occur at a different rate (T. Land, personal communication, June 8, 1999).

5.4.2 Testing the Longevity Qualities of Digital Prints

Although most manufacturers give statistics as to how long prints will last indoors or outdoors, these statistics are generally considered to be inaccurate. Concerns are often voiced regarding how tests are conducted and how they are evaluated. At the Big Picture Conference held in Orlando, Florida in August of 1999, two sessions were dedicated to this subject and the issue was mentioned in many other sessions ("Postcards from," 1999, pp. 61 - 63). There is at least one independent organisation conducting tests for longevity on digital prints. The Rochester Institute of Technology (RIT) has an image permanence section that will run tests for industry clients. The Wilhelm Imaging Research Inc. in Grinnell Iowa has conducted testing on certain processes. Wilhelm is recognised as an expert in this field and was a founding member of the ANSI subcommittee on developing standards for testing the stability of colour photographs ("Postcards from," 1999, p. 65).

The Grinnell testing is done under lighting conditions that mimic standard indoor display illumination with a relative humidity of 60% (Wilhelm, 1999), this factor has received some criticism. Otsuki points out that it is often impossible to duplicate the conditions in which the commercial print will be exhibited and that at present there is no impartial organisation doing comprehensive outdoor testing (personal communication, February 17, 1999). This was confirmed in a presentation on the status of standards for outdoor graphics at the Big Picture Conference (Piekara, 1999).

Another aggravating factor is that "new media or ink is released every few weeks, a good testing program is just not possible" (J. Otsuki, personal communication, February 17, 1999). Otsuki's assessment of longevity, based on his experience in the commercial printing market is far more conservative than that of Wilhelm's institute. For instance he quotes photographic prints as having a ten year indoor life and six months to one year outdoor life. Unlaminated inkjets using dye-based inks, he assess as one to two months indoors (J. Otsuki, personal communication, February 17, 1999). His assessment is purely from the viewpoint of a graphic producer and vendor, based on eleven years of running a digital output business (J. Otsuki, personal communication, February 17, 1999).

In his presentation at the Big Picture conference Wilhelm outlined some of the aspects that his organisation looks at when determining the longevity of digital prints. These include setting up test files that illustrate a comprehensive range of colours and tones, as uneven fading of certain inks is often only noticeable in the grey areas. Other tests evaluate the effect of humidity and heat on colour densities and bleeding. Testing methods and conclusions from the Wilhelm Imaging Research Inc., can be found at www.wilhelm-research.com (Wilhelm, 1999). At present they do not cover a complete range of digital print processes, but additional tests are still being conducted. It must be pointed out that although these tests do not satisfy all possible digital print applications, they are however conducted with fine art applications in mind. The test results can therefore be of great help to both artists and museums and galleries as an indication to how long it will take for digital prints to fade in indoor exhibition environments.

It seems that it will take some time before consensus on testing for image permanence will be achieved to the satisfaction of both artists and commercial clients. This chapter indicates that the two groups appear to have a great deal in common. Both would like to have good quality digital prints that can be used for promotion, display and within installations. The other conclusions are discussed in the next chapter.

6 Conclusion

This conclusion is broken down into four sections, each section describes how the subproblems posed in chapter one, are addressed by the research. Following this are some aspects that are essential for fine artists to follow if they wish to have digital prints made of their work in South Africa. Finally, aspects that can quite possibly lead to future research topics are identified, these may have been indicated by the current research, or are aspects that do not fall within the delimitations of this document.

6.1 What Types of Digital Print Techniques are Available and what are Their Characteristics?

It was established that there are fifteen different types of digital printers available in South Africa (1998/1999). These printers offer a huge range of options in terms of quality, print sizes, print speeds, cost of prints, substrates, running costs, physical dimensions of the printers, longevity characteristics, cost of the printers themselves and manufacturers. This is illustrated in chapter three and Table 1. Although South Africa cannot match the quantity of printers available in for example the USA, all the basic processes are covered.

Although there are a number of Iris printers operating in South Africa, the machine dedicated to fine art print production, the IrisGPRINTER, is not available in South Africa (K. Solomon, personal communication, February 11, 1999). The Iris continuous flow printing technology when used with the correct ink and substrate combinations has established itself as a very accurate method for producing limited edition prints and unique art works (Brown, 1998, p. 2). These days manufacturers other than Iris, such as ColorSpan are marketing cheaper machines that work on the same continuous flow principle. As the number of this type of machine increases in South Africa, it becomes more likely that the bureaux will begin to offer the inks and papers that give better image permanence.

The initial assumption that machines that generally print commercial images can also be used to print fine art images, was in principle accurate. In general, most bureaux will accept work from fine art clients (T. Maio, personal communication, February 9, 1999). However in some cases, it seems that artists cannot compete with commercial clients. For instance the company, Visual Promotions, was not prepared to halt a production run on the only HK digital enlarger in South Africa, merely to output a single image for the researcher. This indicates that unless artists have a substantial number of prints to make, certain processes will not be made available to them. It is understood, however, that a local bureau has purchased at least one more digital enlarger and therefore the possibility does exist that, these printers will become more accessible to the individual artist in due course.

Another point to consider here, is that in the case of a company which houses a scarce resource (*e.g.* Visual Promotion’s digital enlarger), the company might be under contract to produce images for one client only. For example the digital enlarger prints that combine both digital and photographic technologies can achieve sharply defined text, saturated colour and photographic quality on backlit displays. These are ideal for use in the gambling industry, which needs backlit displays for their 'one armed bandits' or slot machines, and for companies such as Macdonalds, which needs backlit displays for their restaurants. The point is that, even if an artist had the financial means to afford a large print run of a particular image, they still might not be accommodated, as the bureau might not need additional business when their livelihood is solely dependant on a major client's needs.

A technical explanation of how each printer lays down colour or tone was given in chapter three. This explanation provides a better understanding of how certain results can be achieved with one printer but not with another. An example of this would be a comparison between a dye sublimation printer and a continuous flow inkjet printer. The dye sublimation process causes a slight diffusion of the dot, resulting in near-photographic quality. Continuous flow inkjet printers by comparison put down a very distinct fine overlapping dot, giving the image a very different quality. This is illustrated in Lowe's close-up photographs Figure 18 and Figure 22. The different techniques and materials used by each printing system makes it unique and will always influence what the final image looks like.

6.2 What Printing Anomalies are encountered when Making Digital Prints?

The identification of print anomalies proved to be a complex task and a number of different approaches were taken. Information gleaned from other sources on print anomalies proved to be rather vague, with general observations on colour accuracy and longevity (J. Cone, personal communication, April 26, 1999), or substrates and inks (N. Weight, personal communication, February 10, 1999). These did not fully describe each process and so a number of practical tests (see chapter four), were conducted to provide more detailed information.

In order to deal only with the influence of the printer itself on print anomalies, the outside factors mentioned in chapter two were either eliminated or standardized. The initial test, which involved eleven different digital printing processes, revealed the following:

- The printer that had the least print anomalies was the piezo inkjet, followed by the Fuji Pictrography, the colour laser, the continuous flow inkjet and the dye sublimation printers.

- All the other machines, the colour copier, the large format electrostatic, the phase-change inkjet, the thermal inkjet, the thermal wax and the aerosol airbrush inkjet had numerous print anomalies.

- Certain printing techniques are not suitable for fine art applications. The airbrush inkjet and the large format electrostatic printers produced poor results, this was confirmed by individuals in the industry (R. Henry, personal communication, September 16, 1999).

From the second test (*i.e.* when actual fine art images were printed and assessed, and when the imagesetter, the extended gamut inkjet and the film recorder were also taken into consideration), the following conclusions were made.

- The results achieved by the thermal inkjet, and the thermal wax machines were not satisfactory. The thermal inkjet achieved only 44% of the criteria specified by the artists' concerned, while the thermal wax achieved 68%. This is illustrated in Tables 3 and 9.

- The piezo machine produced far worse results in the second test than in the initial test, achieving only 61% of the artists' criteria.

- The results achieved with the continuous flow inkjet (100%), the phase change inkjet (95%) and the colour copier (90%) were far better than indicated in the initial test.

