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The life and cost of inkjet prints compared with traditional photographic processes

Irvine Alfred Caleb Meyer
Cape Peninsula University of Technology

THE LIFE AND COST
OF INKJET PRINTS COMPARED WITH TRADITIONAL PHOTOGRAPHIC PROCESSES

By

IRVINE ALFRED CALEB MEYER

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DECLARATION

The contents of this dissertation represent my own work, and the opinions contained therein are my own and not necessarily those of the Technikon. All references have been accurately reported.

Name: Irvine Alfred Caleb Meyer

Signature:

Date: January 2004

This dissertation is dedicated to the memory of my parents. Their images will never fade.

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I wish to thank my family who sacrificed a husband and a father for the duration of this study. This time will be repaid tenfold and gourmet cooking will be resumed.

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THE LIFE AND COST OF INKJET PRINTS COMPARED WITH TRADITIONAL PHOTOGRAPHIC PROCESSES

By

Irvine Alfred Caleb Meyer

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Supervisor: Dr. Theodore Conrad Haupt
Faculty: Engineering
Major Department: Graphic Design

Inkjet printers have evolved in recent years to the extent that many are capable of making prints of a quality closely approximating traditional colour photographs. These printers cost a fraction of the capital outlay needed to equip a traditional colour darkroom and have brought high quality colour printing within the reach of a broad spectrum of users. As they are capable of printing on a wide range of materials and print surfaces prints from inkjet printers are also in demand by fine artists and art collectors. Commercial printmakers, artists, photographers, and amateurs printing in their homes or offices use these printers. The convenience, ease, and quality of inkjet printing have made it a popular additional and alternative photographic printing technique.

However, manufacturers seldom publish data regarding the expected life of the printer output. With traditional colour photographs end users expect some fading to take place with time and can normally have another print made from the original negative. Digital images rely on storage on compact disk or computer hard drive with potential long-term retrieval problems, and it is vital that important images be output in print form on the most stable materials.

This study arose from the author's concern about the archival qualities of photographs in general.

In order to enable end users to make more informed choices about the most suitable printing medium, this study explored two aspects concerning traditional photographs and inkjet prints, namely cost and image permanence. The comparative costs were found by means of a questionnaire survey conducted among a representative sample of printmakers. The limits of image permanence were determined by subjecting sample prints to a high-intensity light source to accelerate the process of image fading over time to the point where the print becomes unacceptable.

The investigation showed that inkjet prints are more expensive than traditional photographs, and that inkjet prints made with pigment inks can last twice as long as traditional photographs.

Different inkjet papers were found to have no significant effect on the life of the print during the period of this test.

Inkjet prints made with dyes were shown to have a short life before fading unacceptably.

The study led to the recommendation that for the longest print life a print to be displayed should be printed on an inkjet paper with pigment inks.

CHAPTER 1
INTRODUCTION

Awareness of the problem

Many photographers are using inkjet printers such as shown in Figure 1.1 for small volume in-house colour printing (Menezes, 2000). In conjunction with image-editing computer software programs total control is allowed over the full printing process for a small capital outlay compared with traditional photographic printing in which dyes linked to exposed silver-halide crystals are rendered visible in a highly controlled chemical process. In addition these photographers have the choice of a wide range of printing papers and surface textures to choose from.

Figure 1.1. Desktop inkjet printer

Commercial inkjet printmakers use wide-format inkjet printers such as shown in Figure 1.2 to print images of 600mm width or more.

Figure 1.2. Wide-format inkjet printer

Regardless of whether a photographer uses a digital camera or conventional film, many images are stored on compact disk (CD) or computer hard disk drives. In the case of digital camera users it is the most feasible and cost effective way to store collections of images. An increasing number of traditional film users are digitising their images by scanning from film and print to collate collections for easy reference, sales distribution on the World Wide Web, and computer restoration of damaged images (Shreve, 2002). Increasingly, art photographers are exploring the different surface textures and materials available with inkjet printers as opposed to traditional photographic printing paper because of:

- Variety of printing media and surfaces;
- Personal control over reproduction;
- Perceptual quality of images; and
- Precise reproduction of hand-worked photographs.

Manufacturer Siemens first patented inkjet-printing technology in 1951. After the introduction of printer manufacturer Epson’s range of photo-quality inkjet printers in 1994, many other manufacturers have followed suit. These manufacturers produce relatively inexpensive inkjet printers capable of producing a visual quality indistinguishable from a traditional photograph at normal viewing distances. The human eye is considered to have a resolution of 5 to 6 lines per millimetre (lpmm) at a viewing distance of 300mm (Langford, 1992), equivalent to a resolution of 254 to 305 dots per inch (dpi). To produce a resolution emulating a traditional photograph an inkjet printer needs to be able to print at a resolution between 250 to 300 dpi.

Manufacturers seldom publish data regarding the expected life of prints produced by their printers. Consequently neither the printer operator nor the client has certainty of the expected print life. This situation holds clear unreliability issues for any potential purchaser of these images. Print life is taken as the time before noticeable fading takes place, such as for example a 30% reduction in the dye starting reflection density, under normal viewing conditions of 300 lux for 8 hours per day, a lux being a unit of illuminance equal to one meter candela.

Some of the key findings of research in the United States of America (U.S.A.) regarding the life of inkjet prints are that paper type, surface, and ink types can influence the print life greatly. For example the same ink printed on an acid-free watercolour paper may have a life of 10 to 20 times of that printed on a glossy paper (Wilhelm, 1999). Depending on the ink, paper surface and base material, the print life can vary from 0,6 years to >100 years (Wilhelm, 1999).

In the South African (S.A.) context consumers are arguably not as sophisticated or critical as in Europe and the U.S.A. and are potentially more liable to acceptance of an inferior product. A further area of concern in SA is the proliferation of low-cost refilled inkjet cartridges with non-Original Equipment Manufacturer (OEM) inks. These non-OEM inks are promoted and used mostly because of their low cost. It is important for the archival qualities of these inks to be tested. Initial testing in the U.S.A. has shown that certain non-OEM inks may produce prints with a display life between 0,54% and 14,8% of prints made with OEM ink (Littman, 2003). Publication of the results of such tests will serve to inform the consumer as well as the inkjet print producer.

The importance of print longevity

There are several reasons why print longevity is important:

1. Collectors of fine-art photographs need to know that their investments are safe and appreciating. An example of this is given by Howard Chapnick who recorded the escalating trend in fine-art B&W prints during a sales boom in the U.S.A. from February 1978 to May 1980 (Chapnick, 1980.) During that time photographer Ansel Adams' *Moonrise Over Hernandez* prints increased in price from South African Rand (ZAR) 2,399 to ZAR 16,000, and prints by André Kertéz and Arthur Fellig doubled in value. On May 14, 1980, Christie's East auctioneers sold an 1848 daguerreotype by Albert Sands Southworth for ZAR 36,000 (see Figure 1.3.). Daguerreotype was the first photographic process in the world, published in Paris, France, 1839 (Keefe and Inch, 1990).
2. Prints need to be preserved for historic or documentary purposes, communicating images of the past (see Figure 1.4.). In this regard black-and-white (B&W) photographs that have not been physically damaged exist since the invention of the medium in 1839 (Daniels, 1978.)
3. A further reason is to perpetuate memories of people, places and events holding an emotional significance to a person or group.

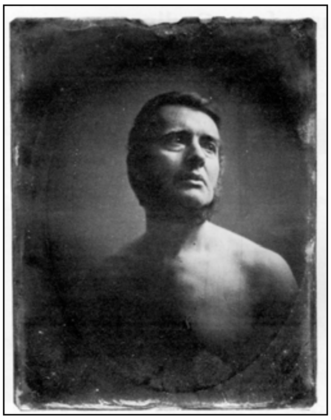

Figure 1.3. Daguerreotype by Albert Sands Southworth (circa 1848.)

Figure 1.4. French soldiers in the field, Jean Tournassou (circa 1915.) (Life Library of Photography, 1973.)

Whereas properly stored B&W images have been shown to have a very long life because the image is made up of metallic silver (Keefe and Inch, 1990), the situation with colour images on film and dye is different. Colour prints from as recent as 50 years ago have faded and changed colour fairly rapidly. Cibachrome (© Ilford, United Kingdom) was marketed as having a very high level of permanence. However Henry Wilhelm showed a test life of 29 years before noticeable fading took place (Wilhelm and Brower, 1993.) His testing suggested that the most permanent colour printing photographic paper currently available would be Fuji Crystal Archive paper with a display life estimated to be greater than 60 years (Wilhelm, 2002.) However, no data exist from studies conducted that confirm this assertion.

Because an increasing number of photographers today are using digital cameras, the life of these images is of concern. Digital images may be stored on magnetic media with the inherent risk of damage or loss. A popular option is storage on CD, but the life of a CD has not been scientifically tested. The computer file types used to store the images, usually JPEG (Joint Photographic Experts Group) or TIFF

(Tagged Image File Format) undergo frequent change (McClelland, 1998). Further, all stored images require constant updating to ensure compatibility with computer software. Computer hardware and software may still be able to open digitally stored image files in 10 to 20 years. However, it is uncertain that compatible software and hardware will exist in 50 to 200 years time. It is therefore imperative that important digital images should be printed to the highest level of archival permanence.

Jenn Shreve (2002:72) cites Katrin Eismann[1]:

> "You have to keep the original piece of film. We're here in 2002, and we are responsible for the people who come after us. Who knows what kind of technology we're going to have? We need that original record. The veracity of the original film cannot be overestimated."

This statement suggests that Sustainable Photography may be defined as photographic processes that meet the needs of the present without compromising the ability of future photographic users and producers to meet their own needs.

The problem statement

The end user has insufficient information regarding the life and cost of inkjet prints compared with traditional photographic prints to make an informed decision about which process to use for optimal benefit.

Hypothesis

The hypotheses to be tested in this study are:

- The price of high quality inkjet prints exceeds that of traditional photographic colour prints;
- The life of an inkjet print, as defined earlier, varies depending on the paper/ink combination;

[1] Katrin Eismann is an internationally respected lecturer and teacher of imaging, restoration and retouching, and the author of several books on digital retouching of images.

- The life of traditional photographic colour prints varies according to the type and quality of the paper used; and
- The life of a print produced using traditional prints photographic processes does not vary according to the paper used as much as do inkjet prints.

Objectives

The objectives of the study may be stated as:

- To conduct a cost-analysis of high quality inkjet printing in order to establish their cost effectiveness or feasibility as an alternative to traditional photographic colour printing;
- To test the life of various inkjet print/paper combinations compared with traditional photographic colour print materials in order to determine if inkjet prints have an adequate life for their intended purpose; and
- To test the life of traditional photographic colour papers by different manufacturers to determine which displays the least fading in order to establish a comparison with the life of inkjet prints produced using these papers.

Methodology

To achieve the objectives of the study the following methodological approach will be followed:

- A short questionnaire will be designed and used to obtain comparative cost data relative to inkjet prints and traditional photographic colour prints. The analysis of this data will provide a direct comparison of inkjet and traditional photographic colour print prices produced by professional printers and laboratories. This will establish if there is a cost benefit in using one process rather than the other.

- By means of an experimental design approach print density data will be collected from print samples subjected to an accelerated light fade test. The test will comprise exposure to a light source approximately 120 times more intense than normal viewing conditions as discussed before. The baseline data will be the maximum reflection densities obtained before testing begins for both inkjet and traditional photographic prints. The variable data will be the changes in reflection densities over time. Data will be plotted on graphs to indicate the end points of acceptability. Findings will be analysed to make possible recommendations.

Limitations

The study is subject to several limitations. These are as follows:

- Since the available funding does not allow for an air-conditioned environment to conduct the tests the air temperature will be monitored manually. A test will be included to measure the influence of temperature on ink fading.

- In the absence of a humidity control instrument the relative humidity (RH) will not be controlled. High RH has been shown to be a key contributor to print deterioration because of mould formation (Wilhelm and Brower, 1993). The prevailing test conditions will imitate normal display conditions in an environment without RH control, such as most homes, galleries, and offices.

- Due to funding constraints use will be made of a reflection densitometer at a commercial laboratory in Cape Town, S.A.

- Depending on the total light intensity available, time may be a limiting factor in achieving long-term fading simulation.

- The test inkjet prints will be produced on the following printers:

- Hewlett-Packard (HP) OfficeJet Pro 1150C, using HP dye inks;
- HP 895cxi, using non-OEM dye inks;
- HP CP1700, using HP pigment inks;
- Epson Stylus Color 480sxu, using Epson dye inks;
- Epson Stylus Photo 2100, using Epson pigment inks; and
- Epson Stylus Photo 1200, using MIS Inksupply Inc. pigment archival inks.

- Traditional photographic colour prints will be produced on:

  Fuji Crystal Archive paper, using a Fuji Frontier processor; and

  Agfa Prestige Digital paper, using an Agfa D-Lab 2 processor.

Delimitations

The scope of the research is subject to the following delimitations:

- While reference might be made to Photographic Quality the concept is not examined or discussed in any detail.

- The term "inkjet" is used throughout this document in preference to "giclée." Inkjet printing is sometimes referred to as giclée printing from the French word meaning "to spurt, or ejaculate." The word has not been universally adopted (Johnson, 2002).

- No comparisons will be made regarding inkjet printing replacing traditional photographic colour processes in the printing of postcard-sized prints by the minilab industry. The research information is intended to advise users on the expected costs and display life of enlargements.

- The effect of reciprocity in accelerated fade testing will not be studied in depth, but trends will be investigated.

- The effect of ultra-violet (UV) light on print life will not be investigated as all test prints will be protected from UV light by filtering the light source through clear glass, emulating normal display conditions in which prints are framed under glass.

- This study will not investigate the image permanence of traditional photographic black-and-white prints.

Assumptions

The assumptions that impact the study are as follows:

- Inksets for inkjet printers are consistent in their chemical structure and the reflection densities they produce.

- Inkjet paper surface absorption is consistent. The depth of absorption is a key contributor to degradation by air-borne chemicals of the ink dyes or pigments.

- Photographic laboratories process their prints to a consistent level of purity to minimise residual processing chemicals, which contribute to image and print support base degradation.

Structure of the study

The dissertation is structured as follows:

Chapter 1: Introduction

This chapter gives a general synopsis of the research problem. In addition it briefly describes the background, research question, objectives and methodology.

Chapter 2: Overview of technology

The concepts of technology related to the research problem are discussed. Theories and previous research done in the field are investigated in detail. Criteria for image illumination and permissible image fading are discussed.

Chapter 3: Methodology

This chapter describes the methodology followed to achieve the objectives of the study.

Chapter 4: Data Analysis

In this chapter the collected data are analysed and discussed.

Chapter 5: Summary, Conclusions and Recommendations

This chapter summarises the research findings, makes recommendations for future research, and concludes the study.

CHAPTER 2
OVERVIEW OF TECHNOLOGY

Traditional photographic processes

A distinction has to be made between the production of inkjet prints and traditional photographic prints in order to understand issues of image life. In traditional black-and-white (B&W), or monochrome photographic printing the process is as follows:

The entire process takes place in a printing laboratory illuminated by a dim light (safelight) filtered to a colour to which the printing paper is insensitive. Photographic paper and film have a similar construction in which a light-sensitive emulsion of various silver halides suspended in gelatine is bound to a support base. In film the base is a transparent plastic, in printing paper it is either a normal fibrous paper base (Fibre-based, or FB paper), or paper sealed on both sides surfaces with a thin resin layer to reduce chemical adsorption (Resin coated, or RC paper). Silver halide crystals are not soluble in water.

A negative film image is optically projected onto a sheet of photographic paper for the correct duration of time (exposure) required to create an invisible latent image. This sheet is immersed in a developer liquid consisting of developing agents such as metol (*p*-methylaminophenol sulphate), phenidone (1-Phenyl-3-pyrazolidinone), and hydroquinone (1,4-dihydroxybenzene) dissolved in an activating alkaline solution. The developing agents reduce the exposed silver halide crystals to their metallic state, silver, and the freed halides are given off as a gas. Development is complete after 1 to 3 minutes at 24°Celsius.The print is then inserted into a stop-bath of 2% glacial acetic acid solution to counter the alkalinity carried over from the developer and immediately stop development. The third chemical bath is the fixer, sodium or ammonium thiosulphate dissolved in a mild buffered acid solution, which converts the remaining undeveloped silver halides into soluble silver thiosulphate. Finally the print is washed in clean running water for 4 minute for RC paper, or 1 hour for FB paper to remove residual chemicals before being air-dried.

Colour printing is based on the same principles as monochrome, with the following additions:

The paper comprises three emulsion layers, each layer consisting of a silver halide and gelatine emulsion with a fine suspension of invisible dye couplers on a RC base, as shown in Figure 2.1.

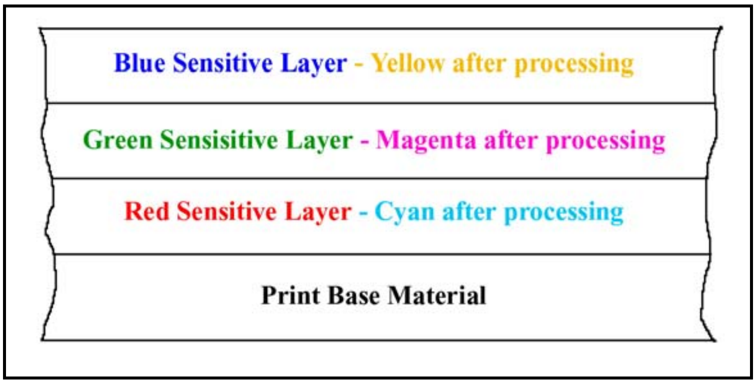

Figure 2.1. Simplified cross-section of colour Photographic paper.

Notably, the top layer is sensitive to blue light only, producing a yellow dye image; the middle layer is sensitive to green light only producing a magenta dye image; and the bottom layer is sensitive to red light only producing a red dye image.

The laboratory is lightless during exposure. Once exposure has taken place and the paper fed into an automated processor normal lighting can be resumed. During the first chemical stage of development, B&W developing agents reduce the exposed silver halides to their metallic state. Exhaustion products of this development process are detected by the colour developing agent paraphenylenediamine, which react locally with the dye-couplers, rendering the dyes visible (Stroebel et al., 1985). The process takes place at a high and stable temperature to maintain an identical contrast in each of the three layers. If this were not the case localised colour shifts called crossed curves may occur giving rise to inaccurate colours. The next step is bleaching and fixing in the image in a ferricyanide solution containing ammonium thiosulphate. The metallic silver is converted into a silver ferrocyanide, which is further converted to a soluble silver thiosulphate and diffused into the solution, leaving only the visible dyes in the emulsion. After washing in a chemical stabiliser or clean water to remove residual chemicals the print is air-dried.

Small processors called Mini-Labs, such as shown in Figure 2.2, are in common use offering a one-hour throughput from the time the exposed film is inserted into a special chamber until the dry prints emerge. However, these machines offer the client, whether professional or display users, no control. More sophisticated processors in use by professional laboratories are extremely expensive, with prices ranging between ZAR 80,000 to more than ZAR1,000,000.

Figure 2.2. Agfa D-Lab2 minilab processor.

Inkjet printing process

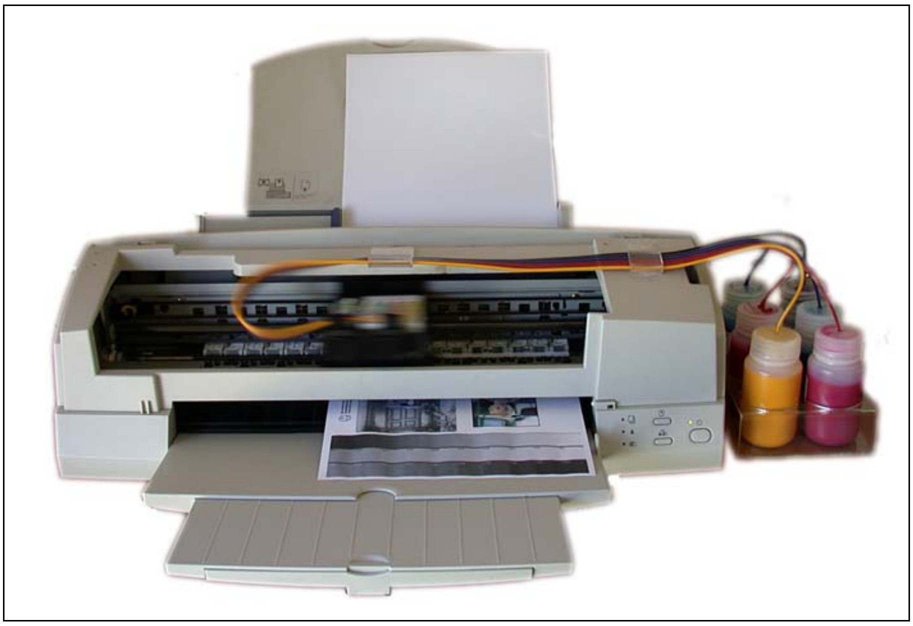

Figure 2.3. Epson Stylus Photo 1200 inkjet printer fitted with a continuous flow inking system.

Inkjet printers such as shown in Figure 2.3 operate on a desk environment connected to a computer in normal room lighting. They release minute droplets of ink from a series of nozzles in the printhead, directly onto the printing material surface where they dry by evaporation. Ink is fed directly by gravity from a cartridge mounted on the printing carriage to the printhead from where the droplets, varying in size from 50 to 60 microns, are ejected either as thermal bubbles or piezo-electrically controlled jets. Each colour, usually cyan, magenta, yellow, and black (CMYK) has its own ink cartridge and printhead. Some printers utilise extra magenta and yellow (and in the case of the Epson 2100 printer black) cartridges, totalling 6 or 7.

The printhead carriage travels transversely over the paper spurting ink on demand. After each complete movement the paper is advanced automatically and printing continues. Printers are capable of printing from 360 to 2 880 dots (of ink) per linear inch (dpi).

Digital images are made up of pixels representing the different colours and tones of the image, as opposed to the silver or dye particles in conventional photographs. During inkjet printing different sizes of droplets and different colour combinations can be sprayed on the same pixel, giving rise to up to 4 096 colour variations closely emulating the continuous tone of conventional photography (Curtin, 2003). Since the human eye is considered to have a resolution of 254 to 305 dpi, to produce a resolution emulating a traditional photograph an inkjet printer does not need to print at a resolution higher than 250 to 300 dpi if there are enough colour combinations. When printer manufacturers claim printing resolutions of 1 440 or 2 880 dpi this relates to dpi combined with over-sprayed colour combinations (Curtin, 2003.)

Inks

There are several requirements for inks used in inkjet printing apart from matching colour specifications. These include:

- The ink should not penetrate so deeply into the medium that it can be seen from the back. Whereas this reduces drying time, risk of smearing and inter-colour bleed, it also reduces image resolution (Vogt, 2001).
- The ink should not fade when exposed to light or be adversely affected by water (Littman, 2003).
- The ink formulation must allow stable drop formation (Vogt, 2001).
- The ink should not show any adverse chemical reaction with the printhead components (Vogt, 2001).
- The ink must not pose any health or safety problems or support microbial growth (Vogt, 2001).

Dyes contain a system of conjugated carbon double bonds. A compound is coloured due to the presence of particular groups, namely the chromophores and auxochromes, which must be linked to a system of conjugated double bonds. Chromophores are divided into chromophores and antiauxochromes. Auxochromes are electron donors. Antiauxochromes are electron acceptors. Chromophores are linear or cyclic systems of conjugated double bonds. The system is sometimes called a chromogen.

Organic compounds (that is to say carbon-based) become coloured by absorbing electromagnetic radiation from the visible spectrum. All the molecules have electron-filled and empty orbitals and the light energy received from the electromagnetic spectrum is absorbed by the colourant molecule to promote an electron from its stable state into an orbital of higher energy (Vogt, 2001). This energy gap determines the colour of the substance (Nelkon and Parker, 1971).

Dye and pigment inks.

Dye crystals are less stable than pigments because the intermolecular forces binding them together are weaker than in pigments. This lack of stability has an advantage in that they can be easily broken up into extremely small particles in a solvent, producing a very fine range of colours (gamut).

Pigments, however, have strong intermolecular forces leading to stable crystals with high lattice energy. They are solid particles that have to be solubilised by using a dispersant to act as a bridge between the solvent of the ink and the pigment's surface molecules. Initially pigments were not used in inkjet printing because of their solubility problems and because they could not match the gamut of dyes. However, continual improvements in design have led to pigmented inks closely approaching the gamut of dyes.

Pigments are more resistant to fading caused by light mainly because there are more chromophores in the pigment particles than in the dye molecules. Light breaks up the chromophores in both dyes and pigments. However the pigment lasts longer because the decomposition of chromophores is less over the same amount of time. Dye molecules have a larger proportion of surface area compared with pigments in which only the surface molecules are affected by electromagnetic radiation. The disadvantage of pigments is that their larger size leads to light scattering on the surface reducing colour saturation and gamut (Vogt, 2001).

Inkjet papers.

Plain papers are not suitable for high quality photographic inkjet printing. They consist mainly of cellulose fibres, which cause ink movement through capillary action, leading to a decrease in sharpness. For this reason paper surfaces are sized to seal the surface fibres and modify the absorption characteristics. Common sizing materials include gelatine, starch, latex, alumina, silica, clay, titanium dioxide, polyvinyl alcohol, and polyvinyl acetate. Whitening agents such calcium carbonate and titanium dioxide are also added (Lavery, 2000).

These coatings serve to improve image sharpness, reduce colour bleed, facilitate ink drying, and improve colour gamut. Some inks, especially pigment based, can have difficulties in penetrating certain paper surfaces, causing them to reside on the paper surface, leading to smudging and poor ink spread. It is therefore important to match ink and paper for optimal results (Lavery, 2000).

Standards for permissible image fading

All colour photographs will fade in time, some more rapidly than others (Wilhelm and Brower, 1993). Agfacolor Paper Type 4, purportedly the worst photographic colour paper ever manufactured, was produced between 1974 and 1982. Its very rapid fading in both light and dark conditions culminated in a nationwide class-action lawsuit in the U.S.A. brought against Agfa by processing laboratories and professional photographers (Wilhelm and Brower, 1993). This raised the awareness of consumers about the importance of information about the permanence of photographs. The beginning of the modern era of photographic preservation in which scientific exploration of the complex deterioration of photographic materials came to the fore was in 1978 during the annual conference of the Society of Photographic Scientists and Engineers (now known as the Society for Imaging Science and Technology, IS&T) during a session called "Stability and Preservation of Photographic Materials" This gradually led to the development of improved international standards for measuring image stability. The first standard for testing colour stability was established in 1969. It was based on work done by Kodak during the 1950's and 1960's, but never became popular. Kodak, other manufacturers, and independent laboratories abandoned it finally during the 1980's. (Wilhelm and Brower, 1993).