- The extended gamut inkjet (92%) and imagesetter (94%) which were only tested in the second test achieved good results. The details of these results are discussed in more detail in section 6.4.

As is described in chapter two, there are numerous factors that influence the result of the digital printing process. Some of these factors are within the control of the artist and others not. Certainly when working with a bureau, the artist must assume those factors such as colour management, printer calibration and profiles are standardized and controlled. In retrospect, it was naive to assume that all the printers are correctly calibrated and running at their optimum at all times. The instance of the dye sublimation printer printing a section out of register, as is mentioned in section 4.6.6, is an example of a machine not operating at its optimum.

Unfortunately not all print operators are well trained or very knowledgeable about fine art digital printing. As was illustrated in section 4.6.10, print operators are sometimes unskilled and may need to make a number of prints before getting the colour balance right. In terms of profitability, they may not be allowed to print too many tests and so the artist may be given a substandard print.

6.3 In What Way do Fine Art Applications Differ from Commercial Applications?

There is no significant difference between how commercial clients or fine artists might use digital prints, in the sense that prints are generally used for promotion and display. They do from that point on, differ substantially in terms of what an artist is attempting to do with their prints. Some artists are responsible for taking the printing processes much further than commercial users and printer manufacturers envisage. Commercial client's budgets will allow them to print enormous prints onto any substrate and allow them to cover the windows and floors of buildings. But artists such as Gindle, Towery, Krause, Lhotka and Schminke transform the digital print into a unique work of art, by working into the prints by hand and manipulating them with additional materials.

In some cases, for instance where photographic negative and positives are printed on imagesetters, digital printing has created the opportunity of marrying computer-based images with traditional processes. As Cox points out, imagesetters allow the artists to output to large-scale black and white film (1997, p. 27). The fact that these negatives or positives can then be contact printed onto virtually any light sensitive material opens up many creative possibilities.

One significant difference between the requirements of the artists and the commercial client is how long they expect images to last. In general, artists and galleries expect prints to last for at least as long as colour photographs from negatives, approximately 12 – 15 years (Wilhelm & Meehan, 1999). As is indicted in section 5.4, The debate about image permanence is a difficult and heated one, fortunately many curators are more interested in the quality of the artwork, than the permanence of the print (Leslie, 1998). As is pointed out in chapter five, very few up-to-date accredited tests exist for assessing the longevity of digital prints. Different organizations use varying criteria and many are unwilling to release their findings, as the tests are often initiated and paid for by printer, ink and substrate manufacturers. In spite of some criticism, the Wilhelm Imaging Research unit does at least make their updated results of their tests available on the Internet (Wilhelm, 1998, 1999).

6.4 Can Digital Print Characteristics be matched to the Original Artwork?

From the information in chapter three and the two tests made in chapter four, original artwork can be matched to its digital print facsimile. Here, one obviously accepts that in some cases the digital print is the original artwork, in the sense that the image was created on-screen and then printed. However, this research did not set out to look at the creative potential of the digital print but rather at the technical quality of the digital print and its relationship to an original artwork, be it an oil painting or an image created with computer software.

It should also be remembered that the success of the digital print from an artist's point of view, must also take into consideration such influencing factors as the intended application of the final print (*e.g*. how does the artist want to employ a particular digital print), its susceptibility to change over a particular period of time (*i.e.* longevity issues), and cost factors.

In terms of applications, with the correct ink and substrate combinations, most types of inkjet printers will deliver a print that will last for at least five years in normal viewing conditions (Wilhelm, 1998, 1999). The laser printer and colour copier prints last indefinitely and so they too can be used to print artwork for sale and exhibition. Any photographic material if processed correctly will last for a minimum of 12 years (Wilhelm, 1998) and so they too are well suited to this application.

When matching artwork to digital print, the following aspects were identified:

- The phase-change inkjet printer proved to be very good at mimicking the layered and textural qualities of the silkscreen print, Figure 51. It is also ideal for rendering bright, vibrant colours, printing fine text and as it can print onto both sides of the substrate, it is well suited to printing promotional material.

- Amongst the other inkjet printers, the extended gamut inkjet and piezo inkjet can print reasonable reproductions of oil paintings on paper. Both of these processes produce a good tonal range and very little visible dot pattern. The oil painting Figure 48 was printed on the extended gamut inkjet and Figure 47 on the piezo inkjet printer. These processes can only be considered for short-term promotional applications because of their limited permanence.

- From the first and second test on the continuous flow inkjet it certainly proved itself to be one of the most accurate digital printing processes available to the artist. It has the ability to reproduce a black and white image, Figure 50 which is characterised by both fine line and areas of subtle tonality, exceptionally well. The Iris continuous flow inkjets are well established as proofing devices, as they give a smooth tonal range, good colour accuracy and capture areas of very fine detail. This process also lends itself to the reproduction of artworks for sale and exhibition. Sizes are limited (55 x 76 cm), but with the wide range of substrates indicated in Table 1, and the fact that good longevity characteristics can be achieved, it is one of the most successful fine art digital mediums. It seems ideal for reproducing computer-based images, photographic images (black and white and colour), lithographs, etchings, platinum and palladium prints, drawings, computer-based images, watercolours and oil paintings.

- Monochrome images reproduce extremely well via the imagesetter, as is illustrated by the print made from Figure 55. This process has the ability to represent an extensive tonal range, maintain good highlight and shadow information, retain sharp detail and can be contact printed onto any photographic substrate. It is well suited to printing photographic images.

- Out of the other photographic processes, the Fuji Pictrography's potential to print final artwork is slightly limited by the small sizes (31 x 46 cm) that can be printed but it reproduces photographic images very well. This is possibly not fully illustrated by the print made from Figure 56 in that the print operator struggled to make colour corrections for this image. The Fuji Pictrography prints can be used very effectively for promotional purposes.

6.5 A Strategy for Making Digital Prints

As is discussed in chapter two, various factors impact on digital printing. It is worth going through a typical process that a fine artist would follow in having a digital print made. By following the methods described in this document, an artist could create and set up images in such a way that they would print efficiently on almost any digital printer. This approach will certainly save time, money and frustration.

6.5.1 Capturing and Setting Up the Image

The input stage is one of the most important in terms of capturing the essential qualities of the original image, decisions made at this stage can govern the success or failure of a print. Critical aspects are to ensure that the image is captured at a high enough resolution on a correctly calibrated scanner or digital back. If the image is to be printed exceptionally large (larger than 1 m x 1 m), then a professionally made drum scan is essential. It is generally better to initially scan at a resolution higher than required and then, subsequently, to size the image at the optimal printer resolution, once the printing process is known. Any changes that are made to the image using image manipulation software have to be done on a calibrated monitor and making use of the appropriate colour management software. Where possible, actual tonal values and colour values should be checked to see that they are within the gamut of the printer and that the highlight and shadow areas will print the appropriate tones. If the same printer and substrates are to be used most of the time, a test print of a chart such as the IT8.7/2 chart shown as Figure 6, should be printed. This can be compared with what the artist sees on the monitor and the monitor calibrated for that specific print type.

6.5.2 Dealing with Bureaux

Once the image has been captured, the artist needs to ensure that the image is correctly set up for the chosen printer type and if dealing with a bureau that all their criteria are met. As has already been discussed, bureaux generally do not have a great deal of time to spend with small clients, they want to print a large quantity of prints as quickly and as economically as possible. To save time and unnecessary expense, the artist needs to make sure that the image is at the correct resolution, in the right format and colour mode, and that the contrast range and colours used are within acceptable parameters for the printer.

When working with a bureau one needs to build a relationship with the print operator, in order to ensure that they understand exactly what it is that you want. This applies to selecting the right ink and substrate combinations and ensuring that they understand what aspects of the original artwork are critical to maintain. By providing a good proof or the original artwork, the artist can ensure that accurate prints can be made. Certainly amongst the smaller bureaux, operators are not always very skilled and they do make mistakes.

When mistakes are made, the artist needs to be able to identify where the problem arose. Is it an incorrectly set up image or a printing fault? They should be able to identify aspects such as if an inkjet printer's heads are out of register, causing uneven stripes or marks, if poor handling of paper has left finger prints on negatives, if a colour cast has been introduced through poor calibration. Pin-pointing why poor colour and tonal accuracy occur is quite difficult. If the image is correctly scanned and set up for the printer and still does not print correctly, it is reasonably safe to say that the fault lies with the RIP or printer. Examples of some of these faults appear as Figures 66 to 70 on that accompanying CD.

6.5.3 Presentation of Digital Prints

Once the print is made, transporting the print and framing, mounting or laminating it can be major tasks, especially if the print is bigger than 50 x 50 cm. Here it is essential to involve the experts in the finishing field and make sure they understand what the application is, what the artist is trying to achieve and, very importantly, what printing process, inks and substrates were used.

6.6 Further Research

While researching this topic, a number of aspects that have potential for future investigation were identified.

- Firstly, how these printers can add to the creative process, or any aesthetic analysis of the test results, does not fall within the delimitations of this research. However the fact that the digital printer is becoming a more common tool in the creative process cannot be denied. The type of impact this will have on the creative process and the aesthetic qualities of the imagery, could provide material for future investigations.

- In chapter five mention was made of artists such as the Starn brothers who use the digital print as a starting point for creating installations (Jones, 1998, p. 15). Others such as Towerey use the digital print as a basis for creating mixed media pieces (Malek, 1999, p. 17). In South Africa, artists have been less adventurous in using a variety of digital prints. In the tests conducted using fine art images, no artists requested prints for use within installations. This is certainly a field that can make use of digital prints, as the Starn brother's work illustrates. Prints made on a digital enlarger could be ideal for these purposes, as photographic materials retain vibrant colour, a good tonal range and render fine detail with ease. Commercial clients already use these prints in backlit displays, in airport concourses, restaurants and outdoor kiosks, and the medium certainly has potential for use within three-dimensional works. The technical application of digital prints in this way, as well as the creative possibilities of this type of work could provide material for future research.

- Within this research, the tests were conducted within specific parameters, for example, no particular brand of printer was tested. Printer types, irrespective of the manufacturer, were considered to be the same. There is certainly a need to do a comparative study of brands of printers that are suitable for fine art images and applications. This study could be further refined into testing the smaller printers that artists could purchase, and those that bureaux purchase.

- The tests conducted in chapter four were printed on commonly available substrates, in most cases onto paper. With the enormous range of substrates available and the potential of some printers (inkjet printers and laser printers) to print onto unconventional substrates, this too could provide an area to research both technical and aesthetic issues.

- Finally, another possible area of investigation is the effect of printing fine art images from different software programs. Testing how images print from a variety of applications, in different modes and with different forms of colour management, has potential for future research projects.

6.7. Discussion

Manufacturers may phase out some printers such as the thermal wax printer, the aerosol inkjet and the large format electrostatic printer, in the future. Although many artists are involved with producing work using the latest technology, there are also those that use old technology very creatively. Older digital printing processes may provide them with the opportunity to develop creative techniques, in the same way that modern photographers use processes such as gum bichromate and cyanotypes.

As most of the other printing processes are still being developed and improved on, it is reasonably safe to assume that they will be used commercially for many more years. Although digital printing processes will no doubt change in the future, this research, like Lowe’s done from 1995 to 1997 (Lowe, 1996, pp.1 - 6), will certainly be relevant for some time to come.

Digital printing is a relatively new medium, some products have only been on the market for a few years. As is pointed out at the beginning of this document, new digital printing techniques are being introduced at a fast pace, as are new inks and substrates (J. Otsuki, personal communication, February 17, 1999). This means that although fourteen printers were tested in the course of this research (1998/1999), it is quite feasible that within a year or two, new untested printers will have appeared on the South African market. Artists wanting to use these new printing techniques could adapt the testing and evaluation methods described in this document to assess the new printers.

To sum up, certain types of digital printers already offer the artists excellent potential for printing their images. In order to use these printers effectively, the original image, the printer anomalies and the final applications of the print must be considered and matched. This document offers an approach to achieving this goal. As technology improves and new products are released, matching image to print will continue to challenge artist and researcher alike.

GLOSSARY OF TERMS

Additive colour theory: White light is made up of equal parts of red, green and blue light.

Additive primaries: These are red, green and blue.

Application: A software program that carries out a task, such as image manipulation or graphics programs.

Backlit: Any object that has the light shining from behind it towards the viewer.

Bi-directional printing: A printer that prints from right to left, advances the substrate and the prints from left to right.

Bit: Binary Digit. The smallest unit of data a computer can process.

Bit map: An image or object that is broken up into individual pixels arranged in a grid pattern. Each pixel is represented by a number of bits of information dictating its position, colour etc.

Bit-mapped graphics: Graphic images that are made up of pixels. Also called raster graphics.

Brightness: The areas in a positive image that contain the least density.

Bureau (x- plural): Service centre where digital files can be played out.

Calibration: A process of adjusting a piece of equipment to a known standard or to match another piece of equipment.

Capstan design: A system used in imagesetters to move the film through the machine during exposure.

Cathode-ray tube (CRT): The vacuum tube used in a TV or video terminal screen.

Charge-coupled devices (CCD): A micro-electronic light sensitive device, used in digital cameras, digital backs and some scanners.

CIE: (Commission Internationale de l'Eclairage) An international committee that creates standard colour models for representing colour.

CIELAB (or CIE L*a*b*, CIE Lab): Colour space in which values L*, a*, and b* are plotted at right angles to one another to form a three-dimensional co-ordinated system.

CMYK: Cyan, Magenta, Yellow and Black. The four subtractive colours and process colours used in four-colour printed reproduction.

Colorimeter: An optical measuring instrument that responds to the RGB quantities of light reflected by objects.

ColorSync: Colour management architecture for Apple Macintosh computers. Third-party vendors utilise the ColorSync framework to provide device calibration, device characterisation, and device profile-building methods.

Colour balance: The overall colour of a print, which depends on the relative strengths of the three primary or secondary colours.

Colour gamut: The range of colours that can be reproduced using a certain process.

Colour management system: A software system used to ensure colour consistency among the different input and output devices so that printed results match originals.

Colour model: A method of representing colour information as numeric data.

Colour space: A three-dimensional geometric representation that can be used to depict the colour gamut of a device, human visual perception, etc.

Compact disc (CD): A standard medium for storage of digital data in machine-readable form, accessible with a laser-based reader.

Compact disc read only memory (CD-ROM): A data storage system using CDs as the medium.

Compression: A software or hardware process that reduces the size of digital files so that they occupy less space.

Contact print: A photographic print made by placing the original in contact with the sensitive material and exposing it to light.

Continuous tone: An image that has not been screened and contains gradient tones from highlight to shadow.

Contrast: The tonal difference between the darkest and lightest part of an image.

Cromalin: A proofing process that uses the four half tone colour separations to create a full colour image. CMYK powders are used to create the image.

Cyanotype: a printing process that is often referred to as the blueprint, or Prussian blue process.

Dedicated device: A piece of hardware that is permanently assigned to one task.

Dedicated system: A system that only does one task.

Densitometer: A photoelectric instrument that measures the density of photographic images or the density of printed inks. There are transmission and reflection densitometers.

Density: A measure of the relative difference between a white area and a toned or black area, or the ability of a material to absorb light.

Device profile: A file, used with a colour management system, that describes the colour characteristics of a properly calibrated input or output device.

Device: Any piece of equipment that is plugged into a computer, such as a scanner, printer or camera.

Device-dependant: Describes a colour space that can be defined only by using information on the colour-rendering capabilities of a specific device.

Device-independent: Describes a colour space that can be defined using the full gamut of human vision, as defined by a standard observer, independent of the colour-rendering capabilities of any specific device.

Digital: The use of binary code to record information. Text would be recorded in a code like ASCII and scanned images in bitmapped form.

Digitize: To convert an image or signal into binary code.

Dithering: Converting tones to an arrangement of dots.