In 1991 the American National Standards Institute (ANSI) replaced the standard ANSI PHI.42-1969 with ANSI IT9.9-1990, *American National Standard for Imaging Media – Stability of Color Images – Methods for Measurement.*

This is still the current standard for image permanence, with additional sections dealing with related issues such as the stability of motion picture film, microfilm, and film storage. In 1993 ANSI IT9.9-1990 was released as an ISO (International Standards Organisation) Standard (Wilhelm and Brower, 1993). This Standard, ISO 10977, is undergoing further changes to deal with issues such as water-fastness, humidity-fastness, thermal degradation, indoor stability, and outdoor stability (Vogt, 2001).

Henry Wilhelm is one of the founding members of the American National Standards Institute subcommittee established in 1978 to write the ANSI IT9.9-1990 Standard on test methods for measuring the stability of colour photographs. He started image permanence tests on colour photographs in 1982 at the Preservation Publishing Company research facility in Grinnell, Iowa, U.S.A. (Wilhelm and Brower, 1993).

Wilhelm (1993: 65-66) states:

> "Neither the old nor the new [ANSI] Standard specifies limits of acceptability for dye fading, color balance shift, or stain formation. Although the new Standard makes use of a set of limits (called "image-life end points" in the Standard) for illustrative purposes, the values given are not part of the Standard, and this is clearly stated in the document. Determining a set of limits for a particular application…is left entirely to the user. For several reasons this is not a very satisfactory situation. With no agreement as to how much fading, color balance change, and staining can be tolerated in common applications, different people using the Standard likely will come up with highly divergent image-life predictions for a particular product stored or displayed in exactly the same way. This will make it difficult to compare product stability data from different testing labs, and could result in confusion for everyone.
> Despite the lack of specific fading and staining limits, the Standard does specify a common format for reporting data and requires that the values chosen by the user for all fading, color balance change, and staining limits be listed."

Depending on the intended use of the image, different viewers may have different perceptions of what constitutes an acceptable level of fading. For example, there may be a bias towards the accurate rendition of skin tones, the colour of a garment in a fashion or wedding context, the colour of food, corporate emblems. Images that are on constant display and viewed daily will experience a gradual fade and colour shift over time that becomes acceptable to the viewer. It would only be in comparison with the original image that the fading and colour shift are noticeable.

Wilhelm (1993: 91) cites ANSI IT9.9-1990 as follows:

> "The image-life parameters listed are the critical characteristics that have practical significance for the visual degradation of color images; however, the numerical end points given here [in the Standard] are only illustrative. The subcommittee that produced this standard was not able to specify broadly applicable "acceptable" end-points because the amount of image change that can be tolerated is subjective, and will vary with the product type and specific consumer or institutional requirements. Each user of this standard shall select end points for the listed parameters which, in that user's judgment, are appropriate for the specific product and intended application."

In order to make an informed choice as to the appropriate end points for image fading to be used in these tests it is necessary to investigate the end points used by other researchers, namely Wilhelm, Kodak and Vogt.

For general home and commercial use Wilhelm's end point criteria for the limit of acceptability in the fading of colour images are when the first limit has been reached in any of the following criteria, as determined from changes measured in grey-scale densities of 0,6 and 1,0 and in d-min (paper white) patches (Wilhelm, 2002):

1. Absolute colour density loss (corrected for base stain) in neutral patches which describes the maximum amount of density loss acceptable as shown in Table 2.1.

Table 2.1. Maximum colour density losses in neutral patches

Loss of cyan	25%
Loss of magenta	20%
Loss of yellow	35%

2. Colour imbalance (not stain corrected) which describes the criteria for the maximum density shifts causing colour imbalances in neutral patches as shown in Table 2.2.

Table 2.2. Maximum colour imbalances in neutral patches

Colour imbalance between cyan (red density) and [minus] magenta (green density)	12%
Colour imbalance between magenta (green density) and [minus] cyan (red density)	15%
Colour imbalance between cyan (red density) and [plus or minus] yellow (blue density)	18%
Colour imbalance between magenta (green density) and [plus or minus] yellow (blue density)	18%

3. Change limits in minimum-density areas (clear whites), expressed in density[2] units which describe limits to the acceptable increases in the colour of the paper base as shown in Table 2.3.

Table 2.3. Maximum colour density shifts in paper base white

Change [increase] in red or green density	0,06
Change [increase] in blue density	0,15
Colour imbalance between red and green densities	0,05
Colour imbalance between red and blue densities	0,10
Colour imbalance between green and blue densities	0,10

Wilhelm has more stringent criteria for images intended for critical museum and archive use. In the context of the current study these are not relevant.

In her studies Vogt (2001) uses the density shifts of the Rochester Institute of Technology (RIT) Image Permanence Institute (IPI) to obtain the following end point data indicating the maximum acceptable reduction in reflection densities in colour and neutral patches as shown in Table 2.4.

[2] Density equals $\log_{10}$ of (incident light/reflected light).

Table 2.4. RIT colour end point criteria

Density change in neutral patches	30%
Density change in colour patches	30%
Density change in colour balance of neutral patches	15%
Change in minimum density, measured in density units	0,10
Change in minimum density colour balance, measured in density units	0,06

Eastman Kodak Company (1991) provides the information in Table 2.5 regarding guidelines for density-loss end points from a 1,0 density neutral patch, in which they describe the percentages of density loss which are observable:

Table 2.5. Kodak end point criteria for 1,0 density neutral patch

Density Loss	**Description**
0,10	Only observable in a critical side-by-side comparison with an unfaded sample of the same image.
0,20	Observable in a critical evaluation of the image by itself by someone familiar with the original quality of the image.
0,30	Sufficient that most observers are aware that the image has faded and has less quality.

However, since the criteria described in Table 2.5 are very subjective evaluation, losses beyond 30% may continue to be acceptable depending on the intended use of the photographic material or the nature of the image (Eastman Kodak Company, 1991). The same criteria can be applied to all images, whether produced by inkjet or traditional photographic materials.

Standards of light intensity for average image viewing

Light intensity for display of photographs varies greatly between home conditions, offices, galleries and museums. Proximity to the light source or a window can also change the light intensity. The ANSI standard ANSI IT9.9-1990 suggests that there is no correct intensity of display for all conditions, and the real world in which the prints are to be displayed should be used to define the specific conditions for reporting (Eastman Kodak Company, 2003).

Standard viewing conditions in an average home are at an intensity of 100 to 200 lux. Typical home display conditions are 120 lux, and 250 lux in an office (Eastman Kodak Company, 2003). According to Wilhelm (1993) 450 lux for 12 hours per day is regarded as normal for interior display purposes.

Research indicates that the type of lighting used does not have a significant effect on image fading compared to the intensity of the light if the UV emission is controlled. Fluorescent tubes of “Cool White” designation are commonly used in accelerated fade tests because of their high output, low cost, and common use worldwide for lighting. These have a small mercury vapour line emission in the 313 nanometer (nm) wavelength which is absorbed by filtering the light through ordinary flat glass such as encountered in picture frames and windows. UV light has been shown to be harmful to images on materials without an integral UV protecting layer (Wilhelm and Brower, 1993). .

Manufacturers’ publication of research data

At times various manufacturers have published expected print life data and have been challenged by consumers (Wilhelm and Brower, 1993). In a recent sales brochure for their Epson Stylus PRO 7600 printer, manufacturer Epson claims a print life >75 years, stating their testing conditions (Epson, 2003). Manufacturers do not usually publish life expectancies for the print materials they produce because they have no control over conditions of printing, processing or display conditions. Therefore independent comparative research gives rise to the only significant data to inform users by publication in newspapers, photographic magazines, electronic journals and e-mail newsgroups on the World Wide Web, and industry related journals.

Lack of absolute accuracy in accelerated light fastness testing

As previously discussed the ANSI and ISO Standards do not prescribe absolute standards for the amount of permissible density change or the amount of light for image viewing or display. Different researchers use different criteria of time and intensity of exposure, as well as separate tests for humidity and pollutant effects, and Arrhenius predictions in dark testing. The way Arrhenius predictions for dark testing are incorporated in accelerated fade tests, and the effect of reciprocity failure can lead to a variation in image life predictions.

Arrhenius predictions in dark fading

Arrhenius testing is predictive testing based on the equation formulated in the late 1800's by Swedish physicist Svante Auguste Arrhenius to describe the relationship between temperature and the rate of simple chemical reactions. All the major photographic material producers use this equation in predicting image stability in dark storage (Wilhelm and Brower, 1993). Under accelerated fading tests, dark fading is a contributing factor to image fading because most images on display are subjected to some periods of darkness or semi-darkness.

Reciprocity failure in accelerated tests

The reciprocity law states that the amount of change in a photochemical process is constant for a constant exposure, where exposure equals light intensity multiplied by time. Therefore the same degree of fading should take place with one hundred times the intensity at one-hundredth of the time. However, many materials do not follow this law, and its failure can further be affected by humidity and temperature (Vogt, 2001). It has been shown that in general lower illumination levels produce a higher proportional rate of fading (Wilhelm and Brower, 1993). After comparative tests at different light intensities, it has been determined that some inkjet materials do not suffer from reciprocity law failure common to photographic materials. This means that high-intensity, short-term tests can be a reliable indicator of long-term stability in these materials. (Zinn, Nishimura, and Reilly, 1999).

CHAPTER 3
RESEARCH METHODOLOGY

The project researches two particular aspects of photographic printmaking, namely, comparative costs to the end user of prints and accelerated fading for traditional and inkjet prints.

Cost Analysis

In order to acquire information regarding the costs of traditional photographs and inkjet print use was made of a short questionnaire. This approach had the following advantages:

- It was the most convenient way in which to obtain data from respondents;
- It was brief, impersonal, and consistent; and
- Specific research objectives could be addressed (Leedy, 1993).

In designing the questionnaire the logical sequence of concepts suggested by De Vaus (2002) was followed, namely:

- Definition of the concept;
- Identification of different dimensions of the concept; and
- Identification of sub-dimensions.

Since the survey was to be conducted telephonically the questions were kept to a minimum. These included closed questions with a limited range of responses, and open questions where more clarification to the closed questions was required (De Vaus, 2002). This approach is common practice (Leedy, 1993). The questionnaire is shown in Appendix B.

The small sample could be regarded as a convenience sample since it represented a cross-section of printmakers known to the author through previous personal interaction. This option was selected to obtain a higher response rate. This personal relationship had no impact on the quality and accuracy of data obtained. Rather it increased the likelihood of acquiring possibly sensitive information. The sample size of seven printmakers represented a cross-section of the printmaking industry. Inkjet printers ranged from large to small operators. Traditional photographic printmakers were all large operators, ranging from specialist printmakers to bulk production printmakers. This is normal for these industries. The sample was therefore a representative one.

The questionnaire was designed to take between 5 and 10 minutes to complete. Potential participants were first called by telephone to explain the purpose of the questionnaire and to request their participation. The anonymity of the person and organisation supplying the information was stressed. The questionnaire document was then sent by e-mail or fax to those persons who during the initial telephone call agreed to participate. This step was necessary to enable respondents to have the questionnaire with them during the subsequent telephone interview. All responses were recorded accurately. The data were statistically analysed and measures of central tendency reported.

Accelerated fade testing

The experimental design involved subjecting identical prints on different media to a high intensity light source to accelerate the fading that light causes on dyes and pigments. To determine the fading of print dyes and pigments due to the effect of light prints need to be exposed to light in order for the fading to be measured over time. To shorten the long time periods involved with, for example, checking the effect of 50 years of exposure, it is normal practice, as stated before, to increase the intensity of light and calculate an equivalent exposure over a shorter time period (Wilhelm, 2002).

Certain density patches were measured on a regular basis to record changes in densities with time. Because the lighting unit generated a high temperature on the prints the effect of temperature without light was also tested as a contributing factor to density loss. The testing by Wilhelm is done under temperature-controlled conditions forcing cooled air over the print surface (Wilhelm and Brower, 1993). The test laboratory used by Vogt did not permit cooling of prints during accelerated fading (Vogt, 2001).

Equipment for accelerated light fading

The materials used for creating the accelerated fading light unit were chosen within budgetary constraints. The resultant light output of 35,5 Klux was similar to Wilhelm’s test conditions of 35 Klux (Wilhelm, 2002). The test conditions used by Vogt utilised a light intensity of 110 Klux (Vogt, 2001).

Six fluorescent light fittings, each taking two 1,47 meter tubes of 25,4mm diameter, were mounted in parallel so that the spacing between each of the 12 tubes was the same at 53mm between centres. The fluorescent tubes used were 52 watts Philips TLD SS/33. The bank of lights was screwed to a wooden beam at each end so that it could be positioned horizontally with the tubes lowermost, and all the fitting were electrically wired together in parallel to operate from a single 220 volt electrical outlet. The area covered by the light was 1470mm by 630mm, permitting the placement of eight A4 prints. Details of the construction are illustrated in Figure 3.1.

Figure 3.1. Accelerated fading exposure apparatus.

A varnished wooden table was covered with aluminium foil. Prints were placed on the foil with the image side facing up to the lights. Two wooden spacers were placed on the table out of the picture area and a sheet of 6 mm thick laminated plain glass was placed to rest on them. Higher spacers were placed on the glass so that the beams holding the lights could rest on them, resulting in an exactly repeatable print-to-light distance when the lights were raised for maintenance or print removal as shown in Figures 3.2 and 3.3.

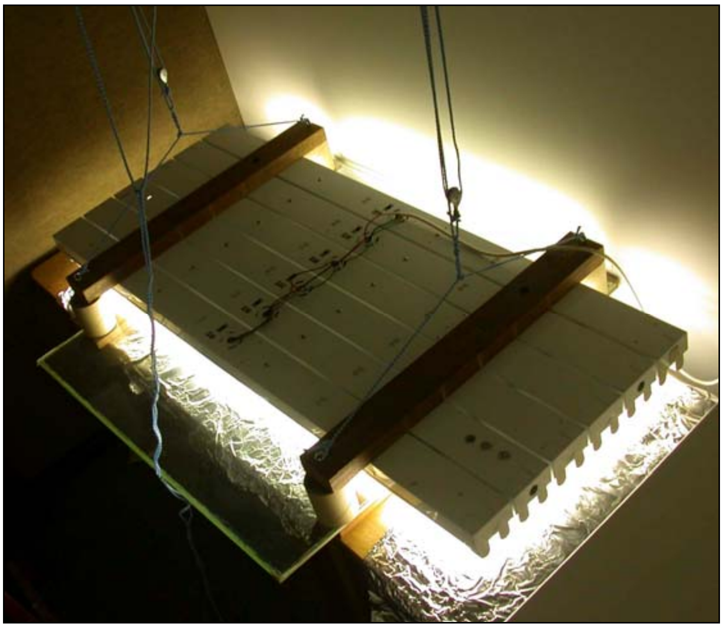

Figure 3.2. Accelerated fading unit, viewed from above.

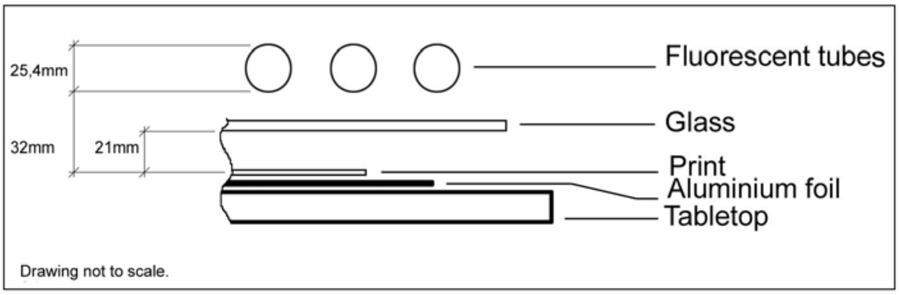

Figure 3.3. Cross-section of accelerated fading exposure apparatus.

The distance from the prints to the glass was 21mm, and from the prints to the lowest circumference of the fluorescent tubes was 32mm. These distances were dictated by the materials available, and were chosen to get the smallest convenient distance between the light source and the prints. The design is similar in principle to that of Wilhelm (1993) and Vogt (2001).

The tabletop had slots routed in it in order to permit the taking of illuminance (lux) measurements at various positions throughout the illuminated area, as well as temperature readings, as shown in Figure 3.4. These readings were taken at precisely the level of the prints, with the prints and aluminium foil removed.

Illuminance measurements were made with a Gossen Mastersix meter before the commencement of testing and weekly thereafter, as well as when a fluorescent tube was changed. The average intensity of light at the print surface was 35,5 Klux. Small fluctuations in light intensity were found across the area of illumination and were averaged. To compensate for this difference prints were rotated in position twice per week. This was similar to the practice followed by Vogt (2001).

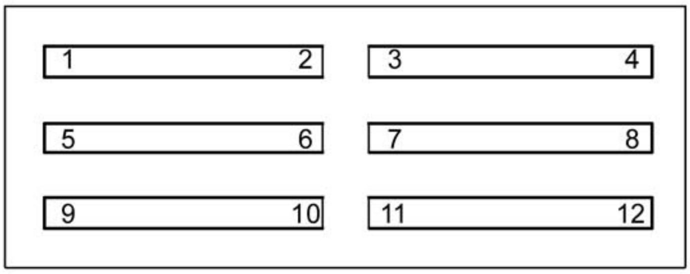

Figure 3.4. Positions of illuminance and temperature measurement points on the test surface.

As no temperature and RH controls were available for use the temperature was monitored regularly throughout the test period. The average temperature was 39,7°C.

To measure trends in fading at a lower light intensity representative print samples were exposed at a light level of 6 Klux in order to obtain information on possible reciprocity law failure.

The lighting unit, which permitted the exposure of two A4 sized prints, is illustrated in Figure 3.5.

Figure 3.5. Reciprocity test exposure unit.

The unit consisted of a light-box covered with 5mm plain glass. Illumination was by four Osram Cool White 20W fluorescent tubes. The level of illumination was measured at six different positions on the cover glass and averaged.

The test data image

The image in Figure 3.6 was produced with Adobe Photoshop 7.0.1 software in RGB format and saved to a CD in various formats for printing: Tagged Image File Format (TIFF), Joint Photographic Experts Group (JPEG), Encapsulated Post-script (EPS), and Portable Document Format (PDF).

Figure 3.6. Colour Test Target.

The colour test target is shown on a larger scale in Appendix A. The colour and monochrome photographs are included for interest and visual perception only. The stepped and continuous greyscale targets were produced on Photoshop 7.0.1 using colour #737373, a 55% screen density of colour 000000, representing R, G, B values of 115 each, and C, M, Y, K values corresponding to 56%, 47%, 47%, and 13% respectively. This closely approximates PANTONE Solid Coated Cool Grey 10CVC with C, M, Y, and K values of 0%, 0%, 0%, and 72% respectively. (See Figure 3.7).

A Kodak 18% reflectance Mid-Grey card[3], (see Figure 3.8) was scanned for comparison on a Heidelberg Linotype-Hell Saphir Ultra 2 scanner, and produced colour results as shown in Table 3.1.

Table 3.1. Adobe Photoshop 7.0.1 colour data for neutral grey.

	Target Data	KODAK grey-card
PANTONE Solid Coated colour	Cool Grey 10CVC	404C
Colour number	737373	79766F
C (cyan)	56%	52%
M (magenta)	47%	46%
Y (yellow)	47%	51%
K (black)	13%	13%
R (red)	115	121
G (green)	115	118
B (blue)	115	111

Figure 3.7. Target grey

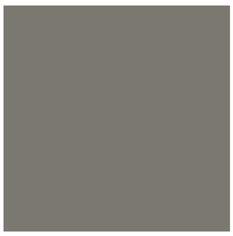

Figure 3.8. Kodak grey

[3] Kodak mid-gray cards have long been used by photographers as a standard of neutral colour tone reproduction.

The colour patches were produced from subtractive primary colours with Adobe Photoshop 7.0.1, using the colour values in Table 3.2:

Table 3.2 Adobe Photoshop 7.0.1 colour data for subtractive primaries.

	Target Data Colour Number
C (cyan) 100%	FFFF00
M (magenta) 100%	FF00FF
Y (yellow) 100%	00CCFF

Inkjet prints

Inkjet prints were made with various printers and paper materials, and air-dried for three to six days prior to exposure to intense light. Research findings show that there can be a difference in print life between images that have undergone drying by air and those that have been dried in contact with an absorbent material for the same time (Wilhelm, 2002). This difference in dying method was not tested in this study.

Traditional photographic prints

Professional printing laboratories using standard equipment, chemicals, and paper produced traditional colour photographic prints for testing. No special treatment was given to the prints, nor was it possible with the Fuji Frontier and Agfa D-Lab 2 processors used.

Table 3.3 lists the combinations of papers, inksets, and printers that were tested. In the cases of traditional photographic prints the processor and chemical manufacturer are listed.

Table 3.3. Printer, ink or chemicals, and paper type tested

Image Number	Printer	Inkset Or chemicals	Paper
1	Epson Stylus Photo 2100	Epson OEM	Epson Premium Glossy Photo Paper S041286
2	Epson Stylus Photo 2100	Epson OEM	Helox Artist Canvas Paper J96C
3	Epson Stylus Photo 2100	Epson OEM	Helox Instant Dry Photo Quality Glossy Paper PGP-180
4	HP 895cxi	Dual (non-OEM)	Epson Photo Quality Ink Jet Paper S041061
5	Epson Stylus Color 480sxu	Epson OEM	Epson Premium Glossy Photo Paper S041286
6	Epson Stylus Photo 1200	MIS Archival pigment	Epson Premium Glossy Photo Paper S041286
7	Epson Stylus Photo 2100	Epson OEM	Somerset Velvet Radiant White M8FZ1041
8	Agfa D-Lab 2	Agfa photographic chemicals	Agfa Prestige Digital Glossy
9	HP CP1700	HP OEM	Epson Premium Glossy Photo Paper S041286
10	HP OfficeJet Pro 1150c	HP colour OEM, Dual (non-OEM) black	Epson Photo Quality Ink Jet Paper S041061
11	Epson Stylus Photo 2100	Epson OEM	Epson Photo Quality Ink Jet Paper S041061
12	Epson Stylus Photo 2100	Epson OEM	Epson Enhanced Matte Paper S041341
13	Epson Stylus Photo 2100	Epson OEM	Epson Semi-Gloss Photo Paper
14	Epson Stylus Photo 2100	Epson OEM	Generic Semi-Gloss Photo Paper
15	Epson Stylus Photo 2100	Epson OEM	Xerox Bond Plain Paper
16	Fuji Frontier	Fuji Frontier photographic chemicals	Fuji Crystal Archive Glossy
17	Fuji Frontier	Fuji Frontier photographic chemicals	Fuji Crystal Archive Lustre

Density measurements

Print densities were measured using an Agfa DENS 1 Type 8500/835 reflection densitometer as shown in Figure 3.9. A certified technician from Agfa, Cape Town, calibrated the instrument before every measurement session.

Figure 3.9. Agfa densitometer used for measuring reflection densities.

Density readings were taken from the white paper base and the C, M, Y, and K patches representing the print patches 100%, 55%, and 5%. (See Figure 3.6 above, and Appendix A). Each patch produced figures representing the C, M, and Y components that made them up. For example, the 55% magenta patch printed on Epson Semi-gloss paper with an Epson Stylus Photo 2100 printer gave starting densities of 0,11 C; 0,88 M; and 0,25 Y. It is very difficult to produce pure colour patches in one subtractive primary colour only, excluding the other two primary colours. Therefore only the pure colour components were measured for analysis. (Vogt, 2001.)

The corresponding figures for 55% black were 0,75, 0,85, and 0,74 respectively. These data were recorded on a control form for later analysis.

Further density measurements were made at approximately weekly intervals and the data recorded. The accumulating time of exposure for each test print was recorded on a control sheet. The black and neutral grey patches were measured for their C, M, and Y components in order to determine the end point of acceptable colour balance. The colour patches were measured for their pure colour components only in order to determine the end point of acceptable colour shift.

Equivalent exposure

In the absence of absolute guidelines from the Standard ANSI IT9.9-1990 the following reasoning was used to determine the equivalent exposure for these accelerated fading tests:

Display time from Monday to Friday, 09:00-17:00, equals 40 hours. Display time on Saturday from 09:00-13:00 equals 4 hours. No display is done on a Sunday. This gives a total of 44 hours for seven days, an average of 6,28 hours per day, with an annual total of 2 292,2 hours. For the purposes of these tests it was assumed that an illumination level of 300 lux was normal.

A normal print exposure for one day was therefore taken as the illumination level multiplied by time according to the standard formula E=I x T, where E = exposure, I = intensity of light, and T = time. Thus the daily exposure is 6,28 hours x 300 lux, equal to 1 884 luxhours, which is equal to 1,884 Kluxhours. Annual exposure is 2 292,2 hours x 300 lux = 687,7 Kluxhours. The illumination produced for the accelerated fading tests was 35,5 Klux. Therefore under the test conditions 24 hours of exposure was 852 Kluxhours (24 hours x 35,5 Klux), simulating a normal display of 1,24 years (852/687,7). One hour exposure was equivalent to 0,05162 years of display.

For the reciprocity test conducted at 6 Klux, 24 hours of exposure was 144 Kluxhours (24 hours x 6 Klux), simulating a normal display of 0,2094 years (144/687,7). One hour exposure was equivalent to 0,008725 years of display.

Dark testing

The print samples exposed to the high intensity light were subject to high temperatures generated by the lighting unit. Because they were behind glass it was not possible to introduce airflow to reduce the temperature. This is in line with the testing techniques employed by IPI of RIT (Vogt, 2001). To measure the possible effect of temperature on the prints two further tests were conducted.

Samples of three different inkjet paper types were sealed in aluminium foil and subjected to the same temperatures as the accelerated fading test prints. The base densities were regularly measured to plot any colour changes.

Samples of two different traditional photographic papers printed with the control image were sealed in aluminium foil and subjected to the same temperatures. The colour and tone densities were regularly measured to plot any colour changes, which may have been caused by temperature only.

All samples were exposed to the same temperature in the accelerated fading light unit. For purposes of comparison the equivalent time of exposure was calculated on the same basis for temperature only, and both light and temperature, namely one hour exposure was equivalent to 0,05162 years.

Acceptable levels of dye fading

The standards proposed by Eastman Kodak Company (Eastman Kodak Company,2003) and RIT (Vogt, 2001) for the limits of acceptable dye fading were used. A density decrease of 30% in any of the cyan, magenta, or yellow pure colour patches with a starting density between 1,0 and 0,6 was considered to be the end point of acceptability. A density decrease producing a difference of 15% between any of the cyan, magenta, or yellow components in a neutral grey patch with a starting density between 1,0 and 0,6 was considered to be the end point of acceptability. When this point was reached the neutral grey patch showed a noticeable colour shift away from neutral. These criteria are similar to the basic criteria used by Wilhelm, but were easier to apply in these tests because of limited access to the densitometer for measurements.

CHAPTER 4
DATA ANALYSIS

As stated previously the data collected was relative to comparative costs to the end user of printing, and accelerated fading for traditional and inkjet prints. In this chapter the findings are presented and discussed relative to the work of others.

Costing Questionnaire

The primary aim of analysing the data from the questionnaire was to obtain a comparison of costs between inkjet prints and traditional colour photographs.

Additionally, the questionnaire was used to obtain information about the printmakers' concerns over the expected life of the prints they produced, and the materials and equipment used. With regard to inkjet printing this included information about the use of non-OEM inks and papers.

It is necessary before discussing the results to define the terms used.

The term 'machine printing' relates to printing without any modifying controls by the printmaker. 'Hand printing' refers to printing with modifications such as, for example, colour balancing and local darkening or lightening certain areas of the print.

The mean price of machine printing a single A4 inkjet print was R60.20. The minimum price quoted was R30.00, and the maximum was R114.00.

The mean price of machine printing a single A4 photographic print was R27.00. The minimum price quoted was R22.00 and the maximum was R32.00.

The mean price of hand printing a single A4 photographic print was R58.25. The minimum price quoted was R49.00 and the maximum was R67.50.

These results are shown in Table 4.1.

Table 4.1. Comparison of print prices

Print type	Mean	Minimum	Maximum
Inkjet	R60.20	R30.00	R114.00
Traditional colour print, machine printed	R27.00	R22.00	R32.00
Traditional colour print, hand printed	R58.25	R49.00	R67.50

All printmakers offered a discount for multiple prints of the same image.

Responses to how the market price of a print was determined indicated that

- 100% of respondents based their prices on material costs;
- 83% based their prices on overhead costs;
- 33,3% based their prices on profit margin; and
- 50% based their prices on comparative market prices.

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The expected mean life of display of a print was 33 years. The minimum life was 8 years and the maximum was 70 years.

Most respondents (71,4%) reported that knowledge regarding the print life was important.

Almost all the respondents (85,7%) reported they would like their prints tested for relative permanence.

Most respondents (83,3%) used OEM inks in their inkjet printers. Reasons given were

- Reliability (33,3%),
- Guarantee and service backup (33,3%),
- Long image life (17%).

One printmaker was negative because of the cost and short image life of the OEM ink for the printer being used. This printmaker used a printer modified to take an external supply of pigmented inks rather than the dye-based OEM inks.

The results relative to the brand of paper used in inkjet printers are shown in Table 4.2. Most used Epson paper.

Table 4.2. Inkjet printing papers used.

Paper make	Percentage
Epson	50%
Kodak	33%
Best	17%
Oji	17%
Other	17%

The following printers were used:

- Epson Stylus Photo 1200 (17%),
- Epson Stylus Photo 2100 (17%),
- Epson Stylus PRO 9600 (50%),
- Epson 10000 (17%), and
- Encad wide-format printers (17%).

With respect to what extent the price of prints was influenced by materials and equipment respondents responded as shown in Table 4.3.

Table 4.3. Influence of ink, paper, and printer costs on print prices.

Input cost	1 (not at all)	2	3	4	5 (totally)	Mean	Standard Deviation
Inks			16,7%	16,7%	66,7%	4,5	0,8366
Paper			16,7%	16,7%	66,7%	4,5	0,8366
Printer	16,7%	16,7%	16,7%		50%	3,5	1,7606

Conclusions

Inkjet prints were found to be more expensive to the end user than traditional photographic colour prints. Hand printed traditional colour photographs were marginally lower in price than inkjet prints. Prices were determined from material costs, overhead costs, and comparative market prices.

Inkjet printmakers made use of Epson printers more than any other make, and all printmakers used pigment-based inks. Most printmakers used OEM inks because of the reliability, guarantee, and back-up service offered by the supplier. One printmaker chose inks because of the image permanence offered.

Printmakers deviated regarding the expected life of the prints they produced. All expressed an interest in having their prints tested for permanence.

Accelerated Fade tests

The results from the accelerated fade testing were analysed to determine if any of the test prints failed the criteria for longevity during the test period. Further data were analysed relative to trends in reciprocity failure and the effect of temperature on image stability under the test conditions.

Each test printer, ink and paper combination produced a range of data for base colour and density changes over time. In the case of the Epson Stylus Photo 2100 printer nine different papers types were printed. Seven of them were removed from exposure as soon as their fading trends emerged.

The minimum time of exposure for all test prints was 12,29 years. Beyond this time prints were removed when they reached their end points, or to obtain further data regarding their fading trends.

The findings of the inkjet test prints are discussed by inkjet printer type while the traditional photographic test prints are discussed by paper type. The inkjet printers were:

- Epson Stylus Photo 2100;

- Epson Stylus Photo 1200;
- Epson Stylus Color 480sxu;
- Hewlett-Packard 895 cxi;
- Hewlett-Packard CP 1700 Color Inkjet, and
- Hewlett-Packard OfficeJet Pro 1150c.

A separate grouping contained the two traditional colour photographs tested, namely Agfa Prestige Digital paper, and Fuji Crystal Archive paper.

In order to analyse the data for each print all raw reflection density, time, and temperature measurements were recorded on separate Microsoft Excel spreadsheets. All readings in the 0,6 to 1,0 density ranges were significant and recorded. The percentage change in densities relative to the original baseline densities for the test period were calculated and recorded (see Appendix D).

No corrections were made for changes in the paper base colour, as these were insignificant compared to changes in the 0,6 to 1,0 density ranges. However, base colour densities were plotted on graphs for different paper types to show the changes in densities.

The greatest density change in a primary colour, for example cyan, or the first density change to indicate a print end point was plotted graphically for each test print.

The colour patches in the 0,6 to 1,0 range showing the greatest density change were plotted in both the accelerated fade tests and dark fade tests. In some instances colour patches showed starting densities slightly below 0,6 and above 1,0. In these cases both density lines were plotted. The equivalent years of normal exposure to light were shown on the horizontal axis, while the percentage reduction of starting density was noted on the vertical axis.

Inkjet Prints

Epson Stylus Photo 2100 inkjet printer, using Epson OEM ink.

This test printer utilises pigment based Epson Autochrome inks. These same inks, for which Epson claims a print life >75 years (Epson, 2003), are also used in Epson Stylus Photo 2200, Epson Stylus PRO 7600, and Epson Stylus PRO 9600 inkjet printers (Wilhelm, 2003).

As this printer, shown in figure 4.1, is capable of printing images up to a maximum size of 329 x 483 mm at a resolution of 2 880 dpi, it is popular with smaller printing establishments.

Figure 4.1. Epson Stylus Photo 2100 inkjet printer.

Several different paper types were tested in order to investigate whether or not the paper type and surface had a significant effect on the life of the pigments. In the tests for this printer part of the aim was to determine whether or not the use of any paper type produced a significantly longer or shorter print life than any other paper. Tests were terminated as soon as trends became evident. Testing continued with two papers which had been shown to display a high degree of image permanence by Wilhelm (2002), namely Epson Premium Glossy Photo Paper, and Somerset Velvet Radiant White M8FZ1041.

Epson Premium Glossy Photo Paper S041286.

The raw data for this paper/printer combination are shown in Appendix D.1.

The 55% yellow colour patch showed the highest rate of fading. The neutral patch produced an initial drop in the yellow component before increasing in density. Magenta was the most stable colour.

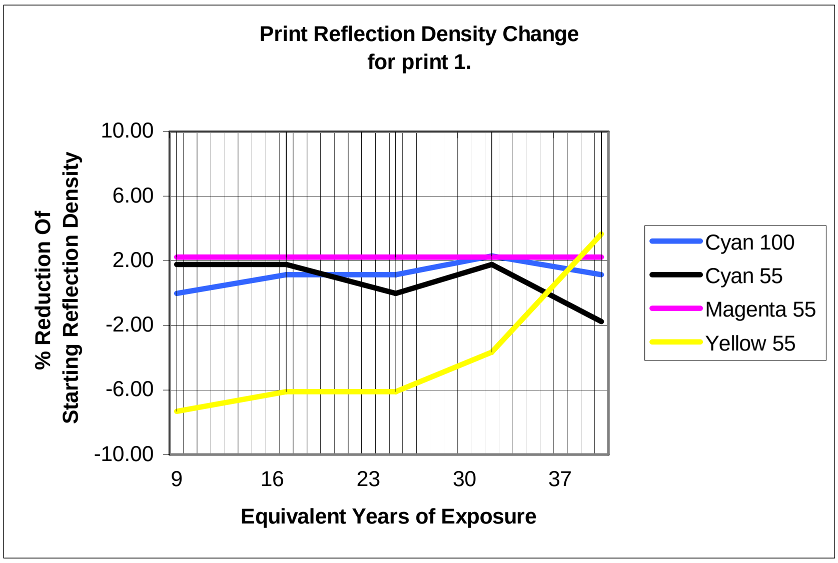

Figure 4.2. Print 1 cyan, magenta, and yellow patches (55%), and cyan (100%).

Figure 4.2 shows the yellow 55% colour patch faded more rapidly than the magenta 55%, cyan 55%, and cyan 100% colour patches.

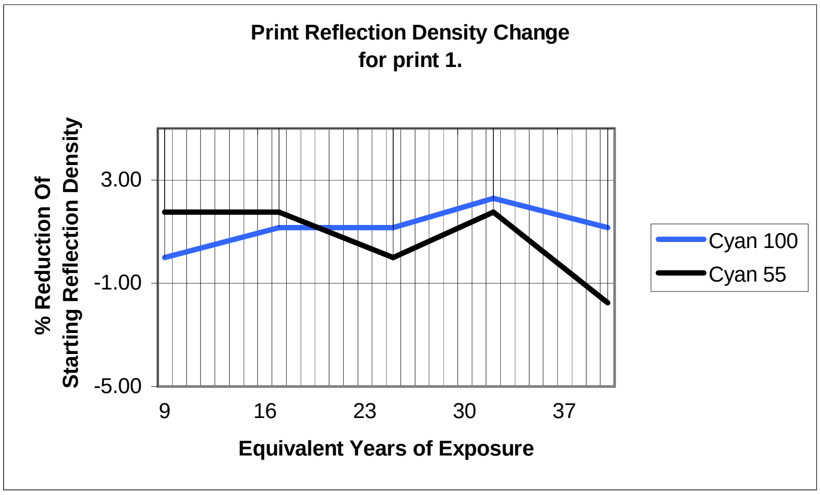

Figure 4.3. Print 1 cyan colour patches (55% and 100%).

Figure 4.3 shows that the cyan 55% colour patch has remained relatively stable, while the cyan 100% colour patch has increased slightly in density during the test period.

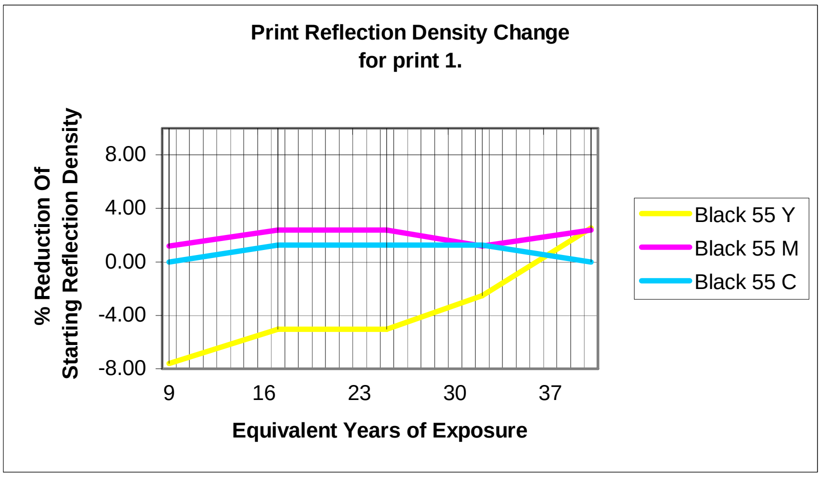

Figure 4.4. Print 1 neutral grey patch (55%).

Figure 4.4 shows that the yellow component of the 55% neutral grey patch faded the most rapidly during the test period.

Helox Artist Canvas Paper J96C.

The raw data for this paper/printer combination are shown in Appendix D.2.

This paper showed the most change in the cyan colour patches. In the neutral grey patch yellow showed the most rapid rate of change. The rate of change of image density was very slow and the test was terminated early.

There was no change in the colour of the paper base during the test period.

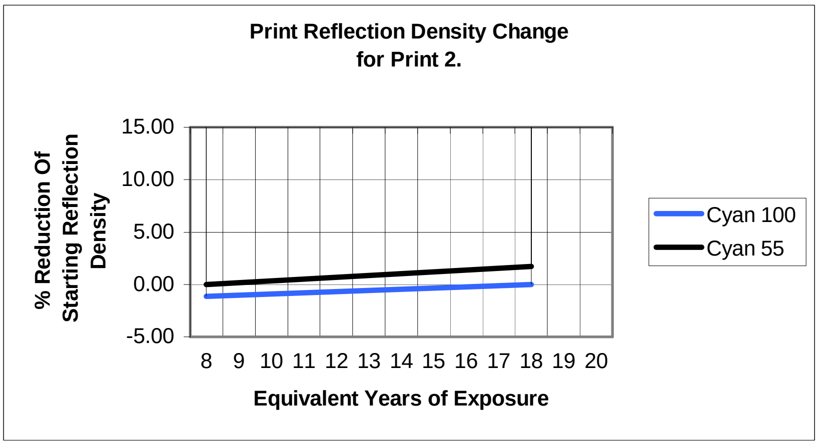

Figure 4.5. Print 2 cyan colour patches (55% and 100%).

Figure 4.5 shows the rate of density change in the cyan 55% and cyan 100% colour patches.

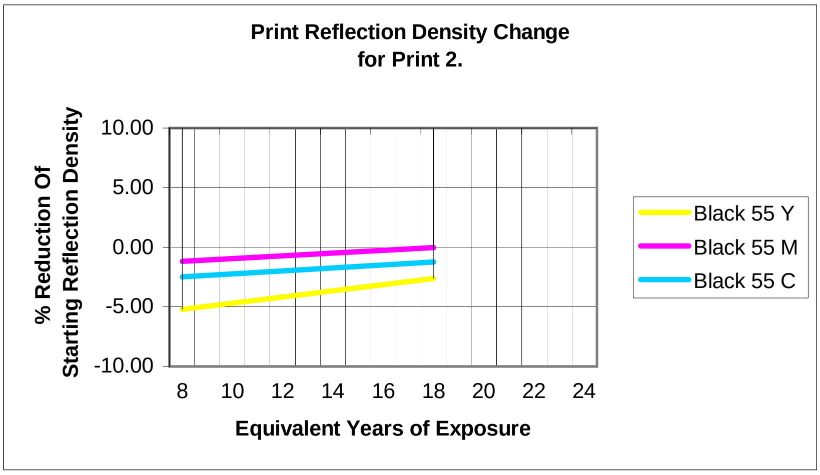

Figure 4.6. Print 2 neutral grey patch (55%).

Figure 4.2 shows the stability of the 55% neutral grey patch. Yellow faded the most but was insufficient to create a colour shift.

Helox Instant Dry Photo Quality Glossy Paper PGP-180.

The raw data for this paper/printer combination are shown in Appendix D.3.

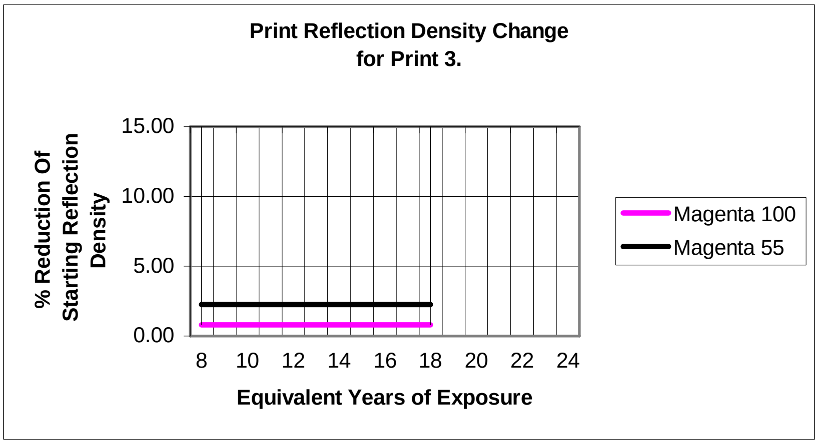

Figure 4.7. Print 3 magenta colour patches (55% and 100%).

This paper was stable in all colours. A slight increase in yellow density of the paper base was measured during the test period. The test was terminated early. The graph in Figure 4.7 shows the lack of fading during the test period in the magenta 55% and 100% patches. Yellow and cyan showed similar results.

Somerset Velvet Radiant White M8FZ1041.

The raw data for this paper/printer combination are shown in Appendix D.7.

Magenta was the most stable colour. Cyan and yellow showed the highest degree of fading. The paper base produced no colour change.

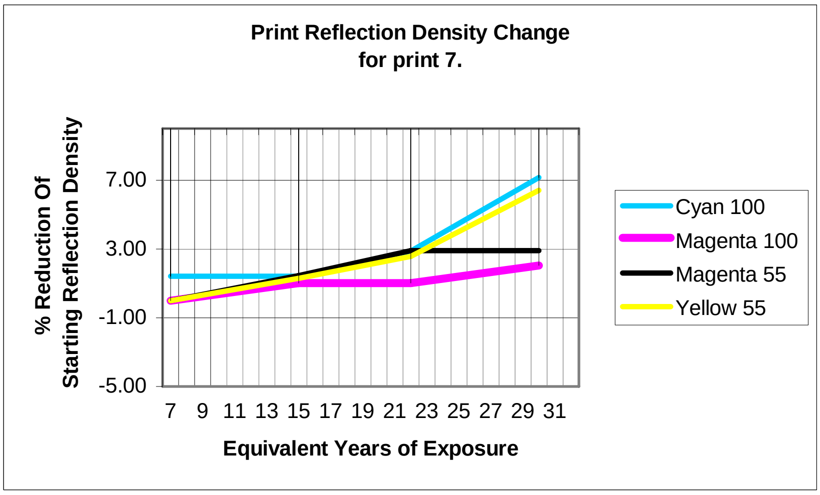

Figure 4.8. Print 7 magenta, and yellow patches (55%), and magenta and cyan (100%).

The cyan 100% and yellow 55% patches faded considerably more than the magenta patches, as shown in Figure 4.8.

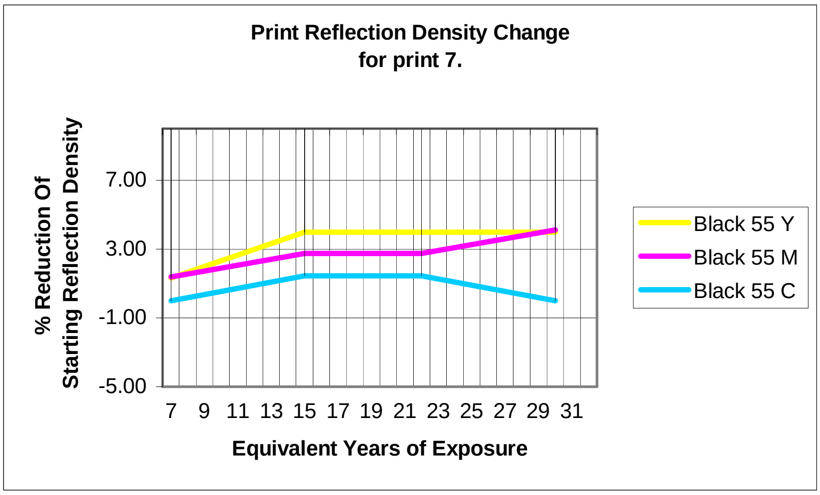

Figure 4.9. Print 7 neutral grey patch (55%).

Figure 4.9 shows the relative stability of all colours in the neutral grey patch.

Epson Photo Quality Ink Jet Paper S041061.

The raw data for this paper/printer combination are shown in Appendix D.11.

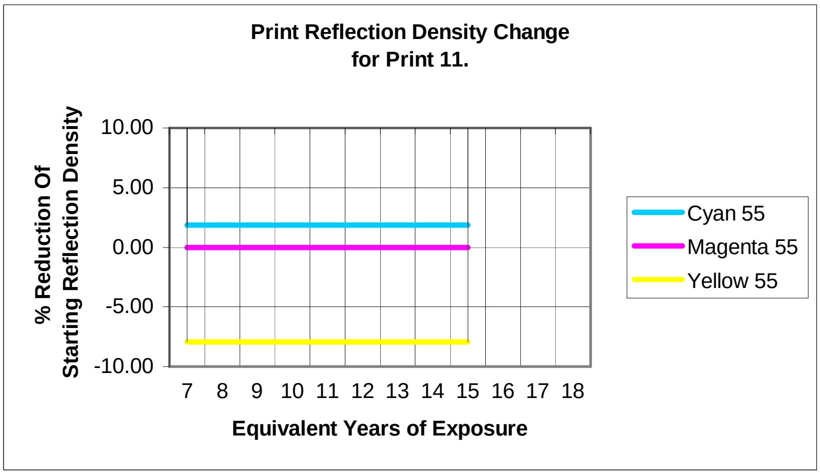

Figure 4.10. Print 11 cyan, magenta, and yellow patches (55%).

As shown in Figure 4.10 the pure colours were all stable on this paper, with no fading.

Figure 4.11 showed a decrease in cyan density in the 55% neutral patch which caused a colour shift towards red.

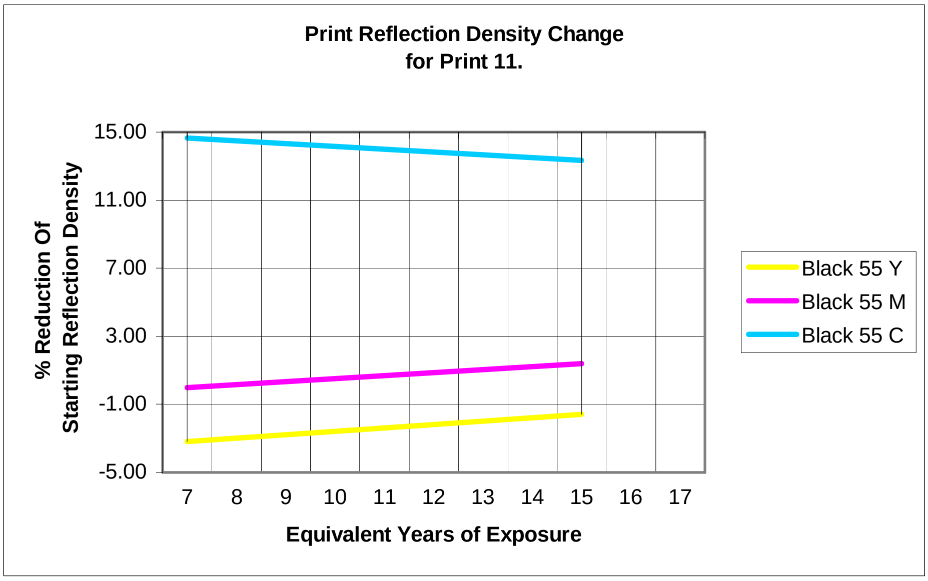

Figure 4.11. Print 11 neutral grey patch (55%).

The base of the paper increased in yellow density during the test period. The test was terminated early.

Epson Enhanced Matte Paper S041341.

The raw data for this paper/printer combination are shown in Appendix D.12.

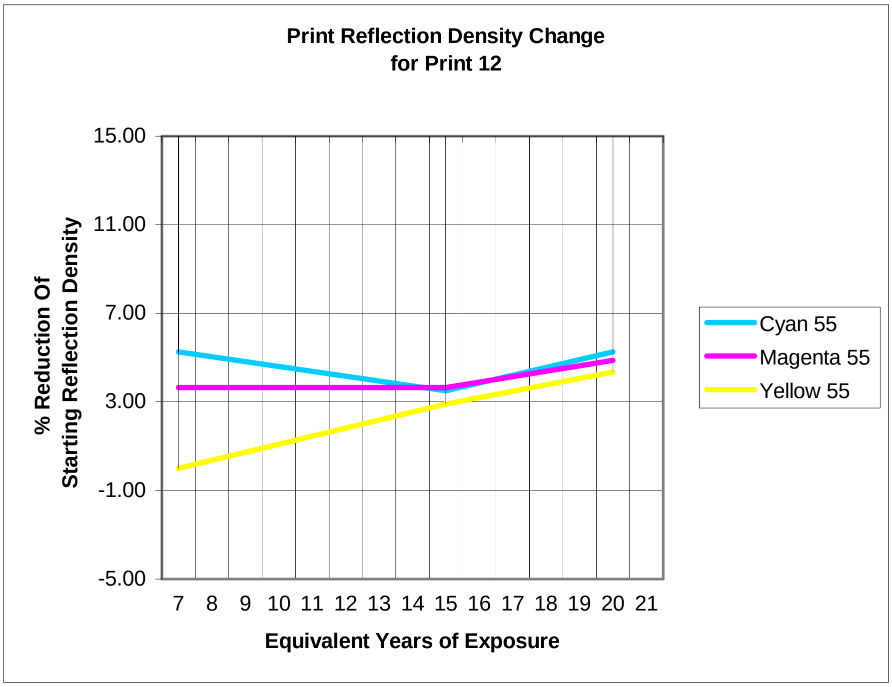

Figure 4.12. Print 12 cyan, magenta, and yellow patches (55%).

Figure 4.12 shows that whereas cyan showed the highest density loss during the test period, yellow had the highest overall fading rate. After approximately fifteen years all colours had a similar rate of fading.

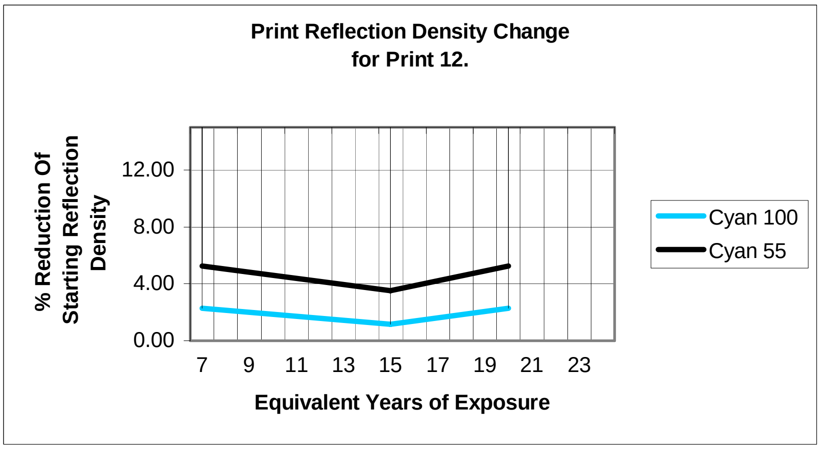

Figure 4.13. Print 12 cyan colour patches (55% and 100%).

The 55% cyan patch showed the largest decrease in density, as shown in Figure 4.13. The actual density differences are small compared with the criteria of acceptability.