Dot gain: An increase in the size of halftone or stochastic dots that can be caused by a number of factors, such as the absorption of ink into the substrate.

Dot: The individual element of a halftone. They can be several shapes including round, square or elliptical.

Dpi: Dots Per Inch. A measurement of output device resolution and quality.

Drum scanner: A scanner in which the original wraps around an internal or external drum.

Dynamic range: A scanner or digital camera's ability to capture an image's brightness range from the highlights to the shadows.

Effective resolution: The resolution of a scan, which may be created by a combination of sampled points and pixels created by interpolation. In this way, the effective resolution of a scan may be greater than the optical resolution of the scanner that captured it.

Electron gun: The device in the CRT that produces the electron beam that activates the phosphors, causing them to emit red, green and blue light.

Electrophotographic printing: The technology used in copy machines, laser printers and large-scale electrostatic devices. Elements within the machine are charged which causes toner to either be attracted or repelled by a charged substrate.

Electrostatic printing: Printing process that uses a special paper that is charged by an electron beam, toner is applied which sticks to the charged areas.

Encapsulated PostScript (EPS): An image description format. EPS files are generally used for graphics and text.

File format: The structure or arrangement of data stored in a file.

File: A document or application that has been given a name.

Flat bed: A flat bed optical input or output device (scanner or plotter) transfers images by means of a flat plane rather than a revolving cylinder.

Flexography: A relief printing process that makes use of halftone negatives.

Four-colour process: A method of printing colours by using tints of cyan, magenta, yellow and black (CMYK).

Gamma: The relationship between the tone values in an image file to the tone values produced by an output device.

Gamut compression: The colour space co-ordinates of a colour space with a larger gamut are reduced to accommodate the smaller gamut of a destination colour space.

Gamut mapping: Converting the co-ordinates of the two more colour spaces into a common colour space. Often results in tonal range compression.

Giclée: The term initially used to describe Iris fine art digital prints, from the French "gicler" – to spray. The term is now used to describe any fine art digital print using the continuous flow inkjet printing system.

Graphics: Graphics are basically pictures and drawings, either created by computer or entered into the computer by scanning or photographing.

Gravure: An intaglio printing process, mainly used in roll-fed web printing presses.

Grey scale: A range of tones of grey between pure white and solid black.

Halftone: When an image is broken up into a number of dots that represent the densities of the original. The dots give an illusion of continuous tone.

Hard copy: A printed copy of output in readable form.

HexaChrome: A sic colour printing process introduced by Pantone. Green and orange plates are added to the standard CMYK plates.

Hi-Fi colour printing: A colour printing method that uses more than the four colours to attain a wider colour gamut.

High resolution: Any image that is displayed in better quality by increasing the number of dots, or pixels, per inch than normal.

Highlight: The lightest or areas in an image.

Hue: The name of a pure colour.

ICC: International Colour Consortium: The ICC consists of a group of companies, its purpose is to create, promote, and encourage an open, vendor-neutral, cross-platform, colour management system architecture and components.

Image processing: Digitized images can be manipulated using image-processing software.

Image processor: Device that takes input data and changes it into the proper formats for imaging devices such as for printing or display.

Image resolution: The fineness or coarseness of an image as it was digitized, measured as dots-per-inch (DPI).

Image: The computerized representation of a picture or graphic.

Input resolution: The number of samples that can be taken per unit of length when digitizing an image.

Interactive: When the computer and the user can communicate, if this happens instantaneously, it is considered to take place in real time.

Internet: The name for a world-wide, TCP/IP-based networked computing community with millions of users world-wide.

Interpolate: To estimate values between two known values; for example, to assign an intermediate colour to a pixel based on the colours of the pixels around it, thereby increasing effective resolution.

Ion deposition: A printing system that makes use of cold pressure fusing and so cannot be used for colour printing. It is used mostly for printing high volumes of small documents.

L*A*B*: A system for describing, measuring, and controlling colour, using hue, luminance, and brightness established by the CIE. (See CIELAB)

Laser: The acronym for light amplification by stimulated emission by radiation. The laser is an intense light beam with a very specific bandwidth.

LCD: Liquid crystal display. An electronic component containing a tiny quantity of liquid that crystallises (turns black) when a small electrical current passes through it and returns to a liquid state when the current is switched off.

Light emitting diode (LED): A solid state device that radiates light at a single frequency.

Lithographic: A planographic printing process that uses ink receptive and water receptive areas, to control what will and will not be printed.

Lpi: (lines per inch) A measure of the resolution of a halftone screen (usually between 55 and 200), referring to the frequency of the horizontal and vertical lines of dots.

Magnetographic: Printing process similar to electrophotographic except that it uses magnetic fields as opposed to electrical charges. It is not suitable for colour printing.

Maximum density: The measurement of the darkest area on film.

MHz: Megahertz

Minimum density: The measurement of the clearest area of an image on film

Monitor: Another term for a display screen.

Nanometer (nm): Unit of length equal to 10^{-9} meter, or one millionth of a millimetre, wavelengths are measured in nanometers.

Negative: In photography, film containing an image in which values of the original are reversed. In lithography; a film containing type or halftones, in which the values are reversed, whites are black and blacks.

Offset lithography: See lithography.

Optical scanner: Input device that translates images to bitmapped or raster machine-readable data.

Optical storage: The means of storing or archiving data on optical discs such as CDs or laser discs.

Output device: Any device by which computer-based information can be read by humans.

Output resolution: Stated in lines per inch or lines per millimetre, output resolution reflects the number of pixels per unit size the printer can put onto the film.

Output: Information that has been manipulated by the computer, and displayed either on the video monitor or rendered on paper or film as hard copy, or saved on disk in a digital format.

pH : Degree of acidity or alkalinity measured on a scale from 0-14, with 7 being the neutral point.

Phosphor: Substance that glows when struck by electrons.

Photomultiplier (PM): A photo cathode having extremely high stability and capable of reading low level light measurements in the entire part of the visible spectrum.

PICT: A common format for bitmapped or object-oriented images.

Pigment: An insoluble colorant, as opposed to a dye, which soluble.

Pixel: An acronym for picture element. The smallest element that can be recorded, edited and output by a digital imaging system.

Positive: In photography and lithography, a film or print containing an image in which the light and dark values are the same as the original.

PostScript: A page definition language (PDL) developed by Adobe Systems. When a page of text and/or graphics is saved as a PostScript file, the page is stored as a set of instructions specifying the measurements, typefaces, and graphic shapes that make up the page.

Ppi: (pixels per inch) A measure of the resolution of scanned images.

Ppm: Pages per minute.

Prepress: The preparation work required to turn artwork into the printing plates needed for mass production.

Primary colours: Additive primaries are red, blue and green. The subtractive primaries are cyan, magenta and yellow.

Print on-demand (POD): A process of printing documents electronically when (and where) needed, rather than printing stock ahead and storing it in advance of need.

Process colours: In printing, the subtractive primary process ink colours are cyan, magenta, yellow plus black.

Raster image (RIP): A device that translates the processor instructions for a page in a page-description or graphic output language to the actual pattern of dots supplied to a printing or display system.

Rasterization: Translation of a vector-based image to a pixel-based image.

RC paper: Resin-coated photographic paper.

Register: In printing and image assembly, the fitting of two or more images on the same exact spot.

Resolution: The measure of fineness and detail in an electronic image.

Retouching: The correction or deliberate manipulation of colour, tone or detail in an original or the scan of an original.

RGB colour model: A colour model used for devices, such as scanners and computer monitors, using the additive primary colours red, green and blue.

RGB: Red, Green, and Blue. The primary colours called 'additive' colours.

Sample: In scanning, to measure a single point on the original to create a value for a pixel in a larger bitmap. A sampled file is created from thousands of individual samples.

Saturation: A measure of the purity of a colour, determined by the amount of grey it contains.

Scan: To convert human-readable images into bit-mapped or ASCII machine-readable code.

Scanner: A device used to digitize images to be manipulated, output, or stored in a computer system.

Screen printing: Printing process which makes use of an image placed onto a fine screen, inks can either print through the screen or are blocked by the image.