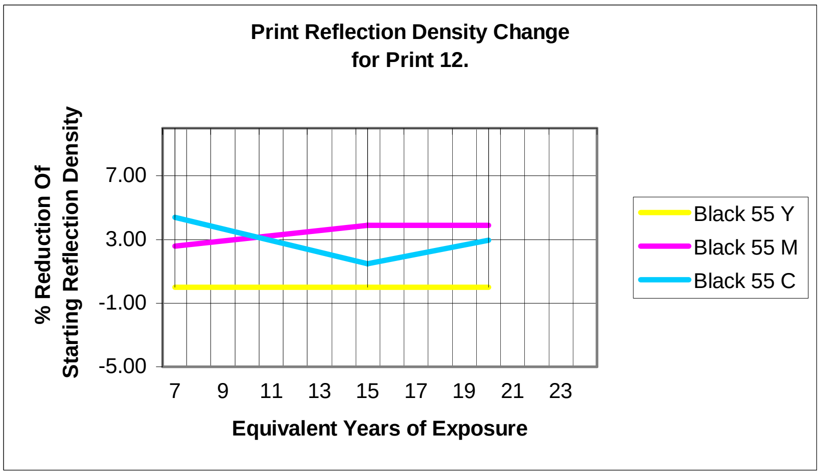

Figure 4.14. Print 12 neutral grey patch (55%).

Figure 4.14 shows that the 55% neutral grey patch had a very small change in colour balance during the test period.

The base of the paper increased in yellow density during the test period. The test was terminated early.

Epson Premium Semi-Gloss Photo Paper S041331.

The raw data for this paper/printer combination are shown in Appendix D.13.

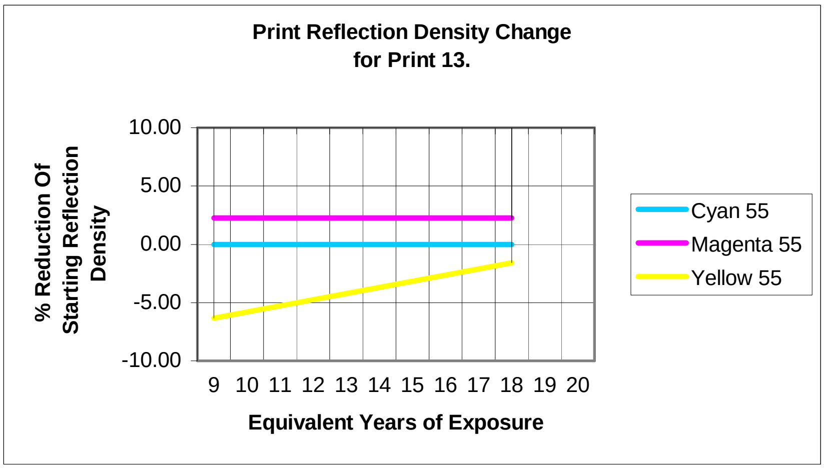

Figure 4.15. Print 13 cyan, magenta, and yellow patches (55%)

Figure 4.15 shows that yellow experienced the most change of the three colours. Yellow increase in density initially before beginning a gradual decrease. Magenta and cyan remained unchanged.

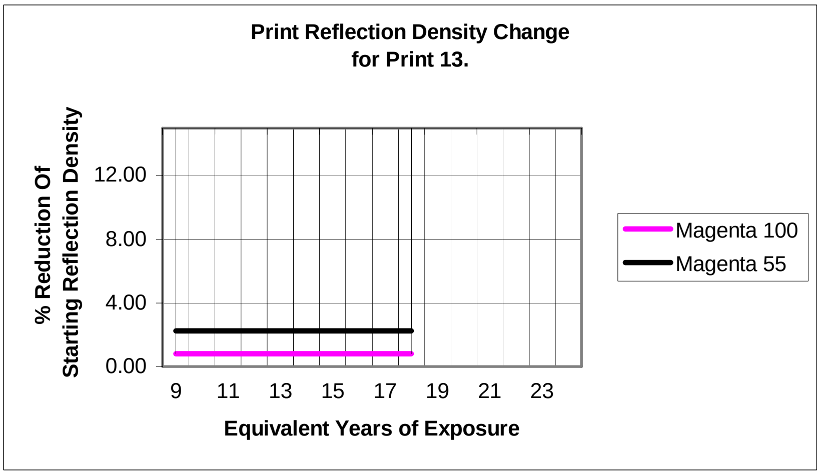

Figure 4.16. Print 13 magenta colour patches (55% and 100%)

Figure 4.16 shows the stability of the magenta colour patches. No density changes were found in the cyan and magenta colour patches. Figure 4.17shows the stability of the colours in the neutral grey patch.

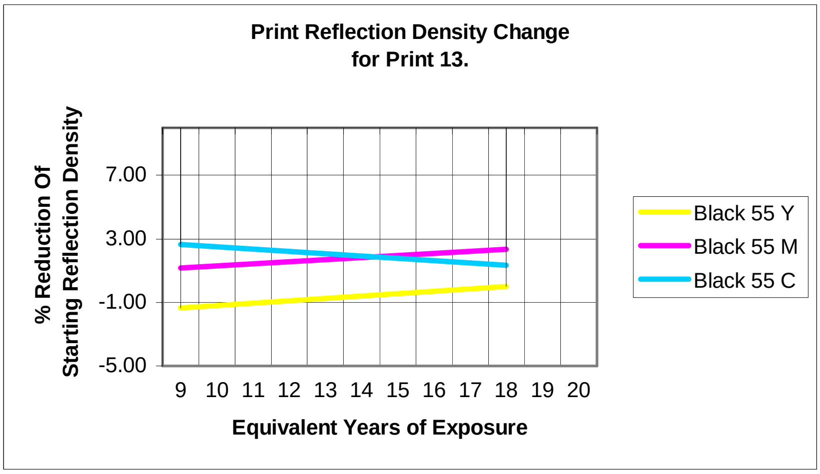

Figure 4.17. Print 13 neutral grey patch (55%)

The paper base colour did not change during the test period.

Generic Semi-Gloss Photo Paper

The raw data for this paper/printer combination are shown in Appendix D.14.

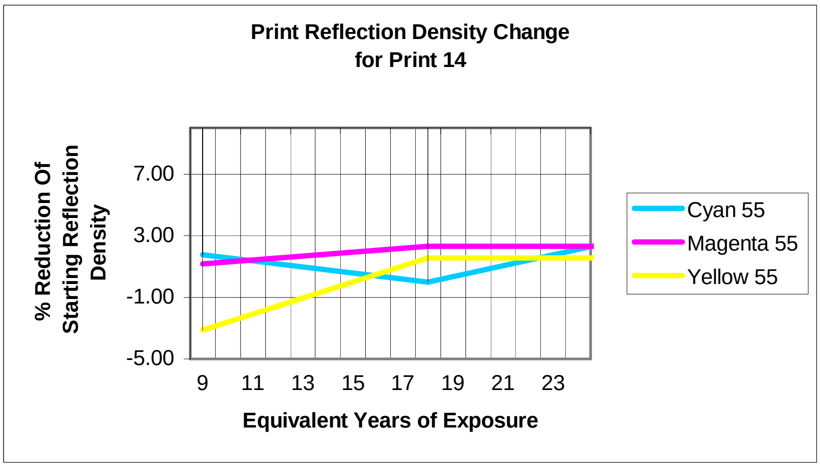

Figure 4.18. Print 14 cyan, magenta, and yellow patches (55%).

Figure 4.18 shows the stability of the colours in the neutral grey patch. The cyan 55% and 100% patches showed the greatest changes on this paper, as shown in Figure 4.19. Figure 4.20 shows the stability of the colours in the 55% neutral patch.

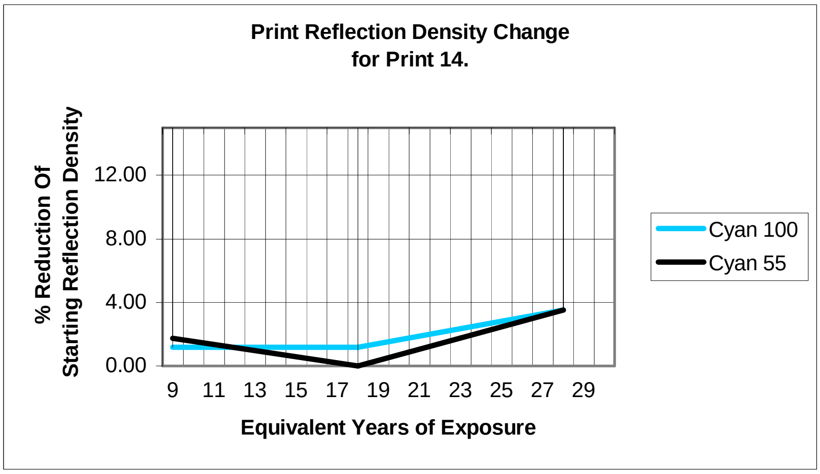

Figure 4.19. Print 14 cyan colour patches (55% and 100%)

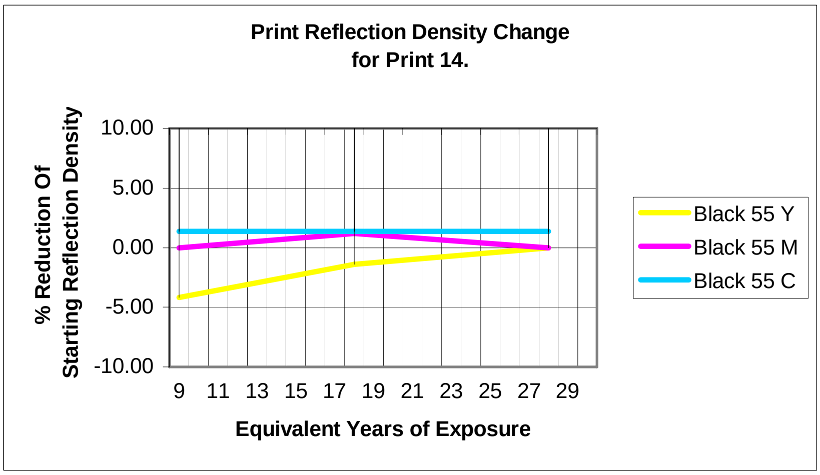

Figure 4.20. Print 14 neutral grey patch (55%)

This paper originated from a reputable dealer and was supplied as an alternative to Epson paper. The paper base showed a gradual increase in yellow density.

Xerox Bond Plain Paper.

The raw data for this paper/printer combination are shown in Appendix D.15.

During the test period the cyan colour patches showed marginally higher fading than the other colours, as shown in Figure 4.21. Figure 4.22 shows the stability of the cyan colour patches, and Figure 4.22 shows a gradual decrease in all colours in the 55% neutral grey patch. These changes are within the limits described in the criteria of acceptability.

The paper base showed a gradual increase in yellow density.

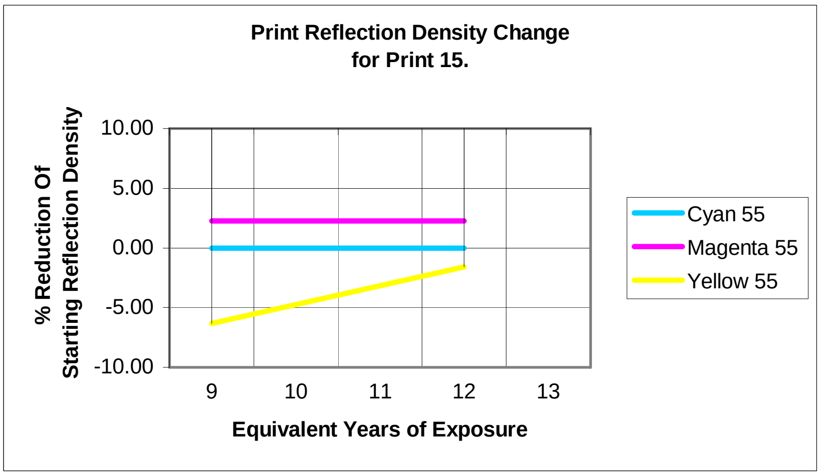

Figure 4.21. Print 15 cyan, magenta, and yellow patches (55%)

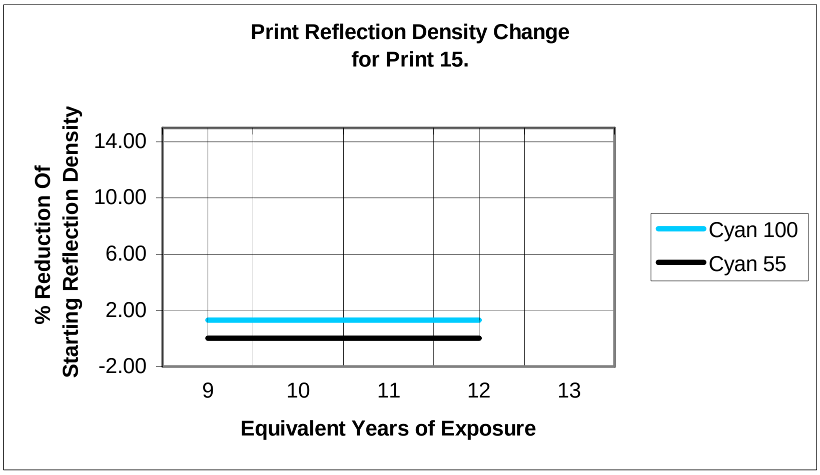

Figure 4.22. Print 15 cyan colour patches (55% and 100%)

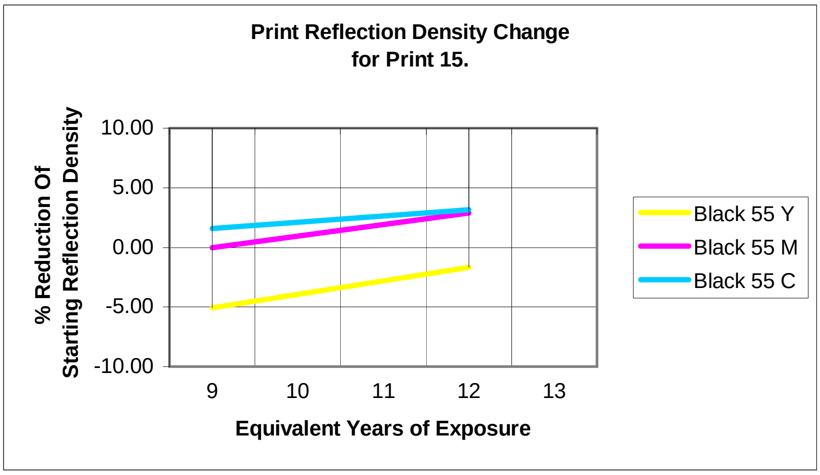

Figure 4.23. Print 15 neutral grey patch (55%)

Overall the Epson Stylus Photo 2100 printer produced prints with a very slow fading rate, regardless of the paper used.

Epson Stylus Color 480sxu inkjet printer, using Epson OEM inks.

Epson Premium Glossy Photo Paper S041286.

This is a low-cost general-purpose office or household printer, shown in Figure 4.12, utilising a dye-based inkset. It can produce an A-4 print at 720 dpi, giving a result which is acceptable as near photographic.

Figure 4.24. Epson Stylus Color 480 sxu inkjet printer

The raw data for this paper/printer combination are shown in Appendix D.5.

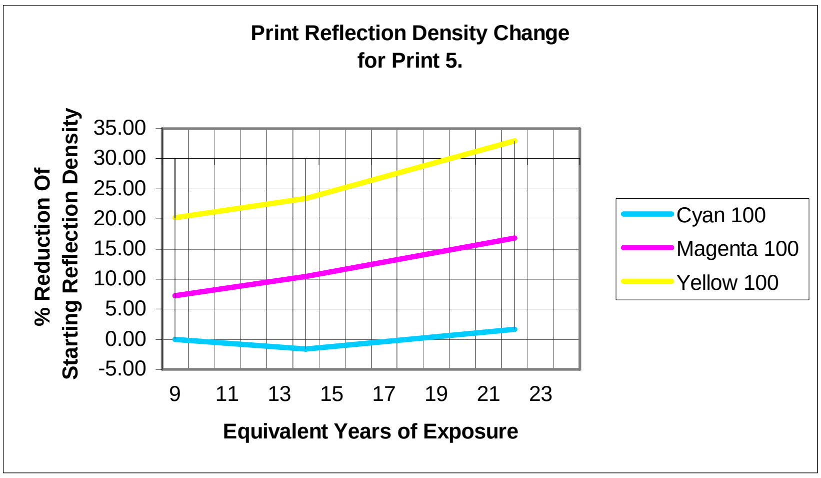

Figure 4.25. Print 5 cyan, magenta, and yellow patches (100%)

In the 55% neutral grey patch the yellow component decreased in density most rapidly. The cyan dye was the most stable as is shown in Figure 4.25. The print failed in the 100% yellow patch when the density dropped by 30% after 20 years equivalent exposure, as is shown in Figure 4.26. Figure 4.27 shows the stability of the cyan colour and the rapid fading of the yellow colour component in the 55% neutral grey patch.

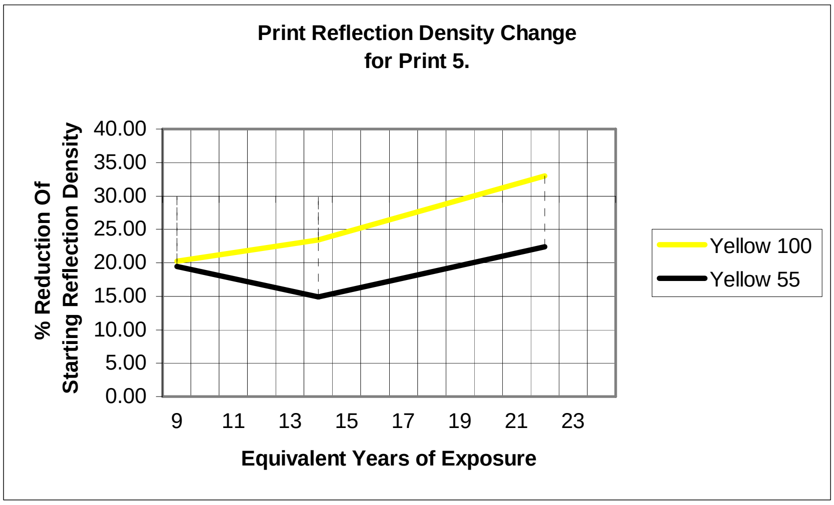

Figure 4.26. Print 5 yellow colour patches (55%. and 100%)

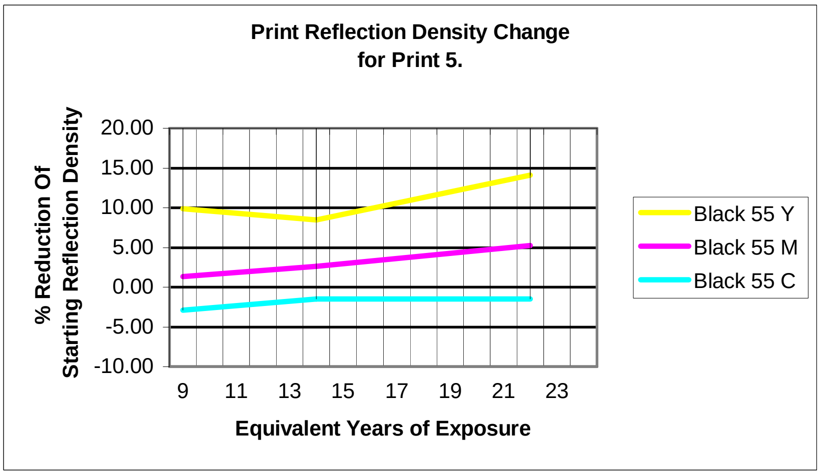

Figure 4.27. Print 5 neutral grey patch (55%)

Epson Stylus Photo 1200 inkjet printer, using MIS Archival pigment inks Epson Premium Glossy Photo Paper S041286 exposed to 35,5 Klux.

This printer is a predecessor of the Stylus Photo 2100, and was released with dye-based inks. It is capable of printing images up to a maximum size of 329 x 483 mm at a resolution of 1 440 dpi. For this test the printer was fitted with a continuous flow inking system and MIS ESCARC archival pigment inks supplied by MIS Associates Inc, U.S.A., as shown in Figure 4.28. MIS markets these inksets as a more permanent and lower cost alternative to Epson inksets. Once the MIS cartridge system is fitted it is permanent and only the inks need to be replaced.

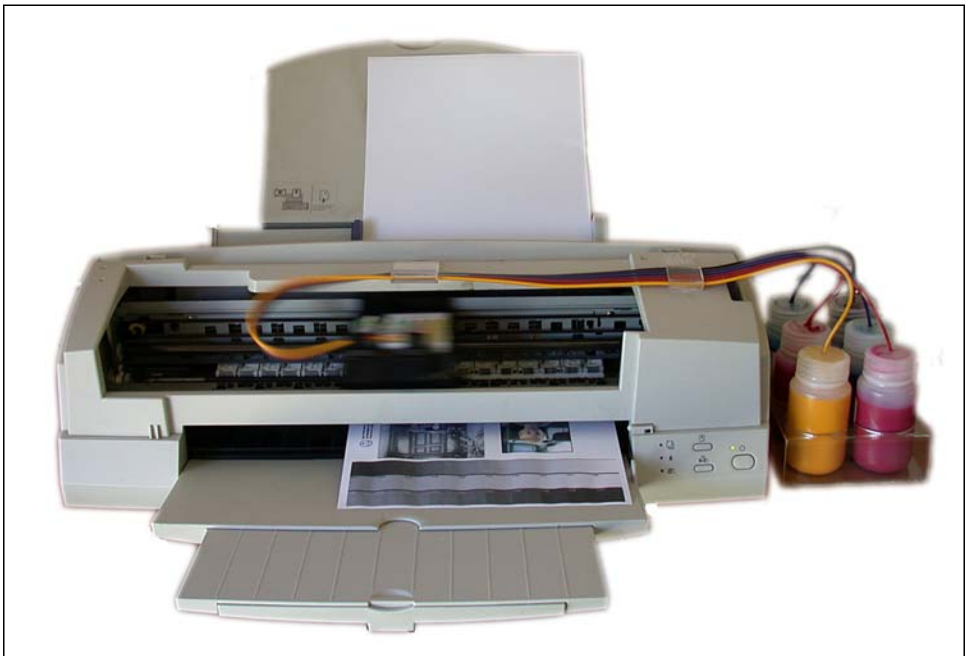

Figure 4.28. Epson Stylus Photo 1200 fitted with a continuous flow inking system.

The raw data for this paper/printer combination are shown in Appendix D.6.

Both the yellow patches, 55% and 100%, fell marginally out of the required starting density range at 1,02 and 0,51 respectively but in the case of the 100% yellow the difference was sufficiently small that the patch was taken into consideration in the predictions of image failure.

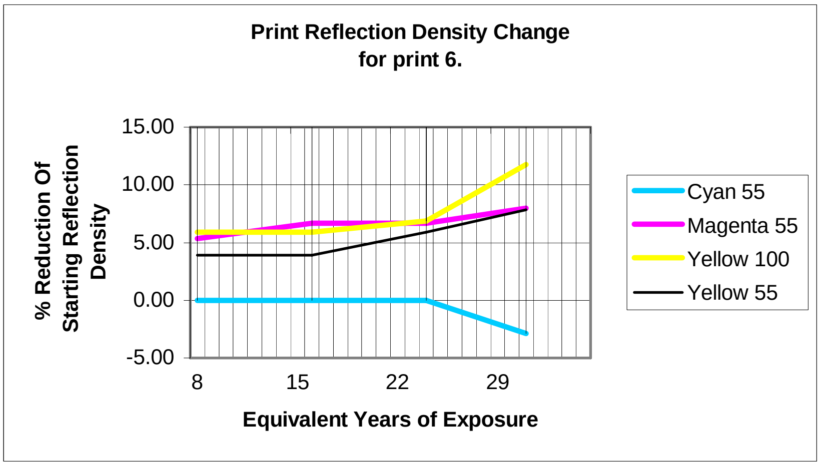

Figure 4.29. Print 6 cyan, magenta, and yellow patches (55%), and yellow (100%).

Cyan was the most stable colour, as shown in Figure 4.29, while yellow (100%) and magenta (55%) produced the greatest decreases in densities. Yellow 100% was the least stable.

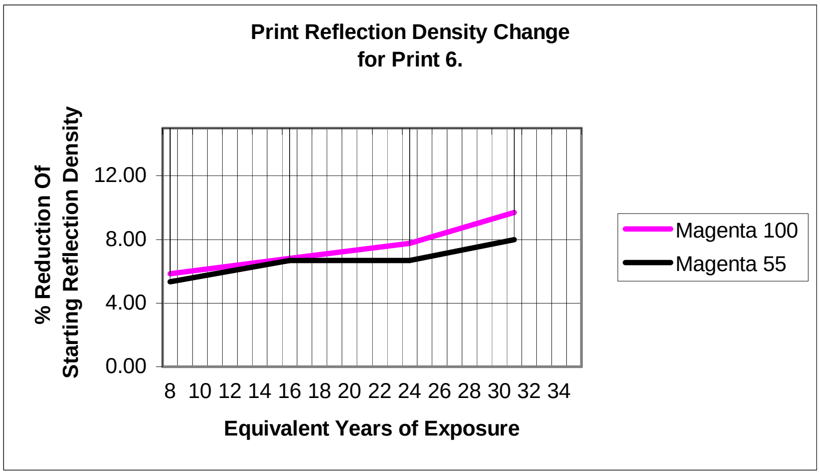

Figure 4.30. Print 6 magenta colour patches (55% and 100%)

Figure 4.30 shows the decrease in densities over time for the magenta 55% and 100% patches. As shown in figure 4.31 yellow and cyan were stable components of the 55% neutral colour patch, while magenta underwent the greatest density loss.

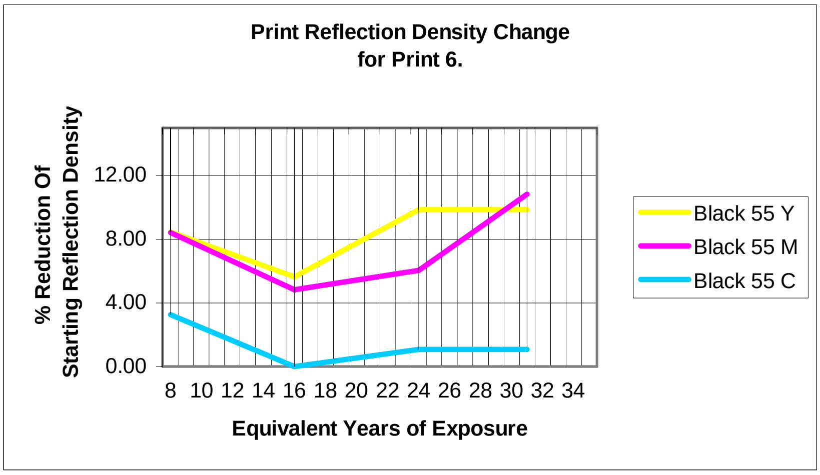

Figure 4.31. Print 6 neutral grey patch (55%).

Hewlett-Packard Deskjet 895 cxi inkjet printer, using Dual non-OEM inks

Epson Photo Quality Ink Jet Paper S041061.