Screen ruling: The number of lines or dots per inch in both directions on a contact screen to make halftones or separations. Screen rulings are available from 55 lines per inch to 200 lines per inch.

Shadows: The darkest (black and near black) colours or levels of grey in an image.

Sharpen: The process of increasing the contrast at specific points in a photographic image, where lighter and darker areas touch.

Soft proof: A proof that is seen on a colour monitor.

Spectrophotometer: An instrument that measures the characteristics of light reflected from or transmitted through an object.

Spi: Samples per inch. A measure of the optical resolution of a scan or scanner.

Substrate: The material on which a pigment or ink is laid down.

TIFF: Tag image file format. A document format developed by Aldus, Microsoft and leading scanner vendors as a standard for bitmapped graphics, including scanned images.

Toner: A dry ink powder that has been electrically charged.

Transparency: A film-based positive image that is viewed and reproduced through transmitted light.

Unsharp mask: A sharpening filter that first blurs the image around the edges of the component shapes and then subtracts the blurred values from the image. The net effect is to sharpen the definition of the image's components.

Value: A measure of the lightness or darkness of a hue. The less white in a colour, the greater its value.

Vector: A line segment of a specified length and direction.

Vector: Images defined by sets of straight lines, defined by the locations of the end points.

Vectorization: Translation of a pixel-based image to a vector-based image.

World Wide Web (WWW): The graphical portion of the Internet.

ZIP Drive: A disk drive designed and marketed by Iomega that stores 100Meg of information.

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APPENDICES

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Appendix A

Form for evaluating print anomalies of digital test prints

The aim of the questionnaire is to assess different types of digital prints, so that the print processes can be matched to fine art images. The fine art images would then be printed using the most suitable digital print process. The digital processes are not expected to mimic art techniques and processes, but it is hoped that they will provide an acceptable means to reproduce fine art images or act as an additional technique/media for fine artists to use.

The test image was recorded on a digital back and the same image was used to make each print. Some of the original objects are displayed and their colours can be compared when assessing the prints. As a number of the prints were printed free of charge, I could not dictate the substrate or the size of the prints.

Rate the first 8 questions on a scale in a range from 1 - 5. Allocation: 1 terrible, 2 bad, 3 reasonable, 4 good, 5 excellent.

Give your opinion for questions 9 & 10.

	1 terrible	2 bad	3 reasonable	4 good	5 excellent
1. Colour accuracy					
2. Tonal range					
3. Ability to render highlight and shadow detail					
4. Sharpness (ability to render fine detail)					
5. Visible dot/line/screen pattern					
6. Surface texture					
7. Size limitations					
8. Variety of substrates					

9. Possible fine art applications, what kind of fine art images would be suitable for this media.	
10. What do you feel are the limitations of the media.	

Appendix B

INTERPRETATION OF BOX AND WHISKER CHARTS

Each property is a characteristic used to identify the print anomalies. Eleven box plots were drawn to compare the printers according to these properties. The dot in the middle represents the sample mean score. The true mean score for the relevant property lies between the two extremes of the box plot with 95% confidence.

The most important observation is that it two box plots do not overlap, there is a significant difference between the two specific printers with relation to that property. The higher up the box, the better that specific printer scored for that property. If the box plot ranges over a big area, it means that the respondents gave a wide variety of gradings to the printer.

Key:

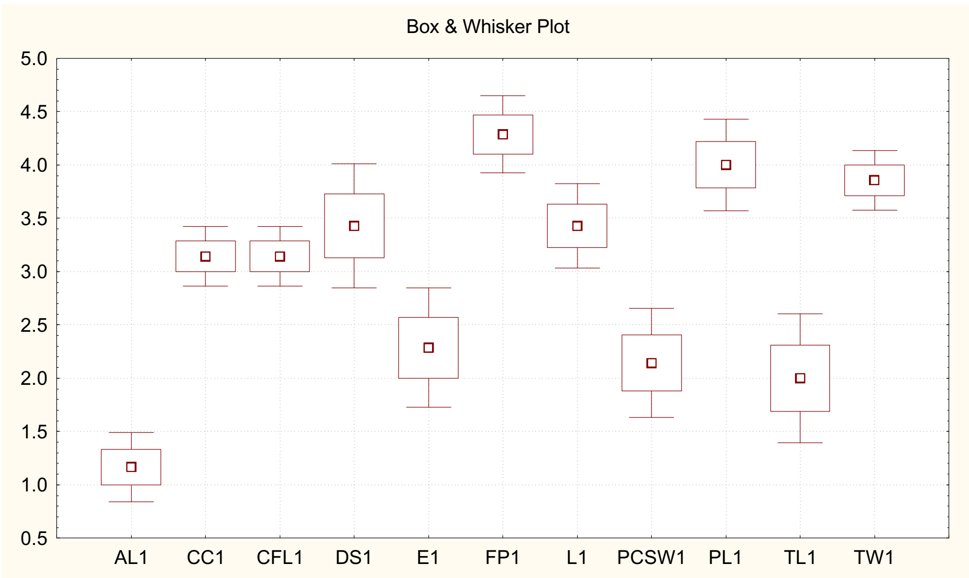
AL:	Aerosol Inkjet
CC:	Colour Copy
CFL:	Continuous Flow Inkjet
DS:	Dye Sublimation
E:	Electrostatic
FP:	Fuji Pictrography
L:	Laser
PCSW:	Phase Change Solid Wax
PL:	Piezo-electric Inkjet
TL:	Thermal Inkjet
TW:	Thermal Wax

(Bekker, personal communication, October 20, 1999)

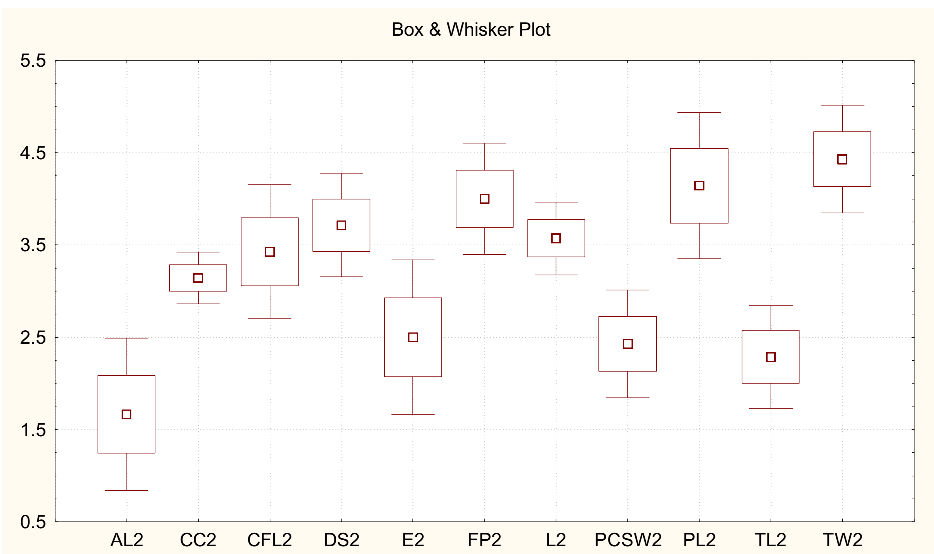
This statistical analysis was compiled by the Department of Mathematical Statistics, Port Elizabeth Technikon

Statistical analysis of eleven different printers according to eight properties

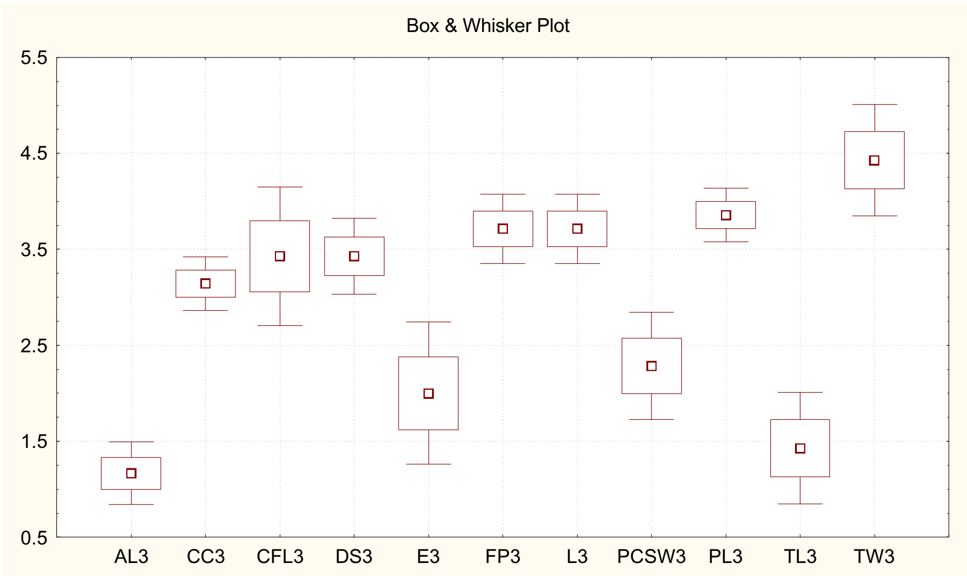
Property 1 Colour Accuracy of Printers



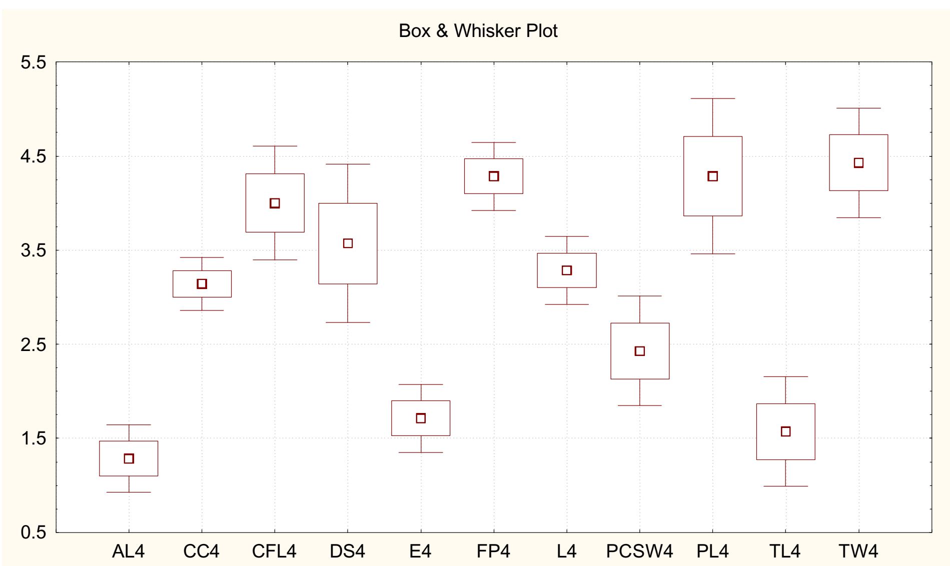
Property 2 Tonal Range



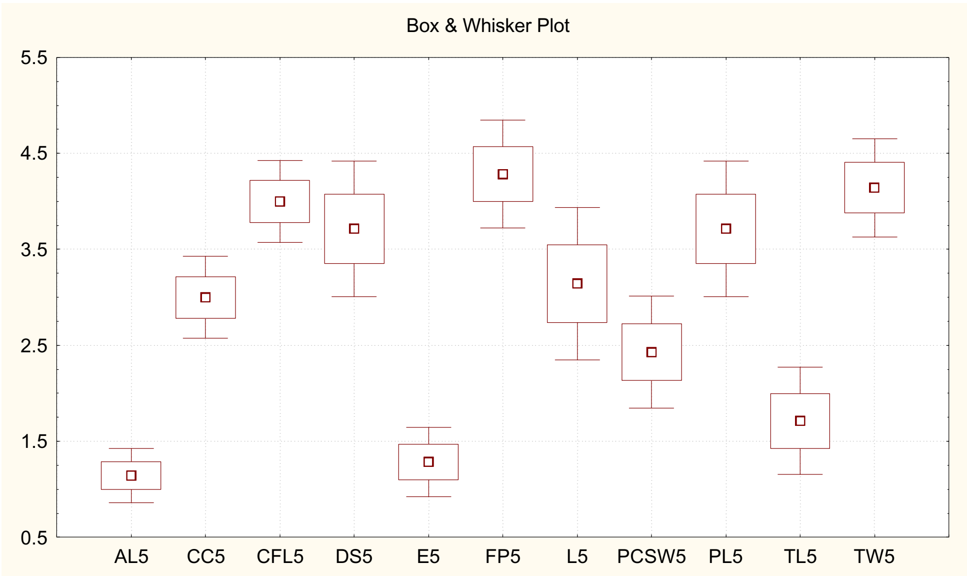
Property 3 Ability to Render Highlight and Shadow Detail



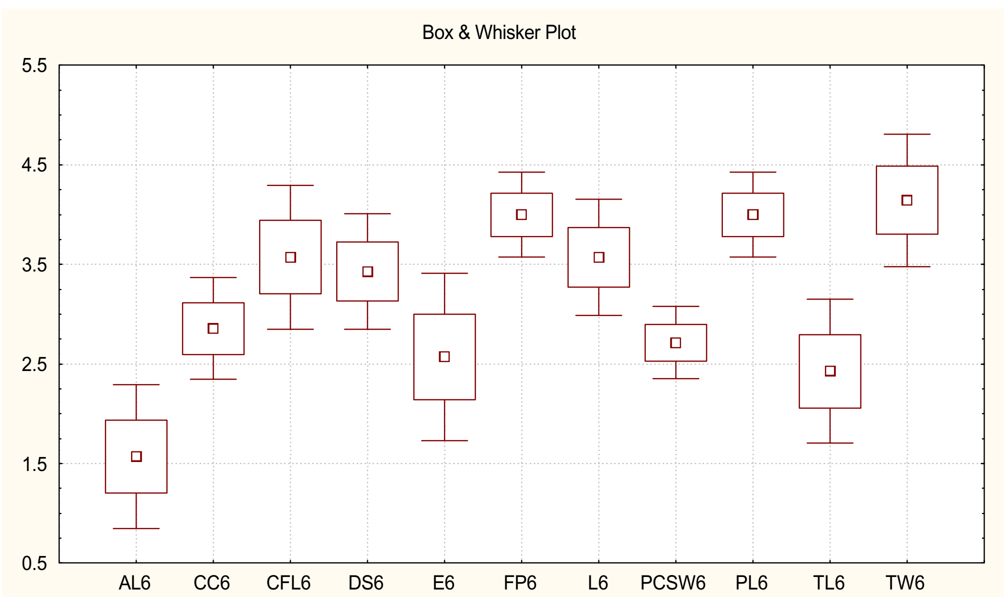
Property 4 Sharpness



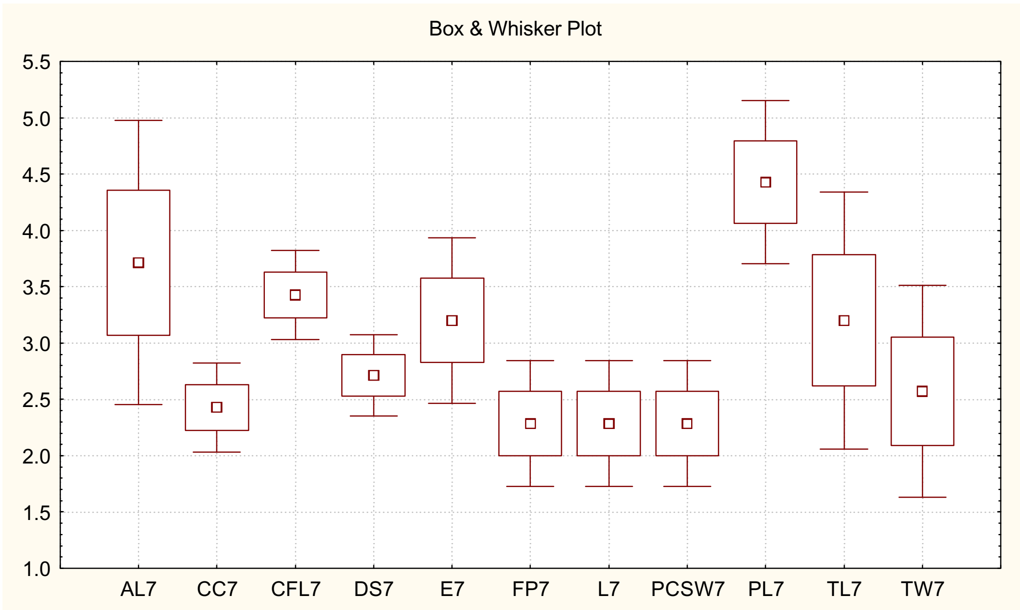
Property 5 Visible dot/line/screen Pattern