Figure 4.32. HP Deskjet 895Cxi inkjet printer.

This is a low-cost general-purpose office or household printer, shown in figure 4.32, utilising a dye-based inkset. It can produce an A-4 print at 360 dpi, giving an acceptable pictorial result. The Dual inkset used for the test is a lower cost alternative to the OEM inkset.

The raw data for this paper/printer combination are shown in Appendix D.4.

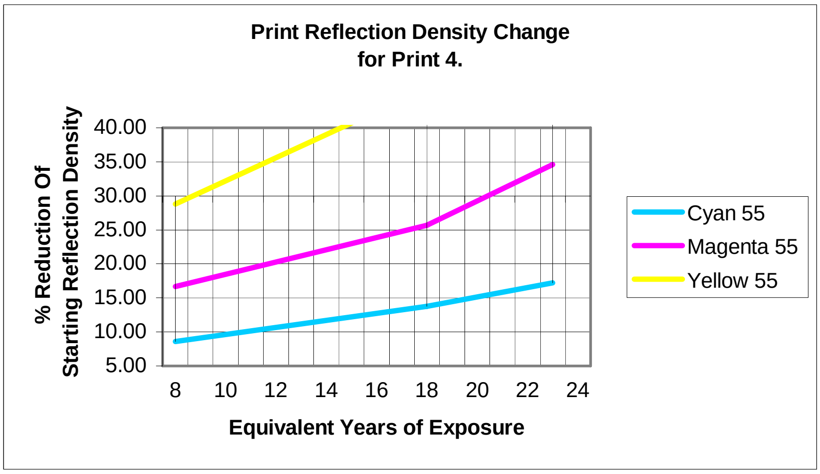

Figure 4.33. Print 4 cyan, magenta, and yellow patches (55%)

Figure 4.33 shows a comparison of the 55% cyan, magenta, and yellow colour patches. The cyan dye was the most stable, while yellow decreased in density most rapidly.

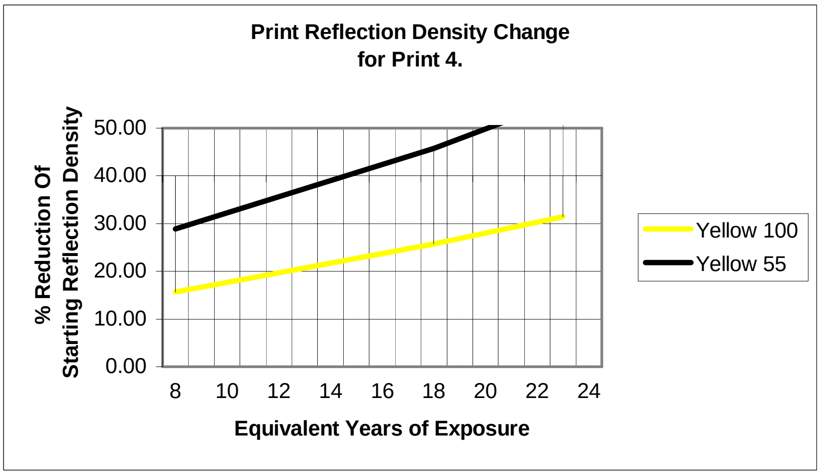

Figure 4.34. Print 4 yellow colour patches (55% and 100%)

Figure 4.34 shows the rapid decrease in the 55% yellow colour patch, and the point of failure at 9 years equivalent exposure.

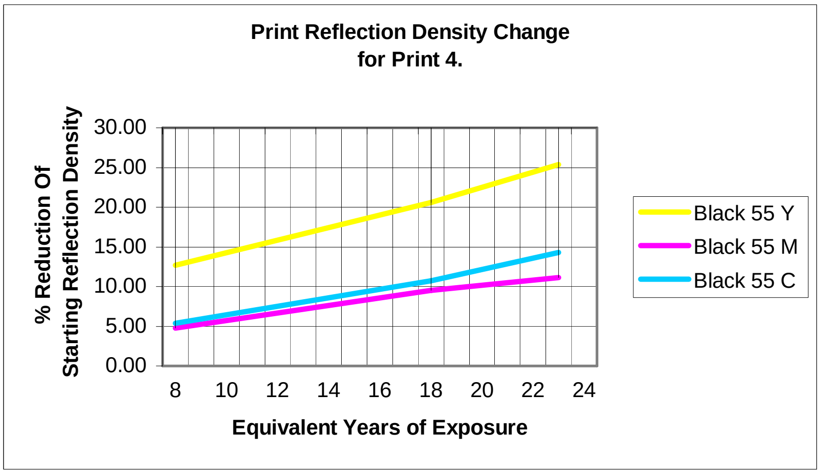

Figure 4.35. Print 4 neutral grey patch (55%)

Figure 4.35 shows the yellow component of the 55% neutral grey colour patch faded the most, as well as at a faster rate, which caused the neutral patch to shift towards blue in colour.

Hewlett Packard CP 1700 Color Inkjet printer, using OEM inks

Epson Premium Glossy Photo Paper S041286.

This is a high quality A3 sized printer, shown in Figure 4.36, intended for business and office use and it can produce photographic quality prints.

Figure 4.36. Hewlett Packard CP 1700 Color Inkjet printer.

The raw data for this paper/printer combination are shown in Appendix D.9.

All colours from this printer decreased in density rapidly. However, the inks had a narrow gamut and in each of the 100% and 55% patches, cyan, magenta, yellow, and neutral grey, the densities fell out of the 0,6 to 1,0 range. The cyan and magenta 55% patches came closest, with starting densities of 0,48 and 0,49 respectively. The neutral grey 55% patch could not be used for an end point prediction as there was not a 15% difference between the cyan, yellow, and magenta components at the end of the test period.

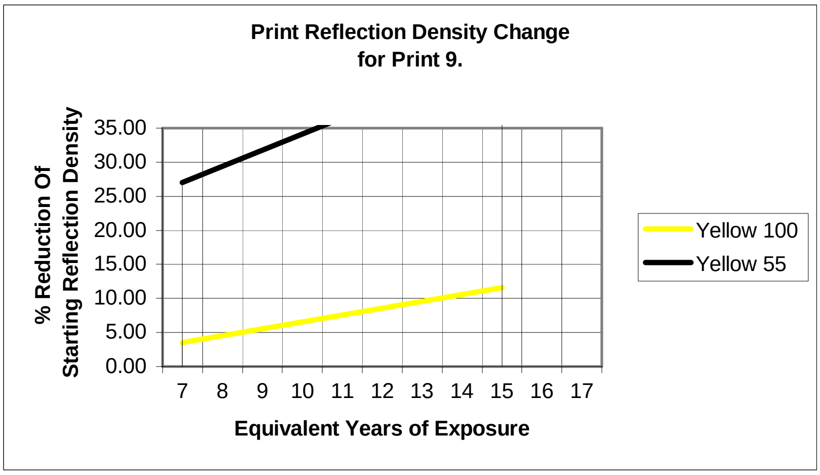

Figure 4.37. Print 9 yellow colour patches (55% and 100%)

Figure 4.37 shows the decrease in yellow density, with the greatest rate of decrease in the 55% yellow patch.

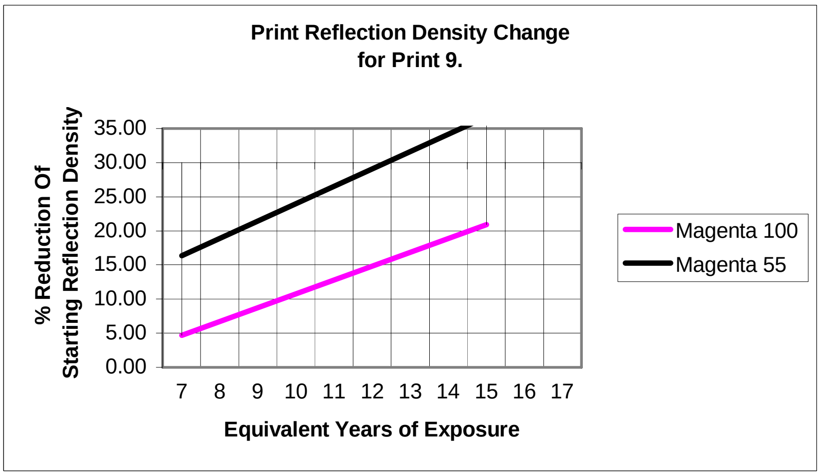

Figure 4.38. Print 9 magenta colour patches (55% and 100%).

Figure 4.38 shows a near parallel decrease in both the 55% and 100% magenta colour patches.

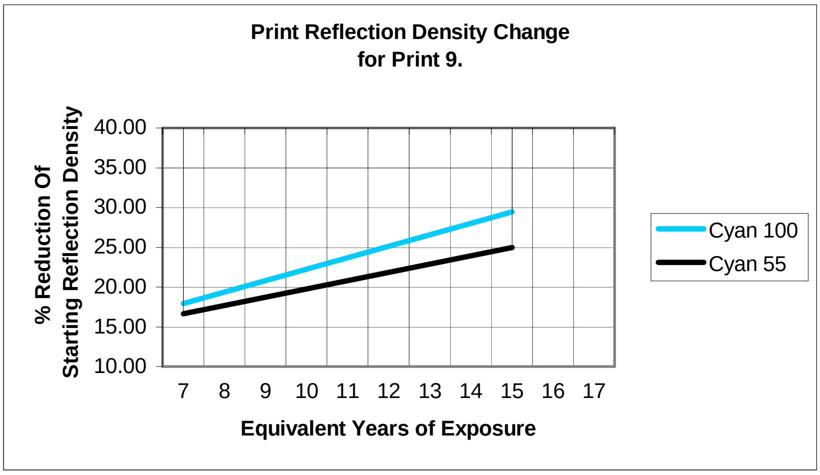

Figure 4.39. Print 9 cyan colour patches (55% and 100%)

Figure 4.39 shows the decrease in the 55% and 100% cyan colour patches.

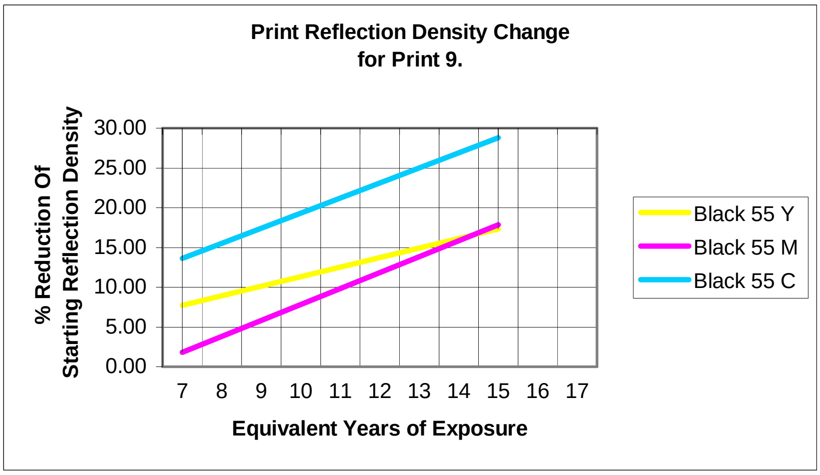

Figure 4.40. Print 9 neutral grey patch (55%)

Figure 4.40 shows the density decreases for cyan, magenta, and yellow in the 55% neutral grey patch. The cyan component faded the most. Magenta faded at a similar rate to the cyan, while yellow faded the least, which caused a shift in colour balance towards red.

Hewlett-Packard OfficeJet Pro 1150c inkjet printer

Epson Photo Quality Ink Jet Paper S041061.

The raw data for this paper/printer combination are shown in Appendix D.10.

This general-purpose office printer, shown in Figure 4.41, also has a scanning and colour photocopy facility. It is capable of producing an acceptable pictorial result at 300 dpi.

Figure 4.41. Hewlett-Packard OfficeJet Pro 1150c inkjet printer.

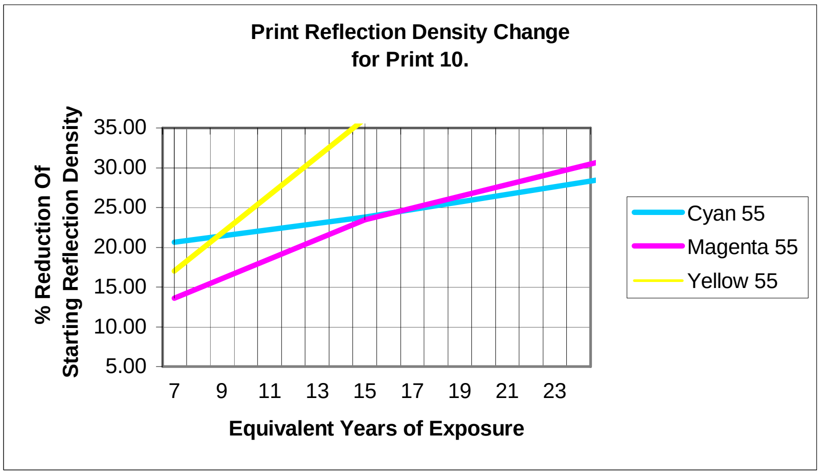

Figure 4.42. Print 10 cyan, magenta, and yellow patches (55%)

The raw data for this paper/printer combination are shown in Appendix D.10.

Both yellow patches, 55% and 100%, fell out of the 0,6 to 1,0 density range and could not be used for analysis. Figure 4.42 shows the increased rate of fading of the yellow patch compared with magenta and cyan.

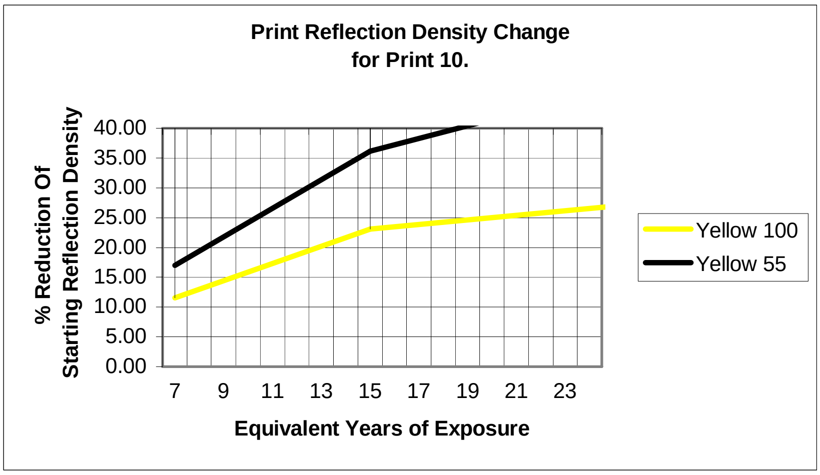

Figure 4.43. Print 10 yellow colour patches (55% and 100%)

Figure 4.43 shows that the yellow 55% faded more rapidly than the 100% patch.

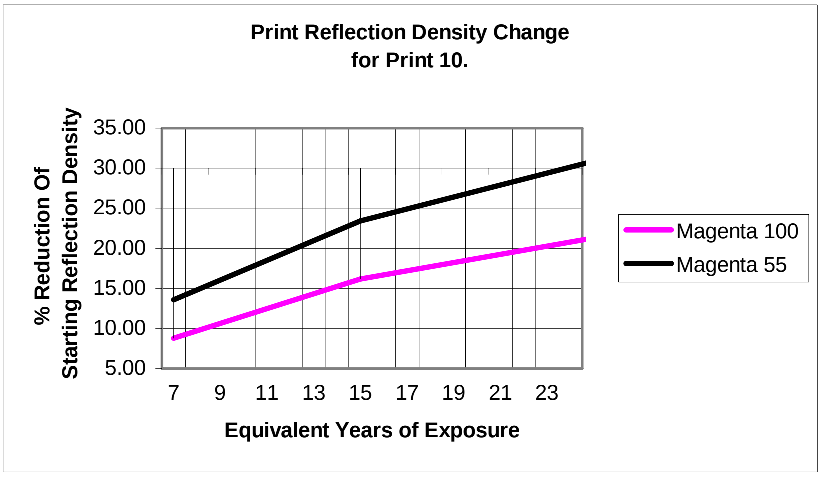

Figure 4.44. Print 10 magenta colour patches (55% and 100%).

On the basis of the 55% magenta colour patch fading this print reached its end point after 24 years, as shown in Figure 4.44.

Conclusions

Epson Autochrome pigment-based ink.

Epson Autochrome pigment-based inks were printed onto several different paper types. There were no significant changes in fade rates of the papers during the first 15 to 20 years equivalent exposure period. From that point the tests were continued only with Epson Premium Glossy paper and Somerset Velvet Radiant White paper. These are two entirely different types of paper: the Epson Glossy retains the inks in the glossy emulsion, while the 100% cotton Somerset Velvet is more absorbent, allowing inks to penetrate deeper. After approximately 25 years on both papers the mid-tone yellow began to fade. Fading was at approximately the same rate for both papers. Adding Excel trendlines to the graphs of density fading for these papers produced a theoretical end point for Somerset Velvet of approximately 120 years, and for Epson Premium Glossy approximately 130 years. These numbers are linear projections and would have to be tested for degree of accuracy by a longer period of accelerated testing. In both cases the yellow ink faded most rapidly.

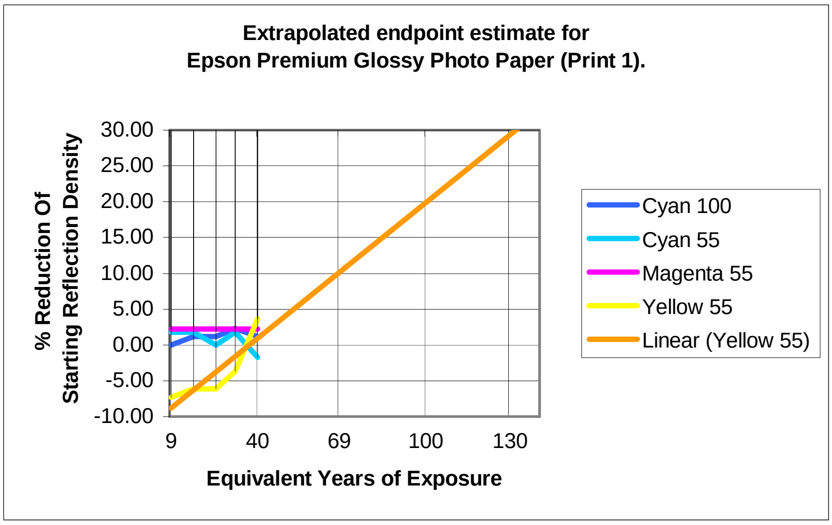

Figure 4.45. Print 1 end point estimate

Figure 4.45 shows a linear trendline prediction for the 55% yellow patch. A predicted end point is reached after approximately 130 years.

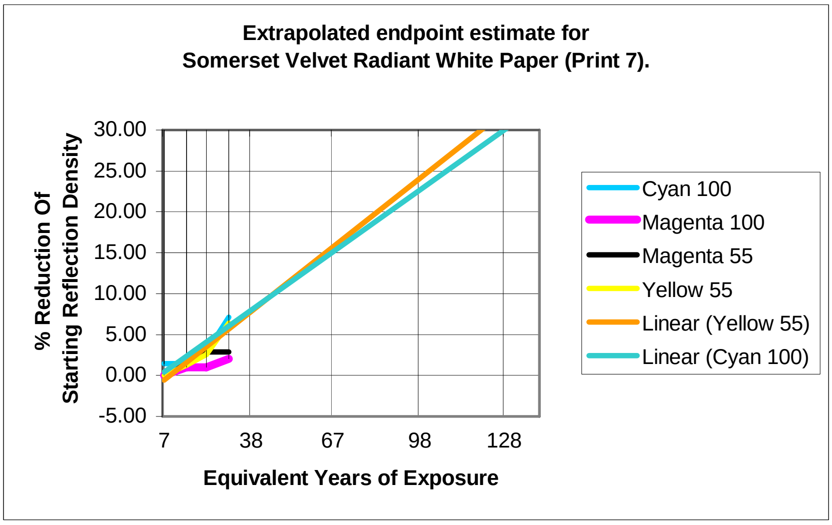

Figure 4.46. Print 7 end point estimate

Figure 4.46 shows a linear trendline prediction for the 55% yellow patch. A predicted end point is reached after approximately 130 years.

Other manufacturers' inks

During the time available for the tests three prints reached their end points, as shown in Table 4.4.

Table 4.4. List of prints, inks, and papers to reach an end point

Print no.	Printer	Ink	Paper	Colour to fail	Years to end point
4	HP 895 cxi	Dual	Epson Photo Quality Ink Jet Paper	Yellow	9
5	Epson Stylus Color 480sxu	OEM	Epson Premium Glossy Photo Paper	Yellow	20
10	HP OfficeJet Pro 1150c	OEM	Epson Photo Quality Ink Jet Paper	Magenta	24

Evidently with Print 10 the yellow 55% and 100% patches fell outside the 0,6 to 1,0 density range and could not be used for end point determination. The trend in yellow fading for this ink was more rapid than for magenta.

Print 9, Epson Premium Glossy Photo Paper printed on a HP CP1700 Color Inkjet Printer did not reach an end point because all three colours fell out of the required starting density range.

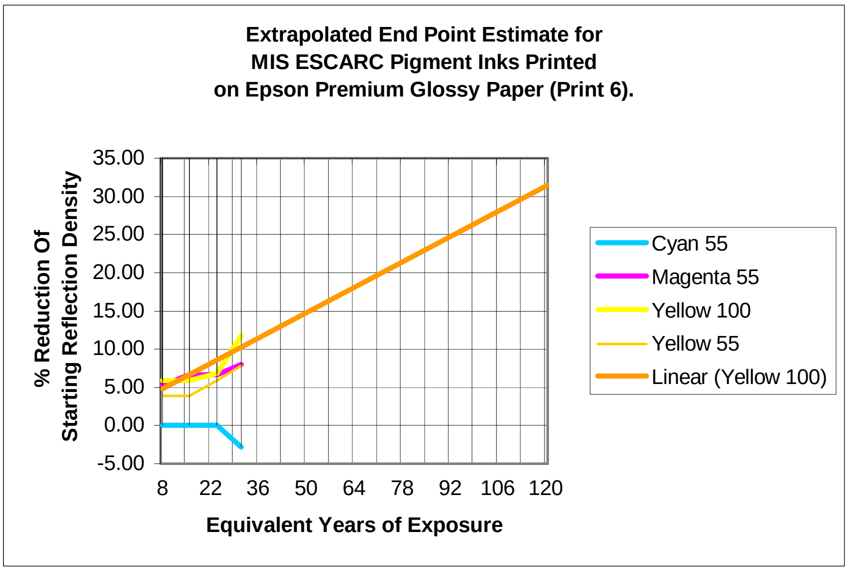

Figure 4.47. Print 6 end point estimate

Print 6 was made on Epson Premium Glossy Photo Paper printed on an Epson Stylus Photo 1200 with MIS ESCARC archival pigment-based inks. Extrapolating the trend of the quickest fading colour patch by means of a trendline led to an end point at approximately 115 years, as shown in figure 4.47.

Traditional colour photographs

Agfa Prestige Digital Glossy CN510 paper.

The raw data for this paper/printer combination are shown in Appendix D.8.

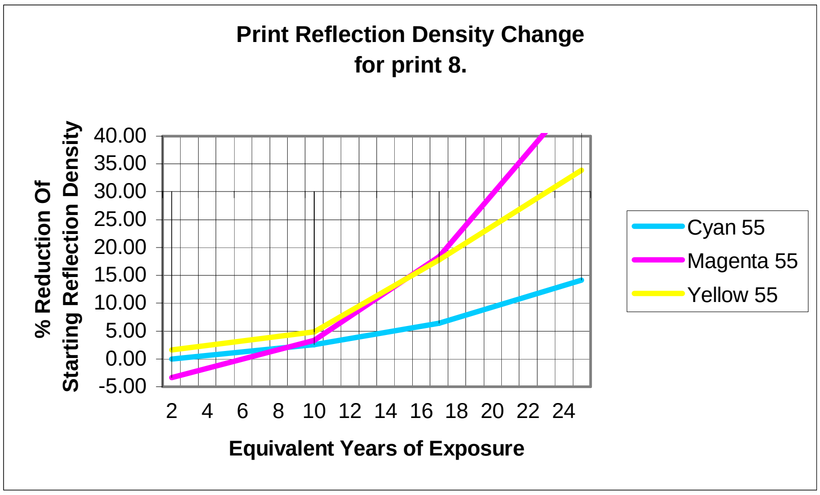

Figure 4.48. Print 8 cyan, magenta, and yellow patches (55%)

The print reached its end point when the 55% magenta patch dropped by 30% in density after 20,5 years, as shown in Figure 4.48. Cyan was most stable.

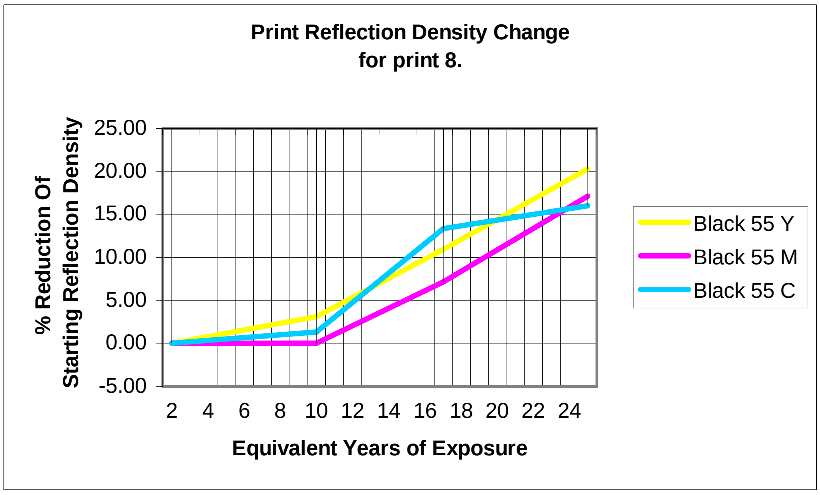

Figure 4.49. Print 8 neutral grey patch (55%)

Figure 4.49 shows that the 55% neutral grey patch remained neutral in colour balance as all colours in this patch reduced evenly in density during the test period.

Fuji Crystal Archive Glossy Type 1 Paper for Frontier.

The raw data for this paper/printer combination are shown in Appendix D.16.

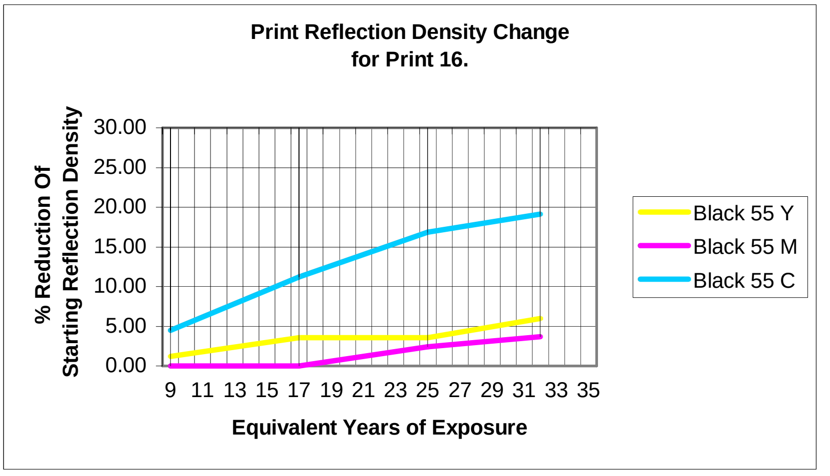

Figure 4.50. Print 16 cyan, magenta, and yellow patches (55%)

Figure 4.50 shows that 55% neutral grey patch approached the limit of colour shift towards a red colour at the print end point. The print reached its end point at 30 years with the failure of the 55% cyan colour patch, as shown in Figure 4.51. The magenta and yellow 55% patches deteriorated at a slower rate. The paper base changed in colour towards red as the yellow density increased and cyan decreased.

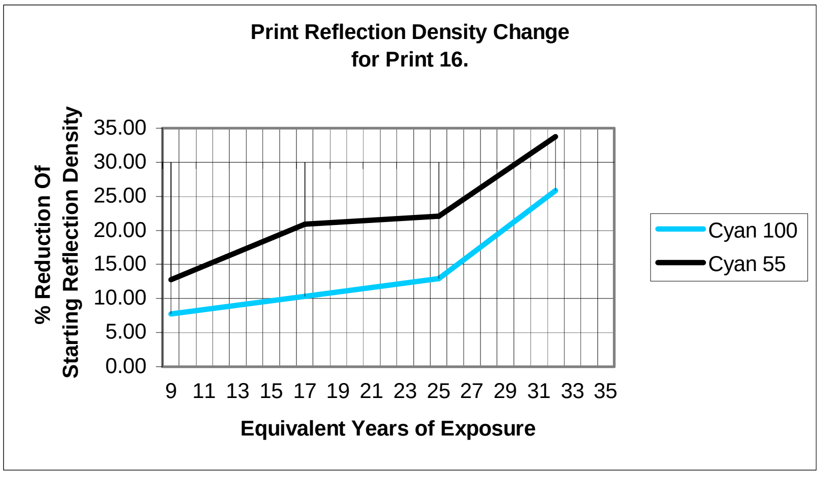

Figure 4.51. Print 16 cyan colour patches (55% and 100%)

Fuji Crystal Archive Lustre Type 1 Paper for Frontier.

The raw data for this paper/printer combination are shown in Appendix D.17.

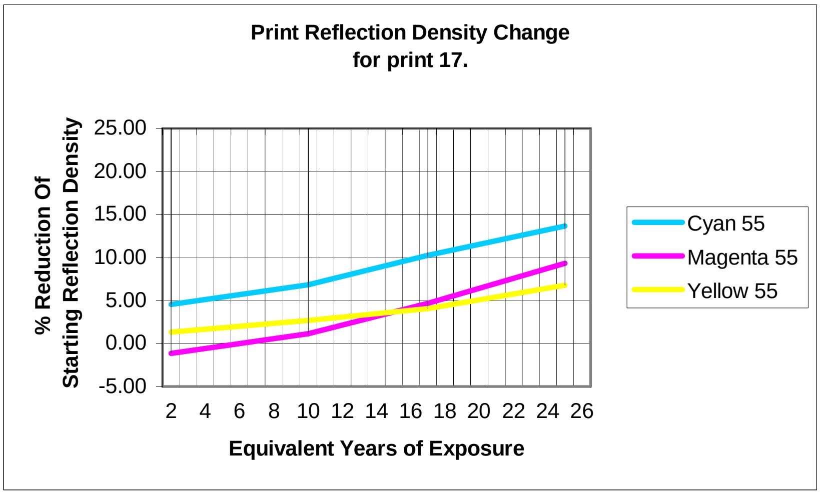

Figure 4.52. Print 17 cyan, magenta, and yellow patches (55%)

The greatest fading, shown in Figure 4.52, occurred in the cyan 55% colour patch. Figure 4.53 shows that the 55% neutral grey patch shifted towards red in colour balance as the cyan component decreased in density.

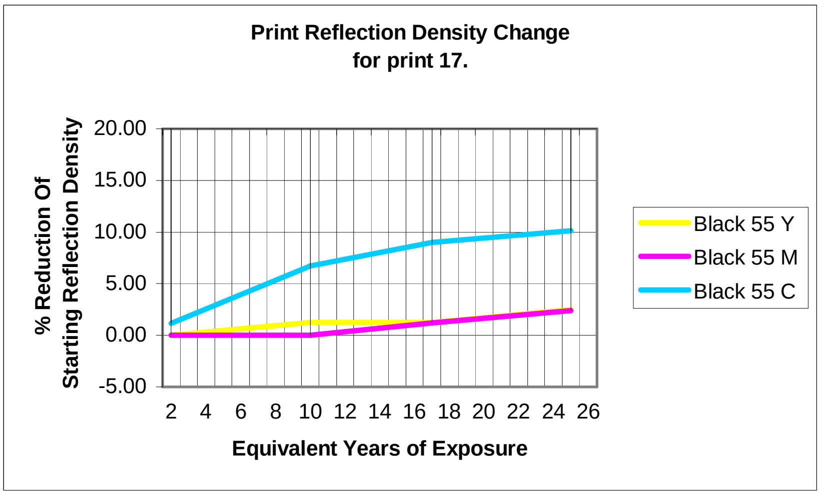

Figure 4.53. Print 17 neutral grey patch (55%)

Conclusions

Agfa Prestige Digital Glossy Paper and Fuji Crystal Archive Glossy Paper both failed relatively quickly. Fuji Crystal Archive Lustre Paper produced an estimated end point at approximately 65 years. The end point estimation is in concurrence with the findings of Wilhelm (2002) in which he lists an estimated life of 60 years for Fuji Crystal Archive paper. Wilhelm does not specify the surface finish of the paper.

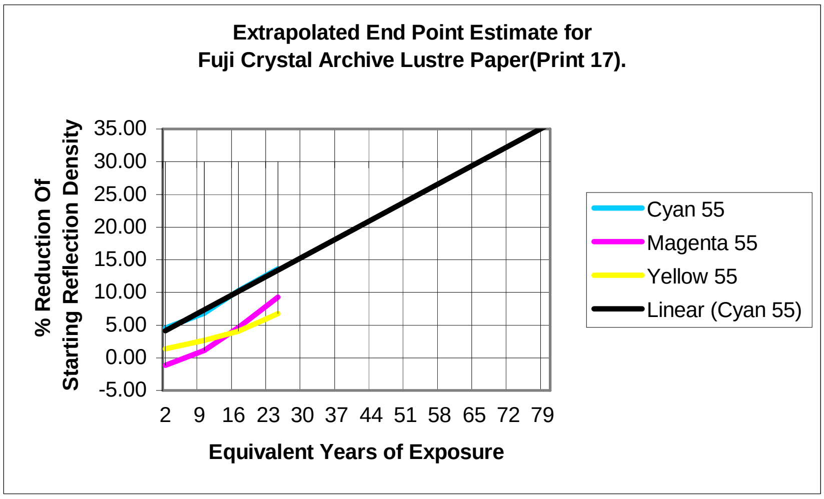

Figure 4.54. Print 17 end point estimate

Extrapolating the trend of the quickest fading colour patch, 55% cyan, by means of a trendline led to an end point at approximately 65 years, as shown in figure 4.54.

Reciprocity tests

The purpose of this test was to determine if trends could be established between the rates of density fading for prints exposed to lower levels of illumination compared with those at higher levels.

Three print samples were tested at an illumination level of 6 Klux. Raw data are shown in Appendices D.1 to D.3. The time period available for this test did not allow any significant trends to develop that could be compared with results from the accelerated fade tests.

Dark fade tests

The purpose of this test was to determine the extent to which temperature may have influenced changes in the colour densities of the traditional photographic test prints.

For this analysis test prints were compared at 20 years equivalent exposure. Raw data are shown in Appendices E.1 and E.2.

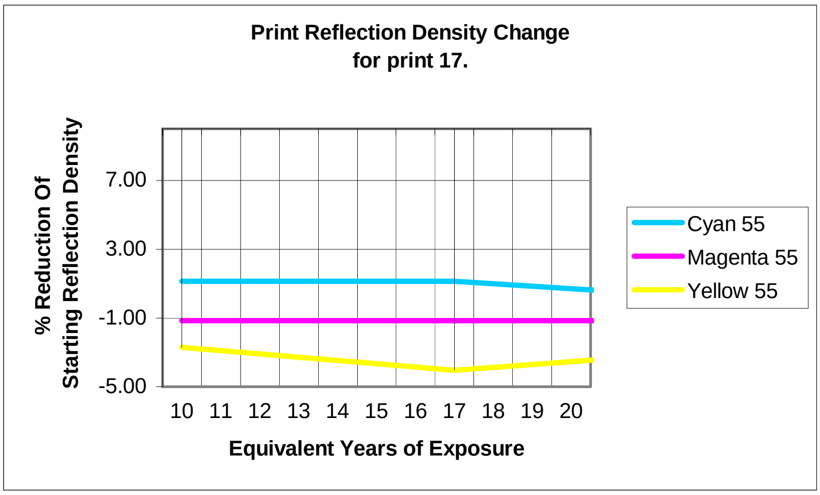

Figure 4.55. Print 17 neutral grey patch (55%),
dark testing for Fuji Crystal Archive Lustre

Figure 4.55 shows the stability of all the colours. No significant changes in density were found during the test period.

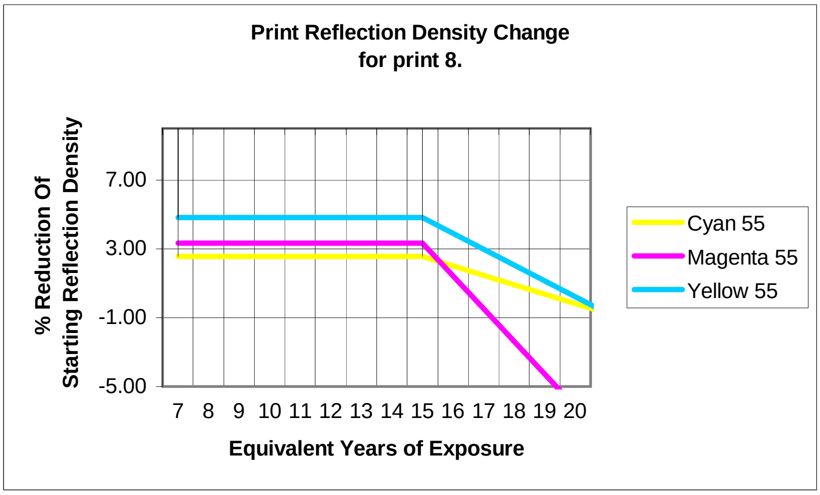

Figure 4.56. Print 17 neutral grey patch (55%),
dark testing for Agfa Prestige Digital Glossy

Agfa Prestige Digital Glossy paper increased in density after 15,5 years, as shown in Figure 4.56.

Paper base test

The purpose of this test was to determine the extent to which the effects of light and temperature changed the colour of the paper base.

Data for discolouration of the paper bases were collected in two ways, namely

- Paper exposed to light and temperature, and
- Paper exposed to temperature only.

For this analysis paper base samples were compared at 20 years equivalent exposure.

The paper samples tested were:

- Epson Premium Glossy Photo Paper S041286;
- Epson Photo Quality Ink Jet Paper S041061;
- Epson Enhanced Matte Paper S041341;
- Agfa Prestige Digital Glossy CN510; and
- Fuji Crystal Archive Lustre Type 1 Paper for Frontier.

The raw data are shown in Appendix G.1 and G.2. The density differences over time were small. As the densitometer could measure minimum increments of 0,1 density units, base colour change was considered a degrading factor in the life of the print only when a clear trend developed. An example is with Epson Enhanced Matte Paper where the yellow of the base changed from –0,01 to 0,02. The effects of changes in cyan and magenta for the same paper were insignificant. A technician from Agfa suggested that fluctuations of 0,01 density units measured by the densitometer were so miniscule that they could be ignored (Carew, 2003). The results are summarised in Table 4.5.

Table 4.5. Results of paper base colour change tests

Print	Effect of light and temperature.	Effect of temperature only.
Epson Premium Glossy Photo Paper	No significant change.	No significant change.
Epson Photo Quality Ink Jet Paper	Increase in yellow.	No significant change.
Epson Enhanced Matte Paper	Increase in yellow.	No significant change.
Agfa Prestige Digital Glossy	Increase in yellow.	No significant change.
Fuji Crystal Archive Lustre	Increase in yellow.	No significant change.

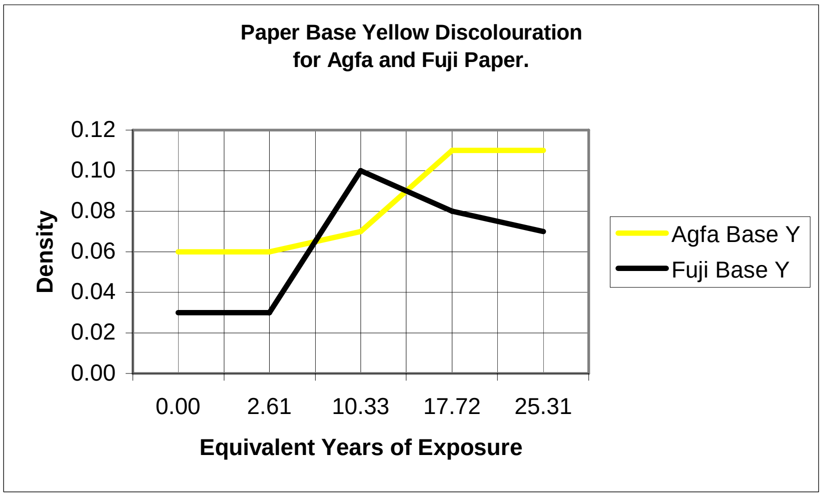

Figure 4.57. Comparison of change in paper base yellow between Fuji Crystal Archive Lustre and Agfa Prestige Digital Glossy

A large increase in yellow density was found with traditional colour photographic papers tested, as shown in Figure 4.57. Figure 4.58 shows the stability of the base colour of Epson Premium Glossy Photo Paper, while Figure 4.59 shows minor fluctuations in base colour of Epson Photo Quality Ink Jet Paper. Figure 4.60 shows noticeable colour changes in the base of Epson Enhanced Matte Paper.

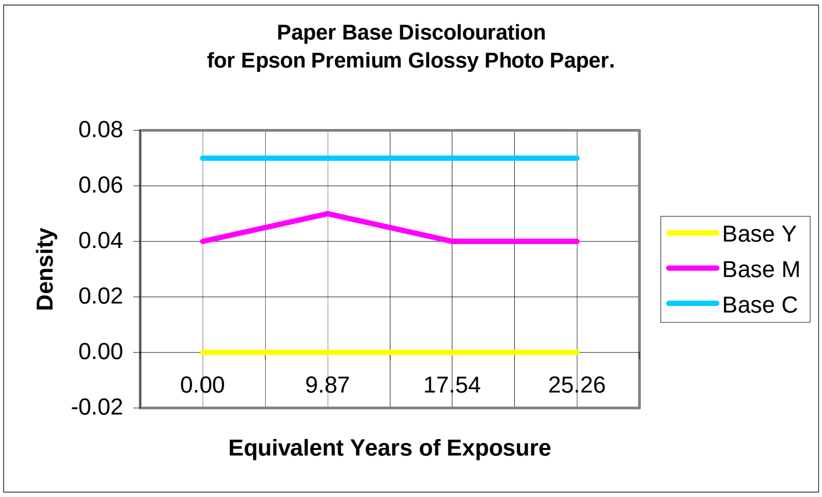

Figure 4.58. Paper base colour change for Epson Premium Glossy Photo Paper, exposed to light and temperature

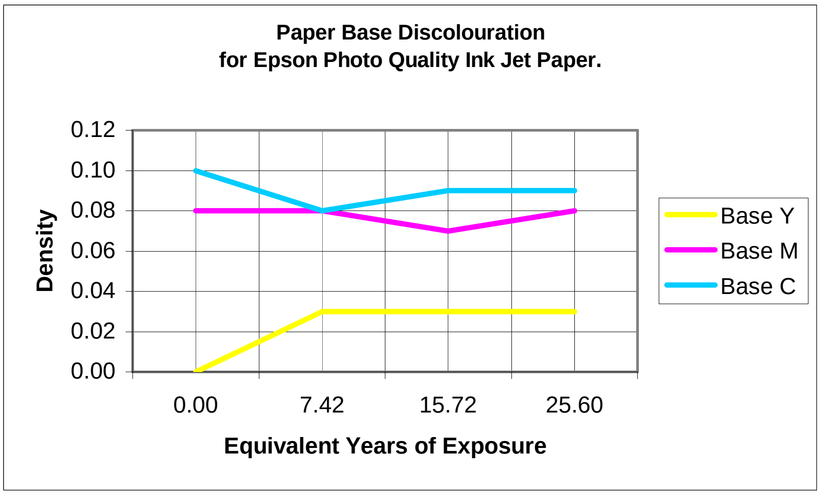

Figure 4.59. Paper base colour change for Epson Photo Quality Ink Jet Paper, exposed to light and temperature

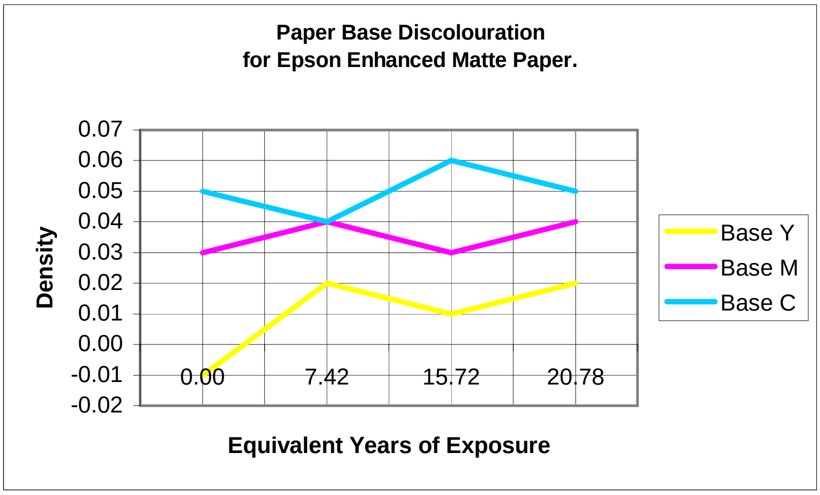

Figure 4.60. Paper base colour change for Epson
Enhanced Matte Paper, exposed to light and temperature

Of the three inkjet papers tested Premium Glossy Photo Paper was least affected by heat and light. The other two paper samples showed small increases in yellow during the initial period of testing before becoming relatively stable.

Overall conclusions

The results of the tests are in agreement with those of researchers such as Wilhelm (2000) and Vogt (2001), namely that image density decreases with duration of exposure to light, and paper base discolours with exposure to light.

A summary of the overall results of the accelerated fade testing is shown in Table 4.6 below. The end points are shown in years, where A is from actual measurement, and P is projected.

Table 4.6. End points of papers tested

No.	Paper	Printer/processor	Ink/chemicals	End point
1	Epson Premium Glossy Photo Paper	Epson 2100	OEM	130 P
4	Epson Photo Quality Inkjet Paper	HP 895 cxi	Dual	9 A
5	Epson Premium Glossy Photo Paper	Epson 480SXU	OEM	20 A
6	Epson Premium Glossy Photo Paper	Epson 1200	MIS ESCARC	115 P
7	Somerset Velvet Radiant White	Epson 2100	OEM	120 P
8	Agfa Prestige Digital Glossy	Agfa D-Lab 2	Agfa	20,5 A
9	Epson Premium Glossy Photo Paper	HP CP 1700	OEM	16,5 P
10	Epson Photo Quality Inkjet Paper	HP 1150c	OEM	24 A
16	Fuji Crystal Archive Glossy Paper	Fuji Frontier	Fuji	30 A
17	Fuji Crystal Archive Lustre Paper	Fuji Frontier	Fuji	65 P

It is evident from Table 4.6 that:

- Pigment-based inkjet prints have the longest life overall, approximately double that of the best traditional colour photograph;
- Non-OEM dye-based inkjet prints have the shortest life;
- OEM dye-base inkjet prints have a shorter life than traditional colour photographs; and
- Fuji Crystal Archive Lustre paper has the longest life compared with the other traditional colour photographs.

CHAPTER 5
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study, as stated in the chapter entitled Introduction, was to examine whether the cost and image permanence of inkjet prints made them a suitable alternative to traditional colour photographs. The primary objectives of the study were:

- To conduct a cost-analysis of high quality inkjet printing in order to establish their cost effectiveness or feasibility as an alternative to traditional photographic printing;
- To test the life of various inkjet print/paper combinations to determine if inkjet prints have an adequate life for their intended purpose; and
- To test the life of traditional photographic papers by different manufacturers to determine which displays the least fading in order to establish a comparison with the life of inkjet prints.

This chapter provides a summary of the findings of the study and conclusions relative to each of these objectives.

Cost analysis of printing

Machine printing traditional colour photographs produced prints at a lower cost than inkjet printers, whereas hand printing increased the cost to a level slightly lower than a high-quality inkjet print. Adding the cost of scanning an original image for inkjet printing increased the cost to approximately double that of hand printing a traditional colour photograph.

Costs of materials, cost of printer, and overhead costs were the main contributing factors to print prices. Printmakers were disinclined to use non-OEM materials in order to reduce costs because of the lack of backup support.

With one exception inkjet printmakers used Epson printers. Epson pigment inks were used in all but one case. In this instance the printmaker used a printer modified to use non-OEM pigment inks, because the OEM inks manufactured for the printer, a Stylus Photo 1200, were dye-based, giving rise to a shorter print life. These inks were considerably lower in cost than the OEM product, resulting in a cost benefit to the end user.

The hypothesis that the price of high quality inkjet prints exceeds that of pure photographic processes cannot be rejected.

Inkjet print testing

The seminal research on the quantitative experimental approach relating to accelerated fade testing of print images was reviewed and the principles applied to the tests conducted in this research.

The research objectives were partly met:

- The time available for testing was not adequate to test all prints to their end points; and
- The time available for the test was not adequate for clear trends to develop in testing prints at lower levels of illumination. Wilhelm has ongoing tests of this nature that were started in 1982 (Wilhelm and Brower, 1993). The best way to predict the fading of a print over time is to display the print for that time under normal lighting conditions and measure the deterioration. However, for practical reasons this is not possible, and use has to be made of accelerated testing techniques as in this study.

It was shown that prints made with dye-based inks faded considerably more rapidly than those made with pigment-based inks regardless of the paper used. This concurs with the findings of Wilhelm (2002). However, in the time available for the tests it could not be shown that the paper type or surface used had any significant influence on the life of a print produced by the same ink.

The hypothesis that the life of an inkjet print varies depending on the paper/ink combination cannot be rejected.

In comparing the effects of light and temperature with that of temperature only on the paper samples it was shown that light was the primary influence on base colour change. All inkjet papers tested were free from base colour change as a result of temperature only.

In no case was base discolouration the cause of a print end point.

Traditional photographic print testing

The research objective was met, namely:

- To test the life of traditional photographic papers in order to establish a comparison with the life of inkjet prints.

In this regard variations were found between manufacturers, and within materials produced by the same manufacturer.

The hypothesis that the life of traditional photographic prints varies according to the manufacturer of the paper cannot be rejected.

The hypothesis that the life of a print produced using traditional photographic processes does not vary according to the paper used as much as inkjet prints, is rejected.

Conclusions

An inkjet print produced on a printer using pigment-based inks will last longer than a traditional colour photograph before noticeable fading takes place, but at a higher cost to the end user.

Traditional colour photographs on paper by the same manufacturer may show a considerable difference in acceptable life depending on the paper surface, even though the chemical emulsions and image dyes are the same.

Inkjet printers using dye-based inks are capable of producing high quality photographic results with the limitation of a short life span.

The results of expected life of display in this study were based on a display illumination of 300 lux, with prints framed behind glass. Unframed prints exposed to higher levels of illumination may fade more rapidly than suggested in this study. Whereas the criteria for reaching the end of the acceptable life of a print in these tests were based on starting print reflection densities in the 0,6 to 1,0 range, end users may have different criteria. For example, pale colours in a print of a wedding dress may show an unacceptable change in colour balance or loss of highlight detail due to the low starting densities much more rapidly than a print in which mid-tone colours are more important.

Recommendations for further research

End point testing of dye-based inks on different paper types needs to be investigated in order to find the extent to which paper absorption of dyes extends the acceptable life of a print. These results will be of benefit to those persons wishing to print their own images on lower-end inkjet printers to the maximum advantage.

Reciprocity effects in accelerated light fading tests needs to be quantified in order to increase the validation of end point predictions in these tests.

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BIOGRAPHICAL SKETCH

Irvine Alfred Caleb Meyer was born in Ladysmith, Kwazulu-Natal, South Africa, in 1953. He took his first photograph at the age of ten on a Kodak Box Brownie, which cost him about R1.00. After several family relocations his schooling concluded as Dux in Empangeni in the same province. He studied mechanical engineering for two years at the University of Natal, Durban, before changing to photography at the (then) Natal College for Advanced Technical Education (now Durban Institute of Technology). A small scholarship permitted him to attend a three-month photography workshop in the U.S.A. in 1979, during which he met an ex-curator of photography of the U.S.A. Library of Congress. This kindled an interest in photographic permanence.