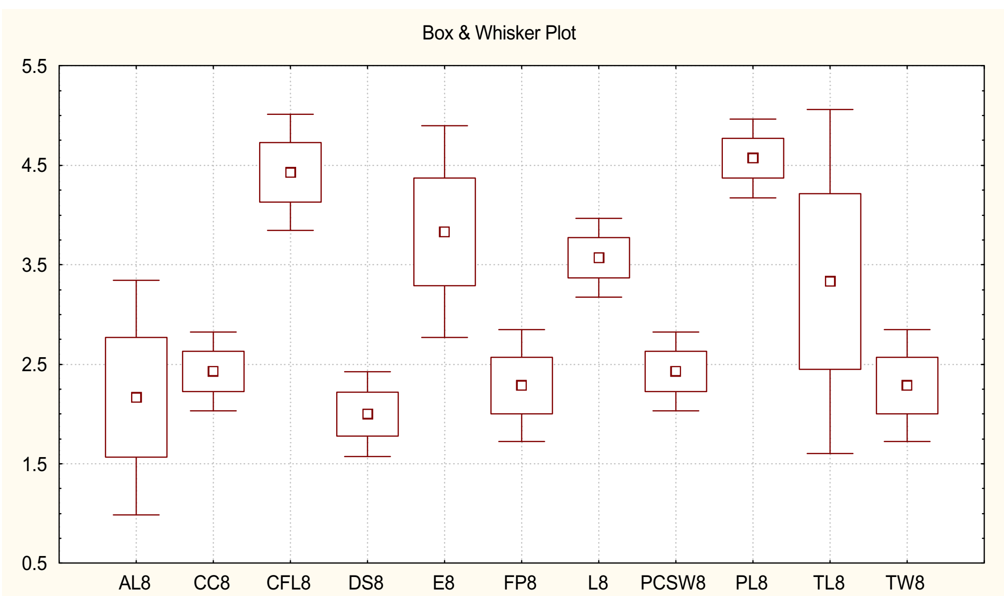
Property 6 Surface Texture



Property 7 Size Limitations



Property 8 Variety of Substrates



Appendix C

Forms used by artists to describe criteria/applications for digitally printed fine art images.

NAME OF ARTIST:	
TITLE OF WORK:	
MEDIUM/SOFTWARE PROGRAM:	
SIZE OF ORIGINAL:	
PROPOSED APPLICATION:	
PREFERED SUBSTRATE:	
PREFERED FINISHING:	
PREFERD SIZE/FINAL SIZE	

	By using an X mark a position between 0 and 9 that indicates the importance of this factor. 0 being of no importance and 9 being of critical importance
	0 9
Colour Accuracy	
Tonal Range	
Rendering of Highlight & Shadow detail	
Sharpness	
Lack of visible dot, lines or screen.	
Surface texture	
Cost	
Archival Longevity	
Criticism	

Appendix D

Example of form used to evaluate digital prints, related to the characteristics and applications suggested by the artists.

NAME OF ARTIST:	
TITLE OF WORK:	
MEDIUM/SOFTWARE PROGRAM:	
SIZE OF ORIGINAL:	
PROPOSED APPLICATION:	
PREFERED SUBSTRATE:	
PREFERED FINISHING:	
PREFERD SIZE/FINAL SIZE	

	By using an X mark a position between 0 and 9 that indicates the success of this factor. 0 unsuccessful and 9 totally successful.
	0 9
Colour Accuracy	
Tonal Range	
Rendering of Highlight & Shadow detail	
Sharpness	
Lack of visible dot, lines or screen.	
Surface texture	
Cost	
Archival Longevity	
Criticism	

The figures were derived form these forms as follows:
The range between 0 and 9 is 7 cm. Each property therefore had a value between 0 and 7 that was allocated by the artist. When the artist evaluated the digital print, they indicated how successfully the print achieved each specific property.

Appendix E

Each fine art prints evaluation. * Indicates importance of this factor, X indicates evaluation if it was less than * and O indicates that print delivered expected result.

NAME OF ARTIST:	Cleone Cull
TITLE OF WORK:	Cull2.tif Blue tree image
MEDIUM/SOFTWARE PROGRAM:	Oil painting **Thermal Inkjet**
SIZE OF ORIGINAL:	31.5 x 31.5 cm (15,796 kb)
PROPOSED APPLICATION:	Limited edition
PREFERED SUBSTRATE:	Canvas
PREFERED FINISHING:	
PREFERED SIZE/PRINT SIZE	Same as original **Final: 42.5 X 49.5cm**

	By using an X mark a position between 0 and 9 that indicates the success of this factor. 0 unsuccessful and 9 totally successful.
	0 9
Colour Accuracy	X *
Tonal Range	X *
Rendering of Highlight & Shadow detail	X *
Sharpness	X *
Lack of visible dot, lines or screen.	O
Surface texture	X *
Cost **R 130.00**	O
Archival Longevity **1 -2 years**	X *
Other criticism	

Appendix F

NAME OF ARTIST:	Cleone Cull
TITLE OF WORK:	Cull1.tif Skin tones, bell jar
MEDIUM/SOFTWARE PROGRAM:	Oil painting **Piezo Inkjet Solvent inks**
SIZE OF ORIGINAL:	34 x 39.5 cm (19,499kb)
PROPOSED APPLICATION:	**Installation**
PREFERED SUBSTRATE:	Adhesive backing/ backlit film
PREFERED FINISHING:	
PREFERED SIZE/PRINT SIZE	**49.5 x 51.2 cm**

	By using an X mark a position between 0 and 9 that indicates the success of this factor. 0 unsuccessful and 9 totally successful.
	0 9
Colour Accuracy	X *
Tonal Range	X *
Rendering of Highlight & Shadow detail	X *
Sharpness	X *
Lack of visible dot, lines or screen.	O
Surface texture	X *
Cost **R225.00**	X *
Archival Longevity **1 – 2 years**	O
Criticism	

Appendix G

NAME OF ARTIST:	Thys Cilliers
TITLE OF WORK:	Cill1. Blue image
MEDIUM/SOFTWARE PROGRAM:	Oil painting **Extended gamut Inkjet**
SIZE OF ORIGINAL:	62 x 97 cm (19.6m)
PROPOSED APPLICATION:	Promotional Poster
PREFERED SUBSTRATE:	
PREFERED FINISHING:	
PREFERD SIZE/FINAL SIZE	21 x 29 cm

	By using an X mark a position between 0 and 9 that indicates the success of this factor. 0 unsuccessful and 9 totally successful.
	0 9
Colour Accuracy	X *
Tonal Range	O
Rendering of Highlight & Shadow detail	O
Sharpness	O
Lack of visible dot, lines or screen.	X *
Surface texture	
Cost **R60**	
Archival Longevity **6 months to 1 year**	O
Criticism	
Blues problematic	

Appendix H

NAME OF ARTIST:	Mary Duker
TITLE OF WORK:	Duker4.tif Mouth B&W
MEDIUM/SOFTWARE PROGRAM:	Painter to Photoshop **IRIS Continuous flow inkjet**
SIZE OF ORIGINAL:	16 mb
PROPOSED APPLICATION:	Exhibition quality print
PREFERED SUBSTRATE:	Semi gloss
PREFERED FINISHING:	
PREFERED SIZE/FINAL SIZE	As large as file will allow **A4**

	By using an X mark a position between 0 and 9 that indicates the success of this factor. 0 unsuccessful and 9 totally successful.
	0 9
Colour Accuracy	*
Tonal Range	O
Rendering of Highlight & Shadow detail	O
Sharpness	O
Lack of visible dot, lines or screen.	O
Surface texture	O
Cost **R 172.37**	O
Archival Longevity **5 –150 years**	O
Criticism	

Appendix I

NAME OF ARTIST:	Ethna Frankenfeld
TITLE OF WORK:	Frank1.tif
MEDIUM/SOFTWARE PROGRAM:	Silkscreen, multi coloured bright **Phase change Inkjet**
SIZE OF ORIGINAL:	64.5 x 45.5 cm (27,969 kb)
PROPOSED APPLICATION:	Postcards for promotion
PREFERED SUBSTRATE:	Glossy card
PREFERED FINISHING:	Should be able to print/write on opposite side
PREFERD SIZE/FINAL SIZE	Post card **20 x 28 cm**

	By using an X mark a position between 0 and 9 that indicates the success of this factor. 0 unsuccessful and 9 totally successful.
	0 9
Colour Accuracy	O
Tonal Range	X *
Rendering of Highlight & Shadow detail	O
Sharpness	O
Lack of visible dot, lines or screen.	O
Surface texture	*
Cost **R12**	O
Archival Longevity **18 - 28 years**	O
Criticism	

Appendix J

NAME OF ARTIST:	Mary Duker
TITLE OF WORK:	Duker3.tif
MEDIUM/SOFTWARE PROGRAM:	Painter to Photoshop **Dye sublimation**
SIZE OF ORIGINAL:	5,629 kb B&W Figure
PROPOSED APPLICATION:	Exhibition Print
PREFERED SUBSTRATE:	Semi gloss **Gloss**
PREFERED FINISHING:	None
PREFERED SIZE/FINAL SIZE	Dictated by file size. **A4**

	By using an X mark a position between 0 and 9 that indicates the success of this factor. 0 unsuccessful and 9 totally successful.
	0 9
Colour Accuracy	*
Tonal Range	*
Rendering of Highlight & Shadow detail	*
Sharpness	O
Lack of visible dot, lines or screen.	O
Surface texture	O
Cost 21 x 29 cm **R 110**	*
Archival Longevity **6months**	X *
Other criticisms	

Appendix K

NAME OF ARTIST:	Mary Duker
TITLE OF WORK:	Duker2.tif Landscape colour **Thermal Wax**
MEDIUM/SOFTWARE PROGRAM:	Painter to Photoshop
SIZE OF ORIGINAL:	1,650 kb
PROPOSED APPLICATION:	Exhibition quality print
PREFERED SUBSTRATE:	Semi gloss
PREFERED FINISHING:	
PREFERD SIZE/FINAL SIZE	As large as file allows

	By using an X mark a position between 0 and 9 that indicates the success of this factor. 0 unsuccessful and 9 totally successful.
	0 9
Colour Accuracy	X *
Tonal Range	X *
Rendering of Highlight & Shadow detail	O
Sharpness	O
Lack of visible dot, lines or screen.	O
Surface texture	O
Cost **R35**	*
Archival Longevity **3 – 5 years**	X *
Criticism	
Lightness of paper problematic for exhibition purposes	

Appendix L

NAME OF ARTIST:	Cleone Cull
TITLE OF WORK:	Cull2.tif Blue tree image
MEDIUM/SOFTWARE PROGRAM:	Oil painting **Colour transparency to Ilfochrome**
SIZE OF ORIGINAL:	31.5 x 31.5 cm (15,796 kb)
PROPOSED APPLICATION:	Installation
PREFERED SUBSTRATE:	
PREFERED FINISHING:	
PREFERED SIZE/PRINT SIZE	**Final: 19.1 x 22 cm**

	By using an X mark a position between 0 and 9 that indicates the success of this factor. 0 unsuccessful and 9 totally successful.
	0 9
Colour Accuracy	X *
Tonal Range	X *
Rendering of Highlight & Shadow detail	X *
Sharpness	X *
Lack of visible dot, lines or screen.	O
Surface texture	O
Cost **R 142.28**	X *
Archival Longevity **29 years**	O
Other criticism	

Appendix M

NAME OF ARTIST:	Eugene Pienaar
TITLE OF WORK:	EP1.tif
MEDIUM/SOFTWARE PROGRAM:	35 B&W negative to **Photoshop** **Imagesetter to colour photo print**
SIZE OF ORIGINAL:	
PROPOSED APPLICATION:	Exhibition, sale, portfolio
PREFERED SUBSTRATE:	Gloss photo paper
PREFERED FINISHING:	
PREFERED SIZE/FINAL SIZE	A4

	By using an X mark a position between 0 and 9 that indicates the success of this factor. 0 unsuccessful and 9 totally successful.
	0 9
Colour Accuracy	O
Tonal Range	O
Rendering of Highlight & Shadow detail	O
Sharpness	X *
Lack of visible dot, lines or screen.	O
Surface texture	O
Cost **R40**	O
Archival Longevity **12 years**	O
Criticism	

Appendix N

NAME OF ARTIST:	Thys Cilliers
TITLE OF WORK:	Cill1. Blue image
MEDIUM/SOFTWARE PROGRAM:	Oil painting **Fujix Print**
SIZE OF ORIGINAL:	62 x 97 cm (19.6m)
PROPOSED APPLICATION:	Promotional portfolio
PREFERED SUBSTRATE:	Glossy paper
PREFERED FINISHING:	
PREFERD SIZE/FINAL SIZE	Fit on A4 **14.3 x 19.5 cm**

	By using an X mark a position between 0 and 9 that indicates the success of this factor. 0 unsuccessful and 9 totally successful.
	0 9
Colour Accuracy	X *
Tonal Range	X *
Rendering of Highlight & Shadow detail	O
Sharpness	O
Lack of visible dot, lines or screen.	O
Surface texture	*
Cost **R 47.00**	X *
Archival Longevity **NA**	*
Criticism	
Poor yellows and no greens	

Appendix O

NAME OF ARTIST:	Mary Duker
TITLE OF WORK:	Duker1.tif Solid black BG, some colour **Laser**
MEDIUM/SOFTWARE PROGRAM:	Painter to Photoshop
SIZE OF ORIGINAL:	994 kb
PROPOSED APPLICATION:	Exhibition quality print
PREFERED SUBSTRATE:	Semi gloss
PREFERED FINISHING:	
PREFERD SIZE/FINAL SIZE	As large as file allows **20 x 28 cm**

	By using an X mark a position between 0 and 9 that indicates the success of this factor. 0 unsuccessful and 9 totally successful.
	0 9
Colour Accuracy	O
Tonal Range	O
Rendering of Highlight & Shadow detail	X *
Sharpness	O
Lack of visible dot, lines or screen.	O
Surface texture	O
Cost **R10**	O
Archival Longevity: **Indefinite**	O
Criticism	
Paper too flimsy for exhibition purposes	

Appendix P

NAME OF ARTIST:	Ethna Frankenfeld
TITLE OF WORK:	Frank2.tif
MEDIUM/SOFTWARE PROGRAM:	Etching B&W **Colour Copy**
SIZE OF ORIGINAL:	33 x 35 cm (23,694 kb)
PROPOSED APPLICATION:	Promotion
PREFERED SUBSTRATE:	Good quality Fabriano type paper
PREFERED FINISHING:	Must be able to write on it
PREFERD SIZE/FINAL SIZE	Small A4

	By using an X mark a position between 0 and 9 that indicates the success of this factor. 0 unsuccessful and 9 totally successful.
	0 9
Colour Accuracy	*
Tonal Range	O
Rendering of Highlight & Shadow detail	O
Sharpness	O
Lack of visible dot, lines or screen.	X *
Surface texture	X *
Cost **R15.00**	O
Archival Longevity: **Indefinite**	O
Criticism	