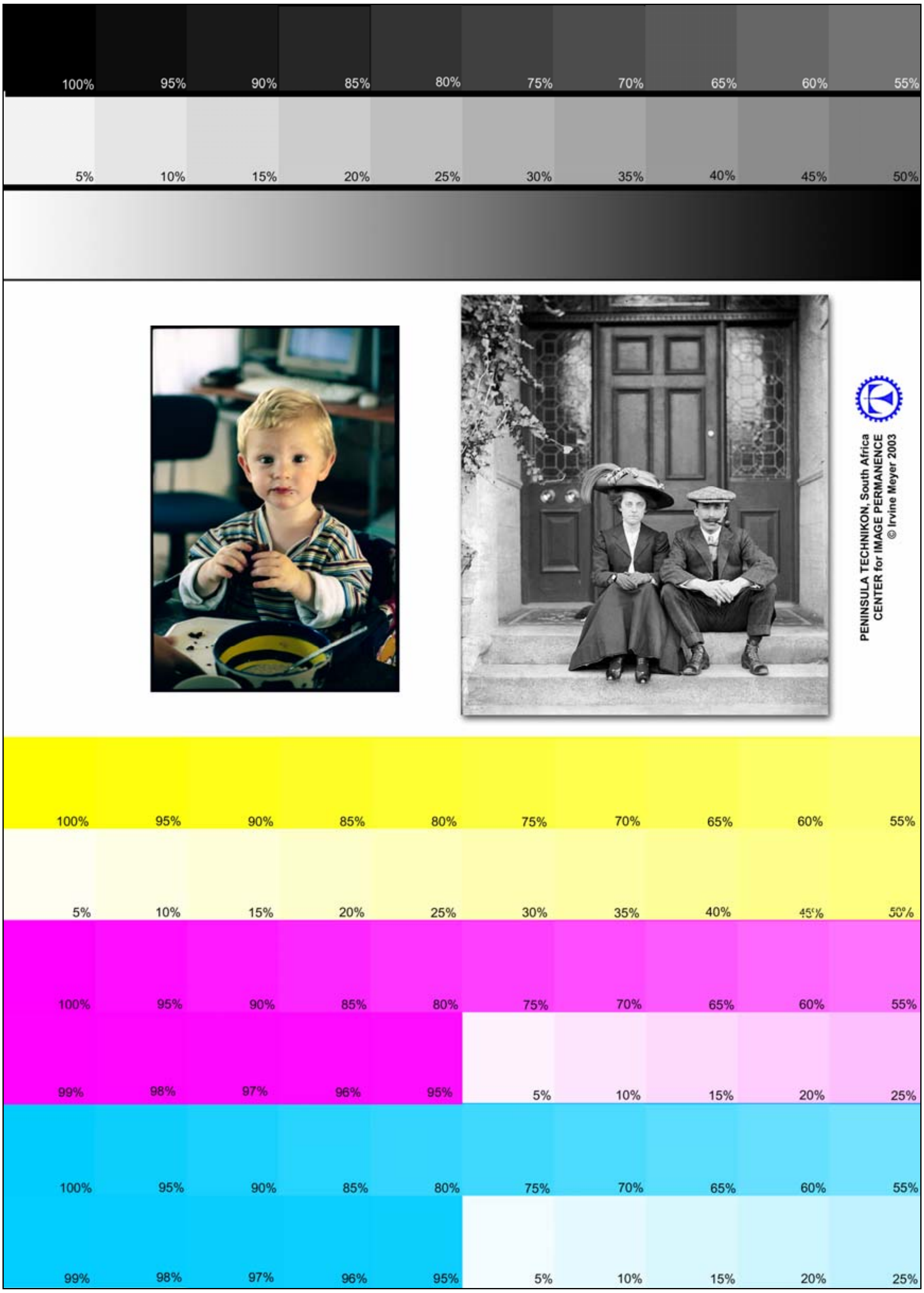
Three years working in the field of commercial photography preceded his entrance in 1981into teaching photography, which remains his present career. He completed the National Higher Diploma: Photography at Peninsula Technikon in 1987. The comparatively recent mushrooming of digital photography and inkjet printers as an alternative to traditional photographic techniques gradually began to raise questions in his mind about digital images: quality, storage, ethics, and the tactile nature of the output.

Considering himself a traditionalist who has embraced new technology, he decided to investigate what happens to the output from digital or digitised images on inkjet printers.

His favourite camera is a traditional wood-and-brass 4x5 folding field camera, which takes no batteries. He bought it in 1981, the same year he bought his first HP PC. He loves his inkjet printer too.

APPENDIX A

TEST IMAGE USED IN THE FADE TESTS IN THIS STUDY



APPENDIX B

COSTING QUESTIONNAIRE FOR INKJET PRINTS AND TRADITIONAL COLOUR PHOTOGRAPHS

Inkjet and traditional colour photographic prints.

Costing questionnaire.

This study is being undertaken to determine the cost of photographic prints compared with inkjet prints.
All information regarding any company names or personnel is strictly confidential.

Questions:

1 What is the price of machine and hand-printing a single A4 print?	Photographic:	R /R	Inkjet:	R	
2 Do you offer a discount for multiple prints of the same image?	YES	NO			
3 How do you determine the market price of a print?					
4 How long do you think the prints you produce will last before observable fading takes place?					
5 Is it important to you or your clients to know the expected print life of the images you produce?	YES	NO			
6 Would you like to have any of your prints tested for relative image permanence?	YES	NO			

The following questions apply only to inkjet printers:

7 Do you use the printer manufacturer's inks?	YES	NO	Why?	
8 Do you use re-fill or "pirate" inks?	YES	NO	Why?	
9 What brand(s) of paper do you use?				
10 What make and model of inkjet printer do you use?				

11 To what extent is the price of prints influenced by:

	1 (not at all)	2	3	4	5 (totally)
Inks					
Paper					
Printer?					

APPENDIX C.1

CONTROL SHEET FOR ACCELERATED FADING PRINT SAMPLES

ACCUMULATED EXPOSURE

Prints exposed to 35,5 Klux.

Print				**Accumulated Hours**	**Kluxhours**	**Equivalent Years**
1	Eps Prem Glossy Ph	**Epson 2100**		779.50	27672.25	40.24
2	Artist Canvas Paper	**Epson 2100**		352.17	12502.04	18.18
3	Helox Glossy	**Epson 2100**		352.17	12502.04	18.18
4	Eps Photo Quality	**HP 895 cxi Dual**		450.17	15981.04	23.24
5	Eps Prem Glossy Ph	**Ep 480SXU**		438.92	15581.66	22.66
6	Eps Prem Glossy Ph	**Ep 1200 MIS ARC**		613.58	21782.09	31.67
7	Somerset Velvet	**Epson 2100**		588.25	20882.88	30.37
8	Agfa Prestige Digital	**Agfa D-Lab 2**		490.25	17403.88	25.31
9	Eps Prem Glossy Ph	**HP CP 1700**		292.75	10392.63	15.11
10	Eps Photo Quality	**HP 1150c**		495.84	17602.32	25.60
11	Eps Photo Quality	**Epson 2100**		304.59	10812.95	15.72
12	Eps Archival Matte	**Epson 2100**		402.59	14291.95	20.78
13	Eps Semi-Gloss	**Epson 2100**		353.34	12543.57	18.24
14	Generic Semi-Gloss	**Epson 2100**		544.59	19332.95	28.11
15	Xerox Bond Plain	**Epson 2100**		238.09	8452.20	12.29
16	Fuji Crystal Archive glossy	**Frontier**		632.50	22453.75	32.65
17	Fuji Crystal Archive lustre	**Frontier**		490.25	17403.88	25.31

	10/8/2003	17-Oct-03	19-Oct-03	27-Oct-03	3-Nov-03	10-Nov-03	17-Nov-03	24-Nov-03
Print	**Hours**	**Hours**	**Hours**	**Hours**	**Hours**	**Hours**	**Hours**	**Hours**
1				191.25	148.5	149.67	143.08	147
2		160.92		191.25	stop			
3		160.92		191.25	stop			
4		160.92		191.25	98	stop		
5				191.25	98	149.67	stop	
6					173.83	149.67	143.08	147
7					148.5	149.67	143.08	147
8					50.5	149.67	143.08	147
9						149.67	143.08	stop
10	143.67	160.92		191.25	stop			
11	143.67	160.92			stop			
12	143.67	160.92			98	stop		
13	192.42	160.92			stop			
14	192.42	160.92		191.25	stop			
15	192.42		45.67		stop			
16				191.25	148.5	149.67	143.08	stop
17					50.5	149.67	143.08	147

APPENDIX C.2

CONTROL SHEET FOR PRINTS SUBJECTED TO RECIPROCITY TEST

RECIPROCITY TEST

Prints exposed to 6Klx.

			3-Nov	10-Nov	17-Nov	24-Nov
	Paper	**printer/ink**	**Hours**	**Hours**	**Hours**	**Hours**
6	**Eps Prem Glossy Photo Paper**	**Ep 1200 MIS ARC**	71.00	149.30	143.08	147.00
8	**Agfa Prestige Digital Glossy**	**Agfa D-Lab 2**	68.75			238.00
17	**Fuji Crystal Archive Velvet**	**Fuji Frontier**		124.83		147.00

	Paper	**printer/ink**	**Accumulated Hours**	**Kluxhours**	**Equivalent Years**
6	**Eps Prem Glossy Photo Paper**	**Ep 1200 MIS ARC**	510.38	3062.28	4.45
8	**Agfa Prestige Digital Glossy**	**Agfa D-Lab 2**	306.75	1840.50	2.68
17	**Fuji Crystal Archive Velvet**	**Fuji Frontier**	271.83	1630.98	2.37

APPENDIX C.3

CONTROL SHEET FOR PRINTS SUBJECTED TO DARK FADING TEST

DARK TEST

	Paper	printer/ink	10-Nov-03 Hours	17-Nov-03 Hours	24-Nov-03 Hours
8	**Agfa Prestige Digital Glossy**	**Agfa D-Lab 2**	149.67	143.08	147.00
17	**Fuji Crystal Archive Velvet**	**Fuji Frontier**	201.17	143.08	147.00

	Paper	printer/ink	Accumulate Hours	Equivalent Years
8	**Agfa Prestige Digital Glossy**	**Agfa D-Lab 2**	439.75	22.69
17	**Fuji Crystal Archive Velvet**	**Fuji Frontier**	491.25	25.35

APPENDIX D.1

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 1 FOR ACCELERATED FADE TEST

PRINT NUMBER:	**1**

Epson Premium Glossy Photo Paper
Printer: Epson Stylus Photo 2100
Inks: Epson OEM

Density values

Years:	0.00	9.87	17.54	25.26	32.65	40.24
Cyan 100	0.87	0.87	0.86	0.86	0.85	0.86
Cyan 55	0.57	0.56	0.56	0.57	0.56	0.58
Cyan 5	0.13	0.13	0.13	0.13	0.13	0.14
Years:	0.00	9.87	17.54	25.26	32.65	40.24
Magenta 100	1.52	1.49	1.49	1.48	1.49	1.48
Magenta 55	0.89	0.87	0.87	0.87	0.87	0.87
Magenta 5	0.13	0.13	0.12	0.12	0.13	0.12
Years:	0.00	9.87	17.54	25.26	32.65	40.24
Yellow 100	1.43	1.47	1.46	1.43	1.44	1.44
Yellow 55	0.82	0.88	0.87	0.87	0.85	0.79
Yellow 5	0.04	0.04	0.04	0.05	0.05	0.04
Years:	0.00	9.87	17.54	25.26	32.65	40.24
Black 100 Y	1.74	1.73	1.74	1.74	1.75	1.73
Black 100 M	1.92	1.91	1.90	1.91	1.92	1.89
Black 100 C	1.91	1.91	1.90	1.90	1.93	1.90
Years:	0.00	9.87	17.54	25.26	32.65	40.24
Black 55 Y	0.79	0.85	0.83	0.83	0.81	0.77
Black 55 M	0.84	0.83	0.82	0.82	0.83	0.82
Black 55 C	0.79	0.79	0.78	0.78	0.78	0.79
Years:	0.00	9.87	17.54	25.26	32.65	40.24
Black 5 Y	0.05	0.11	0.09	0.08	0.07	0.05
Black 5 M	0.11	0.11	0.11	0.11	0.11	0.11
Black 5 C	0.13	0.13	0.12	0.12	0.12	0.13
Base Y	0.00	0.00	0.00	0.00	0.00	0.00
Base M	0.04	0.05	0.04	0.04	0.05	0.05
Base C	0.07	0.07	0.07	0.07	0.07	0.07

% Density decrease

	9.87	17.54	25.26	32.65	40.24
Cyan 100	0.00	1.15	1.15	2.30	1.15
Cyan 55	1.75	1.75	0.00	1.75	-1.75
Cyan 5	0.00	0.00	0.00	0.00	-7.69
	9.87	17.54	25.26	32.65	40.24
Magenta 100	1.97	1.97	2.63	1.97	2.63
Magenta 55	2.25	2.25	2.25	2.25	2.25
Magenta 5	0.00	7.69	7.69	0.00	7.69
	9.87	17.54	25.26	32.65	40.24
Yellow 100	-2.80	-2.10	0.00	-0.70	-0.70
Yellow 55	-7.32	-6.10	-6.10	-3.66	3.66
Yellow 5	0.00	0.00	-25.00	-25.00	0.00
	9.87	17.54	25.26	32.65	40.24
Black 100 Y	0.57	0.00	0.00	-0.57	0.57
Black 100 M	0.52	1.04	0.52	0.00	1.56
Black 100 C	0.00	0.52	0.52	-1.05	0.52
	9.87	17.54	25.26	32.65	40.24
Black 55 Y	-7.59	-5.06	-5.06	-2.53	2.53
Black 55 M	1.19	2.38	2.38	1.19	2.38
Black 55 C	0.00	1.27	1.27	1.27	0.00
	9.87	17.54	25.26	32.65	40.24
Black 5 Y	-120.00	-80.00	-60.00	-40.00	0.00
Black 5 M	0.00	0.00	0.00	0.00	0.00
Black 5 C	0.00	7.69	7.69	7.69	0.00

APPENDIX D.2

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 2 FOR ACCELERATED FADE TEST

PRINT NUMBER:		2

Helox Artist Canvas Paper J96C
Printer: Epson Stylus Photo 2100
Ink: Epson OEM

Density values / **% Density decrease**

Years:	0.00	8.31	18.18		8.31	18.18
Cyan 100	0.89	0.90	0.89	Cyan 100	-1.12	0.00
Cyan 55	0.59	0.59	0.58	Cyan 55	0.00	1.69
Cyan 5	0.14	0.14	0.14	Cyan 5	0.00	0.00
Years:	0.00	8.31	18.18		8.31	18.18
Magenta 100	1.35	1.35	1.36	Magenta 100	0.00	-0.74
Magenta 55	0.84	0.84	0.84	Magenta 55	0.00	0.00
Magenta 5	0.14	0.14	0.14	Magenta 5	0.00	0.00
Years:	0.00	8.31	18.18		8.31	18.18
Yellow 100	1.14	1.16	1.16	Yellow 100	-1.75	-1.75
Yellow 55	0.67	0.67	0.67	Yellow 55	0.00	0.00
Yellow 5	0.04	0.06	0.06	Yellow 5	-50.00	-50.00
Years:	0.00	8.31	18.18		8.31	18.18
Black 100	1.50	1.53	1.53	Black 100	-2.00	-2.00
Black 55	0.80	0.83	0.81	Black 55	-3.75	-1.25
Black 5	0.10	0.11	0.11	Black 5	-10.00	-10.00
Years:	0.00	8.31	18.18		8.31	18.18
Black 100 Y	1.47	1.51	1.52	Black 100 Y	-2.72	-3.40
Black 100 M	1.55	1.57	1.57	Black 100 M	-1.29	-1.29
Black 100 C	1.48	1.51	1.51	Black 100 C	-2.03	-2.03
Years:	0.00	8.31	18.18		8.31	18.18
Black 55 Y	0.77	0.81	0.79	Black 55 Y	-5.19	-2.60
Black 55 M	0.84	0.85	0.84	Black 55 M	-1.19	0.00
Black 55 C	0.80	0.82	0.81	Black 55 C	-2.50	-1.25
Years:	0.00	8.31	18.18		8.31	18.18
Black 5 Y	0.05	0.06	0.07	Black 5 Y	-20.00	-40.00
Black 5 M	0.13	0.13	0.13	Black 5 M	0.00	0.00
Black 5 C	0.12	0.14	0.13	Black 5 C	-16.67	-8.33
Base Y	0.00	0.00	0.00			
Base M	0.07	0.07	0.07			
Base C	0.07	0.08	0.08			

APPENDIX D.3

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 3 FOR ACCELERATED FADE TEST

PRINT NUMBER:		3

Helox: Instant Dry Photo Quality Glossy Paper PGP-180
Printer: Epson Stylus Photo 2100
Ink: Epson OEM

Density values / **% Density decrease**

Years:	0.00	8.31	18.18		8.31	18.18
Cyan 100	0.76	0.75	0.75	Cyan 100	1.32	1.32
Cyan 55	0.48	0.48	0.48	Cyan 55	0.00	0.00
Cyan 5	0.12	0.13	0.12	Cyan 5	-8.33	0.00
Years:	0.00	8.31	18.18		8.31	18.18
Magenta 100	1.25	1.24	1.24	Magenta 100	0.80	0.80
Magenta 55	0.89	0.87	0.87	Magenta 55	2.25	2.25
Magenta 5	0.14	0.13	0.13	Magenta 5	7.14	7.14
Years:	0.00	8.31	18.18		8.31	18.18
Yellow 100	1.03	1.05	1.04	Yellow 100	-1.94	-0.97
Yellow 55	0.63	0.67	0.64	Yellow 55	-6.35	-1.59
Yellow 5	0.08	0.12	0.10	Yellow 5	-50.00	-25.00
Years:	0.00	8.31	18.18		8.31	18.18
Black 100	1.46	1.48	1.48	Black 100	-1.37	-1.37
Black 55	0.78	0.78	0.78	Black 55	0.00	0.00
Black 5	0.10	0.11	0.11	Black 5	-10.00	-10.00
Years:	0.00	8.31	18.18		8.31	18.18
Black 100 Y	1.40	1.44	1.44	Black 100 Y	-2.86	-2.86
Black 100 M	1.51	1.53	1.53	Black 100 M	-1.32	-1.32
Black 100 C	1.46	1.48	1.48	Black 100 C	-1.37	-1.37
Years:	0.00	8.31	18.18		8.31	18.18
Black 55 Y	0.73	0.75	0.75	Black 55 Y	-2.74	-2.74
Black 55 M	0.85	0.84	0.84	Black 55 M	1.18	1.18
Black 55 C	0.75	0.75	0.75	Black 55 C	0.00	0.00
Years:	0.00	8.31	18.18		8.31	18.18
Black 5 Y	0.07	0.09	0.09	Black 5 Y	-28.57	-28.57
Black 5 M	0.13	0.12	0.12	Black 5 M	7.69	7.69
Black 5 C	0.11	0.12	0.11	Black 5 C	-9.09	0.00
Base Y	0.01	0.03	0.03			
Base M	0.07	0.06	0.06			
Base C	0.06	0.07	0.06			

APPENDIX D.4

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 4 FOR ACCELERATED FADE TEST

PRINT NUMBER:	**4**

Epson Photo Quality Ink Jet Paper S041061
Printer: Hewlett-Packard Deskjet 895 cxi.
Ink: Dual non-OEM inkset.

Density values / **% Density decrease**

Years:	0.00	8.31	18.18	23.24		8.31	18.18	23.24
Cyan 100	1.13	1.02	0.96	0.93	Cyan 100	9.73	15.04	17.70
Cyan 55	0.58	0.53	0.50	0.48	Cyan 55	8.62	13.79	17.24
Cyan 5	0.14	0.15	0.14	0.14	Cyan 5	-7.14	0.00	0.00
Years:	0.00	8.31	18.18	23.24		8.31	18.18	23.24
Magenta 100	1.70	1.57	1.45	1.37	Magenta 100	7.65	14.71	19.41
Magenta 55	0.78	0.65	0.58	0.51	Magenta 55	16.67	25.64	34.62
Magenta 5	0.12	0.12	0.11	0.11	Magenta 5	0.00	8.33	8.33
Years:	0.00	8.31	18.18	23.24		8.31	18.18	23.24
Yellow 100	1.40	1.18	1.04	0.96	Yellow 100	15.71	25.71	31.43
Yellow 55	0.59	0.42	0.32	0.26	Yellow 55	28.81	45.76	55.93
Yellow 5	0.07	0.06	0.06	0.05	Yellow 5	14.29	14.29	28.57
Years:	0.00	8.31	18.18	23.24		8.31	18.18	23.24
Black 100	1.49	1.49	1.47	1.47	Black 100	0.00	1.34	1.34
Black 55	0.61	0.56	0.52	0.50	Black 55	8.20	14.75	18.03
Black 5	0.10	0.10	0.10	0.09	Black 5	0.00	0.00	10.00
Years:	0.00	8.31	18.18	23.24		8.31	18.18	23.24
Black 100 Y	1.48	1.46	1.43	1.44	Black 100 Y	1.35	3.38	2.70
Black 100 M	1.54	1.54	1.53	1.53	Black 100 M	0.00	0.65	0.65
Black 100 C	1.46	1.47	1.44	1.45	Black 100 C	-0.68	1.37	0.68
Years:	0.00	8.31	18.18	23.24		8.31	18.18	23.24
Black 55 Y	0.63	0.55	0.50	0.47	Black 55 Y	12.70	20.63	25.40
Black 55 M	0.63	0.60	0.57	0.56	Black 55 M	4.76	9.52	11.11
Black 55 C	0.56	0.53	0.50	0.48	Black 55 C	5.36	10.71	14.29
Years:	0.00	8.31	18.18	23.24		8.31	18.18	23.24
Black 5 Y	0.05	0.06	0.06	0.05	Black 5 Y	-20.00	-20.00	0.00
Black 5 M	0.13	0.12	0.12	0.11	Black 5 M	7.69	7.69	15.38
Black 5 C	0.12	0.12	0.12	0.11	Black 5 C	0.00	0.00	8.33

APPENDIX D.5

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 5 FOR ACCELERATED FADE TEST

PRINT NUMBER:	5

Epson Premium Glossy Photo Paper
Printer: Epson Stylus Color 480sxu.
Inkset: Epson OEM

Density values at 35,5 Klux

Years:	0.00	9.87	14.93	22.66
Cyan 100	0.62	0.62	0.63	0.61
Cyan 55	0.46	0.47	0.47	0.47
Cyan 5	0.11	0.12	0.11	0.11
Years:	0.00	9.87	14.93	22.66
Magenta 100	1.25	1.16	1.12	1.04
Magenta 55	0.81	0.78	0.74	0.72
Magenta 5	0.11	0.10	0.09	0.10
Years:	0.00	9.87	14.93	22.66
Yellow 100	0.94	0.75	0.72	0.63
Yellow 55	0.67	0.54	0.57	0.52
Yellow 5	0.05	0.05	0.04	0.04
Years:	0.00	9.87	14.93	22.66
Black 100	2.77	2.42	2.39	2.29
Black 55	0.72	0.70	0.70	0.68
Black 5	0.08	0.08	0.08	0.07
Years:	0.00	9.87	14.93	22.66
Black 100 Y	2.23	2.15	2.14	2.10
Black 100 M	2.52	2.42	2.39	2.34
Black 100 C	3.55	2.70	2.64	2.45
Years:	0.00	9.87	14.93	22.66
Black 55 Y	0.71	0.64	0.65	0.61
Black 55 M	0.76	0.75	0.74	0.72
Black 55 C	0.69	0.71	0.70	0.70
Years:	0.00	9.87	14.93	22.66
Black 5 Y	0.04	0.04	0.03	0.03
Black 5 M	0.09	0.09	0.09	0.08
Black 5 C	0.10	0.10	0.11	0.11
Base Y	0.00	0.00	0.00	0.00
Base M	0.05	0.05	0.04	0.04
Base C	0.07	0.07	0.07	0.07

% Density decrease

	9.87	14.93	22.66
Cyan 100	0.00	-1.61	1.61
Cyan 55	-2.17	-2.17	-2.17
Cyan 5	-9.09	0.00	0.00
	9.87	14.93	22.66
Magenta 100	7.20	10.40	16.80
Magenta 55	3.70	8.64	11.11
Magenta 5	9.09	18.18	9.09
	9.87	14.93	22.66
Yellow 100	20.21	23.40	32.98
Yellow 55	19.40	14.93	22.39
Yellow 5	0.00	20.00	20.00
	9.87	14.93	22.66
Black 100	12.64	13.72	17.33
Black 55	2.78	2.78	5.56
Black 5	0.00	0.00	12.50
	9.87	14.93	22.66
Black 100 Y	3.59	4.04	5.83
Black 100 M	3.97	5.16	7.14
Black 100 C	23.94	25.63	30.99
	9.87	14.93	22.66
Black 55 Y	9.86	8.45	14.08
Black 55 M	1.32	2.63	5.26
Black 55 C	-2.90	-1.45	-1.45
	9.87	14.93	22.66
Black 5 Y	0.00	25.00	25.00
Black 5 M	0.00	0.00	11.11
Black 5 C	0.00	-10.00	-10.00

APPENDIX D.6

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 6 FOR ACCELERATED FADE TEST

PRINT NUMBER:	**6**

Epson Premium Glossy Photo Paper
Printer: Epson 1200.
Ink: MIS Archival CFS inkset

Density values / **% Density decrease**

Years:	0.00	8.96	16.70	24.09	31.67		8.96	16.70	24.09	31.67
Cyan 100	1.01	1.00	0.99	1.01	1.01	Cyan 100	0.99	1.98	0.00	0.00
Cyan 55	0.70	0.70	0.70	0.70	0.72	Cyan 55	0.00	0.00	0.00	-2.86
Cyan 5	0.16	0.16	0.16	0.16	0.17	Cyan 5	0.00	0.00	0.00	-6.25
Years:	0.00	8.96	16.70	24.09	31.67		8.96	16.70	24.09	31.67
Magenta 100	1.03	0.97	0.96	0.95	0.93	Magenta 100	5.83	6.80	7.77	9.71
Magenta 55	0.75	0.71	0.70	0.70	0.69	Magenta 55	5.33	6.67	6.67	8.00
Magenta 5	0.12	0.12	0.13	0.13	0.12	Magenta 5	0.00	-8.33	-8.33	0.00
Years:	0.00	8.96	16.70	24.09	31.67		8.96	16.70	24.09	31.67
Yellow 100	1.02	0.96	0.96	0.95	0.90	Yellow 100	5.88	5.88	6.86	11.76
Yellow 55	0.51	0.49	0.49	0.48	0.47	Yellow 55	3.92	3.92	5.88	7.84
Yellow 5	0.04	0.03	0.04	0.05	0.04	Yellow 5	25.00	0.00	-25.00	0.00
Years:	0.00	8.96	16.70	24.09	31.67		8.96	16.70	24.09	31.67
Black 100 Y	2.03	2.04	2.04	2.06	1.88	Black 100 Y	-0.49	-0.49	-1.48	7.39
Black 100 M	2.24	2.25	2.26	2.25	2.06	Black 100 M	-0.45	-0.89	-0.45	8.04
Black 100 C	2.06	2.06	2.09	2.08	1.91	Black 100 C	0.00	-1.46	-0.97	7.28
Years:	0.00	8.96	16.70	24.09	31.67		8.96	16.70	24.09	31.67
Black 55 Y	0.71	0.65	0.67	0.64	0.64	Black 55 Y	8.45	5.63	9.86	9.86
Black 55 M	0.83	0.76	0.79	0.78	0.74	Black 55 M	8.43	4.82	6.02	10.84
Black 55 C	0.92	0.89	0.92	0.91	0.91	Black 55 C	3.26	0.00	1.09	1.09
Years:	0.00	8.96	16.70	24.09	31.67		8.96	16.70	24.09	31.67
Black 5 Y	0.03	0.02	0.03	0.03	0.06	Black 5 Y	33.33	0.00	0.00	-100.00
Black 5 M	0.11	0.10	0.10	0.10	0.11	Black 5 M	9.09	9.09	9.09	0.00
Black 5 C	0.13	0.13	0.13	0.13	0.14	Black 5 C	0.00	0.00	0.00	-7.69
Base Y	0.00	0.00	0.00	0.00	0.00					
Base M	0.05	0.04	0.05	0.05	0.05					
Base C	0.07	0.07	0.07	0.07	0.08					

APPENDIX D.7

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 7 FOR ACCELERATED FADE TEST

PRINT NUMBER:	7

Somerset Velvet Radiant White M8FZ1041

Printer: Epson 2100

Inks: Epson OEM with Matte Black.

Density values

Years:	0.00	7.67	15.39	22.78	30.37
Cyan 100	0.70	0.69	0.69	0.68	0.65
Cyan 55	0.51	0.51	0.51	0.50	0.50
Cyan 5	0.11	0.11	0.11	0.11	0.11
Years:	0.00	7.67	15.39	22.78	30.37
Magenta 100	0.99	0.99	0.98	0.98	0.97
Magenta 55	0.69	0.69	0.68	0.67	0.67
Magenta 5	0.12	0.11	0.11	0.11	0.10
Years:	0.00	7.67	15.39	22.78	30.37
Yellow 100	1.03	1.02	1.03	1.00	1.01
Yellow 55	0.78	0.78	0.77	0.76	0.73
Yellow 5	0.07	0.06	0.07	0.06	0.06
Years:	0.00	7.67	15.39	22.78	30.37
Black 100 Y	1.45	1.41	1.45	1.44	1.43
Black 100 M	1.47	1.44	1.47	1.46	1.46
Black 100 C	1.35	1.32	1.35	1.35	1.35
Years:	0.00	7.67	15.39	22.78	30.37
Black 55 Y	0.75	0.74	0.72	0.72	0.72
Black 55 M	0.73	0.72	0.71	0.71	0.70
Black 55 C	0.69	0.69	0.68	0.68	0.69
Years:	0.00	7.67	15.39	22.78	30.37
Black 5 Y	0.09	0.09	0.08	0.09	0.08
Black 5 M	0.11	0.11	0.10	0.10	0.10
Black 5 C	0.11	0.12	0.11	0.11	0.12
Base Y	-0.01	-0.01	-0.01	-0.01	-0.01
Base M	0.02	0.02	0.02	0.02	0.02
Base C	0.03	0.03	0.03	0.03	0.04

% Density decrease

	7.67	15.39	22.78	30.37
Cyan 100	1.43	1.43	2.86	7.14
Cyan 55	0.00	0.00	1.96	1.96
Cyan 5	0.00	0.00	0.00	0.00
	7.67	15.39	22.78	30.37
Magenta 100	0.00	1.01	1.01	2.02
Magenta 55	0.00	1.45	2.90	2.90
Magenta 5	8.33	8.33	8.33	16.67
	7.67	15.39	22.78	30.37
Yellow 100	0.97	0.00	2.91	1.94
Yellow 55	0.00	1.28	2.56	6.41
Yellow 5	14.29	0.00	14.29	14.29
	7.67	15.39	22.78	30.37
Black 100 Y	2.76	0.00	0.69	1.38
Black 100 M	2.04	0.00	0.68	0.68
Black 100 C	2.22	0.00	0.00	0.00
	7.67	15.39	22.78	30.37
Black 55 Y	1.33	4.00	4.00	4.00
Black 55 M	1.37	2.74	2.74	4.11
Black 55 C	0.00	1.45	1.45	0.00
	7.67	15.39	22.78	30.37
Black 5 Y	0.00	11.11	0.00	11.11
Black 5 M	0.00	9.09	9.09	9.09
Black 5 C	-9.09	0.00	0.00	-9.09

APPENDIX D.8

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 8 FOR ACCELERATED FADE TEST

PRINT NUMBER:	**8**

Agfa Prestige Digital Glossy CN510
Printer: Agfa D-Lab 2

Density values						**% Density decrease**				
Years:	0.00	2.61	10.33	17.72	25.31		2.61	10.33	17.72	25.31
Cyan 100	2.76	2.80	2.72	2.57	2.47	Cyan 100	-1.45	1.45	6.88	10.51
Cyan 55	0.78	0.78	0.76	0.73	0.67	Cyan 55	0.00	2.56	6.41	14.10
Cyan 5	0.12	0.12	0.11	0.11	0.12	Cyan 5	0.00	8.33	8.33	0.00
Years:	0.00	2.61	10.33	17.72	25.31		2.61	10.33	17.72	25.31
Magenta 100	2.10	2.20	2.10	2.01	1.90	Magenta 100	-4.76	0.00	4.29	9.52
Magenta 55	0.60	0.62	0.58	0.49	0.31	Magenta 55	-3.33	3.33	18.33	48.33
Magenta 5	0.09	0.11	0.10	0.10	0.10	Magenta 5	-22.22	-11.11	-11.11	-11.11
Years:	0.00	2.61	10.33	17.72	25.31		2.61	10.33	17.72	25.31
Yellow 100	1.91	1.97	1.94	1.83	1.75	Yellow 100	-3.14	-1.57	4.19	8.38
Yellow 55	0.62	0.61	0.59	0.51	0.41	Yellow 55	1.61	4.84	17.74	33.87
Yellow 5	0.07	0.08	0.08	0.08	0.09	Yellow 5	-14.29	-14.29	-14.29	-28.57
Years:	0.00	2.61	10.33	17.72	25.31		2.61	10.33	17.72	25.31
Black 100 Y	2.14	2.21	2.20	2.19	2.16	Black 100 Y	-3.27	-2.80	-2.34	-0.93
Black 100 M	2.38	2.48	2.46	2.49	2.46	Black 100 M	-4.20	-3.36	-4.62	-3.36
Black 100 C	3.38	3.29	3.11	2.92	2.92	Black 100 C	2.66	7.99	13.61	13.61
Years:	0.00	2.61	10.33	17.72	25.31		2.61	10.33	17.72	25.31
Black 55 Y	0.64	0.64	0.62	0.57	0.51	Black 55 Y	0.00	3.13	10.94	20.31
Black 55 M	0.70	0.70	0.70	0.65	0.58	Black 55 M	0.00	0.00	7.14	17.14
Black 55 C	0.75	0.75	0.74	0.65	0.63	Black 55 C	0.00	1.33	13.33	16.00
Years:	0.00	2.61	10.33	17.72	25.31		2.61	10.33	17.72	25.31
Black 5 Y	0.08	0.08	0.08	0.12	0.10	Black 5 Y	0.00	0.00	-50.00	-25.00
Black 5 M	0.11	0.11	0.11	0.11	0.11	Black 5 M	0.00	0.00	0.00	0.00
Black 5 C	0.12	0.12	0.12	0.11	0.11	Black 5 C	0.00	0.00	8.33	8.33
Base Y	0.06	0.06	0.07	0.11	0.11					
Base M	0.08	0.09	0.09	0.10	0.10					
Base C	0.10	0.10	0.10	0.10	0.10					

APPENDIX D.9

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 9 FOR ACCELERATED FADE TEST

PRINT NUMBER:	**9**

Epson Premium Glossy Photo Paper
Printer: Hewlett Packard CP 1700 Color Inkjet printer
Ink: Hewlett-Packard

Density values / **% Density decrease**

Years:	0.00	7.73	15.11		7.73	15.11
Cyan 100	1.73	1.42	1.22	Cyan 100	17.92	29.48
Cyan 55	0.48	0.40	0.36	Cyan 55	16.67	25.00
Cyan 5	0.08	0.08	0.08	Cyan 5	0.00	0.00
Years:	0.00	7.73	15.11		7.73	15.11
Magenta 100	1.91	1.82	1.51	Magenta 100	4.71	20.94
Magenta 55	0.49	0.41	0.31	Magenta 55	16.33	36.73
Magenta 5	0.06	0.06	0.06	Magenta 5	0.00	0.00
Years:	0.00	7.73	15.11		7.73	15.11
Yellow 100	1.98	1.91	1.75	Yellow 100	3.54	11.62
Yellow 55	0.37	0.27	0.20	Yellow 55	27.03	45.95
Yellow 5	0.00	0.00	0.01	Yellow 5	0.00	#DIV/0!
Years:	0.00	7.73	15.11		7.73	15.11
Black 100	1.68	1.58	1.28	Black 100	5.95	23.81
Black 55	0.58	0.53	0.45	Black 55	8.62	22.41
Black 5	0.05	0.04	0.05	Black 5	20.00	0.00
Years:	0.00	7.73	15.11		7.73	15.11
Black 100 Y	1.49	1.41	1.12	Black 100 Y	5.37	24.83
Black 100 M	1.56	1.55	1.33	Black 100 M	0.64	14.74
Black 100 C	1.98	1.79	1.38	Black 100 C	9.60	30.30
Years:	0.00	7.73	15.11		7.73	15.11
Black 55 Y	0.52	0.48	0.43	Black 55 Y	7.69	17.31
Black 55 M	0.56	0.55	0.46	Black 55 M	1.79	17.86
Black 55 C	0.66	0.57	0.47	Black 55 C	13.64	28.79
Years:	0.00	7.73	15.11		7.73	15.11
Black 5 Y	0.00	0.00	0.02	Black 5 Y	0.00	#DIV/0!
Black 5 M	0.06	0.05	0.05	Black 5 M	16.67	16.67
Black 5 C	0.08	0.08	0.07	Black 5 C	0.00	12.50

APPENDIX D.10

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 10 FOR ACCELERATED FADE TEST

Cyan 100	1.00	0.84	0.77	0.74	Cyan 100	16.00	23.00	26.00
Cyan 55	0.63	0.50	0.48	0.45	Cyan 55	20.63	23.81	28.57
Cyan 5	0.13	0.11	0.13	0.11	Cyan 5	15.38	0.00	15.38
Years:	0.00	7.42	15.72	25.60		7.42	15.72	25.60
Magenta 100	1.36	1.24	1.14	1.07	Magenta 100	8.82	16.18	21.32
Magenta 55	0.81	0.70	0.62	0.56	Magenta 55	13.58	23.46	30.86
Magenta 5	0.12	0.12	0.12	0.11	Magenta 5	0.00	0.00	8.33
Years:	0.00	7.42	15.72	25.60		7.42	15.72	25.60
Yellow 100	1.30	1.15	1.00	0.95	Yellow 100	11.54	23.08	26.92
Yellow 55	0.47	0.39	0.30	0.25	Yellow 55	17.02	36.17	46.81
Yellow 5	0.01	0.04	0.04	0.04	Yellow 5	-300.00	-300.00	-300.00
Years:	0.00	7.42	15.72	25.60		7.42	15.72	25.60
Black 100	1.64	1.62	1.60	1.60	Black 100	1.22	2.44	2.44
Black 55	0.66	0.67	0.66	0.66	Black 55	-1.52	0.00	0.00
Black 5	0.11	0.11	0.11	0.11	Black 5	0.00	0.00	0.00
Years:	0.00	7.42	15.72	25.60		7.42	15.72	25.60
Black 100 Y	1.61	1.61	1.59	1.59	Black 100 Y	0.00	1.24	1.24
Black 100 M	1.66	1.67	1.65	1.65	Black 100 M	-0.60	0.60	0.60
Black 100 C	1.61	1.57	1.57	1.56	Black 100 C	2.48	2.48	3.11
Years:	0.00	7.42	15.72	25.60		7.42	15.72	25.60
Black 55 Y	0.62	0.65	0.64	0.64	Black 55 Y	-4.84	-3.23	-3.23
Black 55 M	0.69	0.69	0.68	0.69	Black 55 M	0.00	1.45	0.00
Black 55 C	0.66	0.66	0.66	0.65	Black 55 C	0.00	0.00	1.52
Years:	0.00	7.42	15.72	25.60		7.42	15.72	25.60
Black 5 Y	0.05	0.07	0.08	0.08	Black 5 Y	-40.00	-60.00	-60.00
Black 5 M	0.13	0.13	0.13	0.13	Black 5 M	0.00	0.00	0.00
Black 5 C	0.14	0.12	0.13	0.13	Black 5 C	14.29	7.14	7.14
Base Y	0.00	0.03	0.03	0.03				
Base M	0.08	0.08	0.07	0.08				
Base C	0.10	0.08	0.09	0.09				

APPENDIX D.11

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 11 FOR ACCELERATED FADE TEST

PRINT NUMBER:	**11**

Epson Photo Quality Ink Jet Paper S041061
Printer: Epson Stylus Photo 2100
Ink: Epson OEM

Density values / **% Density decrease**

Years:	0.00	7.42	15.72		7.42	15.72
Cyan 100	0.78	0.77	0.77	Cyan 100	1.28	1.28
Cyan 55	0.54	0.53	0.53	Cyan 55	1.85	1.85
Cyan 5	0.16	0.14	0.15	Cyan 5	12.50	6.25
Years:	0.00	7.42	15.72		7.42	15.72
Magenta 100	1.17	1.15	1.15	Magenta 100	1.71	1.71
Magenta 55	0.76	0.76	0.76	Magenta 55	0.00	0.00
Magenta 5	0.15	0.16	0.15	Magenta 5	-6.67	0.00
Years:	0.00	7.42	15.72		7.42	15.72
Yellow 100	1.06	1.08	1.07	Yellow 100	-1.89	-0.94
Yellow 55	0.63	0.68	0.68	Yellow 55	-7.94	-7.94
Yellow 5	0.03	0.08	0.07	Yellow 5	-166.67	-133.33
Years:	0.00	7.42	15.72		7.42	15.72
Black 100	1.37	1.37	1.36	Black 100	0.00	0.73
Black 55	0.67	0.69	0.67	Black 55	-2.99	0.00
Black 5	0.11	0.12	0.12	Black 5	-9.09	-9.09
Years:	0.00	7.42	15.72		7.42	15.72
Black 100 Y	1.35	1.36	1.35	Black 100 Y	-0.74	0.00
Black 100 M	1.40	1.41	1.40	Black 100 M	-0.71	0.00
Black 100 C	1.35	1.34	1.34	Black 100 C	0.74	0.74
Years:	0.00	7.42	15.72		7.42	15.72
Black 55 Y	0.63	0.65	0.64	Black 55 Y	-3.17	-1.59
Black 55 M	0.72	0.72	0.71	Black 55 M	0.00	1.39
Black 55 C	0.75	0.64	0.65	Black 55 C	14.67	13.33
Years:	0.00	7.42	15.72		7.42	15.72
Black 5 Y	0.05	0.08	0.09	Black 5 Y	-60.00	-80.00
Black 5 M	0.14	0.14	0.14	Black 5 M	0.00	0.00
Black 5 C	0.14	0.14	0.14	Black 5 C	0.00	0.00
Base Y	0.00	0.03	0.03			
Base M	0.07	0.08	0.08			
Base C	0.09	0.08	0.09			

APPENDIX D.12

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 12 FOR ACCELERATED FADE TEST

PRINT NUMBER:	**12**

Epson Enhanced Matte Paper S041341

Printer: Epson 2100

Ink: Epson OEM

Density values

Years:	0.00	7.42	15.72	20.78
Cyan 100	0.87	0.85	0.86	0.85
Cyan 55	0.57	0.54	0.55	0.54
Cyan 5	0.12	0.11	0.12	0.11
Years:	0.00	7.42	15.72	20.78
Magenta 100	1.29	1.27	1.26	1.26
Magenta 55	0.82	0.79	0.79	0.78
Magenta 5	0.11	0.10	0.10	0.10
Years:	0.00	7.42	15.72	20.78
Yellow 100	1.18	1.17	1.16	1.15
Yellow 55	0.69	0.69	0.67	0.66
Yellow 5	0.04	0.06	0.05	0.06
Years:	0.00	7.42	15.72	20.78
Black 100	1.47	1.48	1.48	1.47
Black 55	0.71	0.69	0.70	0.69
Black 5	0.09	0.09	0.09	0.09
Years:	0.00	7.42	15.72	20.78
Black 100 Y	1.46	1.49	1.48	1.47
Black 100 M	1.51	1.53	1.52	1.51
Black 100 C	1.43	1.43	1.44	1.43
Years:	0.00	7.42	15.72	20.78
Black 55 Y	0.68	0.68	0.68	0.68
Black 55 M	0.77	0.75	0.74	0.74
Black 55 C	0.68	0.65	0.67	0.66
Years:	0.00	7.42	15.72	20.78
Black 5 Y	0.06	0.08	0.07	0.08
Black 5 M	0.10	0.10	0.10	0.09
Black 5 C	0.11	0.10	0.11	0.10
Base Y	-0.01	0.02	0.01	0.02
Base M	0.03	0.04	0.03	0.04
Base C	0.05	0.04	0.06	0.05

% Density decrease

	7.42	15.72	20.78
Cyan 100	2.30	1.15	2.30
Cyan 55	5.26	3.51	5.26
Cyan 5	8.33	0.00	8.33
	7.42	15.72	20.78
Magenta 100	1.55	2.33	2.33
Magenta 55	3.66	3.66	4.88
Magenta 5	9.09	9.09	9.09
	7.42	15.72	20.78
Yellow 100	0.85	1.69	2.54
Yellow 55	0.00	2.90	4.35
Yellow 5	-50.00	-25.00	-50.00
	7.42	15.72	20.78
Black 100	-0.68	-0.68	0.00
Black 55	2.82	1.41	2.82
Black 5	0.00	0.00	0.00
	7.42	15.72	20.78
Black 100 Y	-2.05	-1.37	-0.68
Black 100 M	-1.32	-0.66	0.00
Black 100 C	0.00	-0.70	0.00
	7.42	15.72	20.78
Black 55 Y	0.00	0.00	0.00
Black 55 M	2.60	3.90	3.90
Black 55 C	4.41	1.47	2.94
	7.42	15.72	20.78
Black 5 Y	-33.33	-16.67	-33.33
Black 5 M	0.00	0.00	10.00
Black 5 C	9.09	0.00	9.09

APPENDIX D.13

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 13 FOR ACCELERATED FADE TEST

PRINT NUMBER:	**13**

Epson Premium Semi-Gloss Photo Paper S041331.
Printer: Epson Stylus Photo 2100
Ink: Epson OEM

Density values				**% Density decrease**		
Years:	0.00	9.92	18.23		9.92	18.23
Cyan 100	0.86	0.85	0.87	Cyan 100	1.32	1.32
Cyan 55	0.57	0.56	0.56	Cyan 55	0.00	0.00
Cyan 5	0.12	0.12	0.12	Cyan 5	-8.33	0.00
Years:	0.00	9.92	18.23		9.92	18.23
Magenta 100	1.42	1.42	1.41	Magenta 100	0.80	0.80
Magenta 55	0.88	0.87	0.86	Magenta 55	2.25	2.25
Magenta 5	0.11	0.11	0.10	Magenta 5	7.14	7.14
Years:	0.00	9.92	18.23		9.92	18.23
Yellow 100	1.18	1.22	1.20	Yellow 100	-1.94	-0.97
Yellow 55	0.70	0.74	0.71	Yellow 55	-6.35	-1.59
Yellow 5	0.06	0.10	0.09	Yellow 5	-50.00	-25.00
Years:	0.00	9.92	18.23		9.92	18.23
Black 100	2.14	2.14	2.10	Black 100	-1.37	-1.37
Black 55	0.78	0.77	0.79	Black 55	0.00	0.00
Black 5	0.10	0.11	0.11	Black 5	-10.00	-10.00
Years:	0.00	9.92	18.23		9.92	18.23
Black 100 Y	1.99	2.05	1.97	Black 100 Y	-3.02	1.01
Black 100 M	2.22	2.25	2.18	Black 100 M	-1.35	1.80
Black 100 C	2.21	2.25	2.16	Black 100 C	-1.81	2.26
Years:	0.00	9.92	18.23		9.92	18.23
Black 55 Y	0.74	0.75	0.74	Black 55 Y	-1.35	0.00
Black 55 M	0.85	0.84	0.83	Black 55 M	1.18	2.35
Black 55 C	0.75	0.73	0.74	Black 55 C	2.67	1.33
Years:	0.00	9.92	18.23		9.92	18.23
Black 5 Y	0.06	0.08	0.08	Black 5 Y	-33.33	-33.33
Black 5 M	0.12	0.12	0.12	Black 5 M	0.00	0.00
Black 5 C	0.13	0.12	0.13	Black 5 C	7.69	0.00
Base Y	0.00	0.00	0.00			
Base M	0.04	0.05	0.05			
Base C	0.07	0.06	0.07			

APPENDIX D.14

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 14 FOR ACCELERATED FADE TEST

Cyan 100	0.85	0.84	0.84	0.82	Cyan 100	1.18	1.18	3.53
Cyan 55	0.57	0.56	0.57	0.55	Cyan 55	1.75	0.00	3.51
Cyan 5	0.14	0.13	0.14	0.13	Cyan 5	7.14	0.00	7.14
Years:	0.00	9.93	18.24	28.11		9.93	18.24	28.11
Magenta 100	1.36	1.35	1.35	1.34	Magenta 100	0.74	0.74	1.47
Magenta 55	0.87	0.86	0.85	0.85	Magenta 55	1.15	2.30	2.30
Magenta 5	0.12	0.13	0.12	0.13	Magenta 5	-8.33	0.00	-8.33
Years:	0.00	9.93	18.24	28.11		9.93	18.24	28.11
Yellow 100	1.13	1.14	1.11	1.10	Yellow 100	-0.88	1.77	2.65
Yellow 55	0.64	0.66	0.63	0.63	Yellow 55	-3.13	1.56	1.56
Yellow 5	0.10	0.10	0.08	0.10	Yellow 5	0.00	20.00	0.00
Years:	0.00	9.93	18.24	28.11		9.93	18.24	28.11
Black 100	1.99	2.00	1.98	1.97	Black 100	-0.50	0.50	1.01
Black 55	0.76	0.77	0.76	0.76	Black 55	-1.32	0.00	0.00
Black 5	0.12	0.12	0.12	0.12	Black 5	0.00	0.00	0.00
Years:	0.00	9.93	18.24	28.11		9.93	18.24	28.11
Black 100 Y	1.90	1.90	1.88	1.87	Black 100 Y	0.00	1.05	1.58
Black 100 M	2.11	2.11	2.09	2.08	Black 100 M	0.00	0.95	1.42
Black 100 C	2.07	1.99	1.96	1.96	Black 100 C	3.86	5.31	5.31
Years:	0.00	9.93	18.24	28.11		9.93	18.24	28.11
Black 55 Y	0.72	0.75	0.73	0.72	Black 55 Y	-4.17	-1.39	0.00
Black 55 M	0.83	0.83	0.82	0.83	Black 55 M	0.00	1.20	0.00
Black 55 C	0.74	0.73	0.73	0.73	Black 55 C	1.35	1.35	1.35
Years:	0.00	9.93	18.24	28.11		9.93	18.24	28.11
Black 5 Y	0.08	0.10	0.10	0.09	Black 5 Y	-25.00	-25.00	-12.50
Black 5 M	0.13	0.13	0.13	0.13	Black 5 M	0.00	0.00	0.00
Black 5 C	0.14	0.13	0.14	0.13	Black 5 C	7.14	0.00	7.14
Base Y	0.01	0.03	0.02	0.04				
Base M	0.06	0.06	0.06	0.06				
Base C	0.08	0.07	0.08	0.07				

APPENDIX D.15

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 15 FOR ACCELERATED FADE TEST

PRINT NUMBER:	**15**

Xerox Bond Plain Paper
Printer: Epson Stylus Photo 2100
Ink: Epson OEM

Density values / **% Density decrease**

Years:	0.00	9.92	12.29		9.92	12.29
Cyan 100	0.78	0.78	0.76	Cyan 100	1.32	1.32
Cyan 55	0.58	0.56	0.57	Cyan 55	0.00	0.00
Cyan 5	0.14	0.14	0.14	Cyan 5	-8.33	0.00
Years:	0.00	9.92	12.29		9.92	12.29
Magenta 100	0.96	0.95	0.95	Magenta 100	0.80	0.80
Magenta 55	0.70	0.69	0.68	Magenta 55	2.25	2.25
Magenta 5	0.15	0.15	0.14	Magenta 5	7.14	7.14
Years:	0.00	9.92	12.29		9.92	12.29
Yellow 100	1.06	1.06	1.08	Yellow 100	-1.94	-0.97
Yellow 55	0.74	0.75	0.75	Yellow 55	-6.35	-1.59
Yellow 5	0.05	0.08	0.08	Yellow 5	-50.00	-25.00
Years:	0.00	9.92	12.29		9.92	12.29
Black 100	1.06	1.07	1.06	Black 100	-1.37	-1.37
Black 55	0.64	0.64	0.64	Black 55	0.00	0.00
Black 5	0.11	0.11	0.11	Black 5	-10.00	-10.00
Years:	0.00	9.92	12.29		9.92	12.29
Black 100 Y	1.05	1.08	1.07	Black 100 Y	-2.86	-1.90
Black 100 M	1.10	1.12	1.11	Black 100 M	-1.82	-0.91
Black 100 C	1.01	1.02	1.01	Black 100 C	-0.99	0.00
Years:	0.00	9.92	12.29		9.92	12.29
Black 55 Y	0.59	0.62	0.60	Black 55 Y	-5.08	-1.69
Black 55 M	0.69	0.69	0.67	Black 55 M	0.00	2.90
Black 55 C	0.63	0.62	0.61	Black 55 C	1.59	3.17
Years:	0.00	9.92	12.29		9.92	12.29
Black 5 Y	0.05	0.09	0.08	Black 5 Y	-80.00	-60.00
Black 5 M	0.13	0.13	0.13	Black 5 M	0.00	0.00
Black 5 C	0.14	0.12	0.13	Black 5 C	14.29	7.14
Base Y	0.00	0.03	0.03			
Base M	0.07	0.07	0.07			
Base C	0.08	0.07	0.08			

APPENDIX D.16

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 16 FOR ACCELERATED FADE TEST

PRINT NUMBER:	16

Fuji Crystal Archive Glossy Type 1 Paper for Frontier
Fuji Frontier

Density values						**% Density decrease**				
Years:	0.00	9.87	17.54	25.26	32.65		9.87	17.54	25.26	32.65
Cyan 100	1.55	1.43	1.39	1.35	1.15	Cyan 100	7.74	10.32	12.90	25.81
Cyan 55	0.86	0.75	0.68	0.67	0.57	Cyan 55	12.79	20.93	22.09	33.72
Cyan 5	0.14	0.11	0.11	0.11	0.10	Cyan 5	21.43	21.43	21.43	28.57
Years:	0.00	9.87	17.54	25.26	32.65		9.87	17.54	25.26	32.65
Magenta 100	1.85	1.85	1.82	1.79	1.64	Magenta 100	0.00	1.62	3.24	11.35
Magenta 55	0.83	0.83	0.78	0.74	0.67	Magenta 55	0.00	6.02	10.84	19.28
Magenta 5	0.12	0.11	0.10	0.10	0.09	Magenta 5	8.33	16.67	16.67	25.00
Years:	0.00	9.87	17.54	25.26	32.65		9.87	17.54	25.26	32.65
Yellow 100	1.74	1.65	1.57	1.49	1.34	Yellow 100	5.17	9.77	14.37	22.99
Yellow 55	0.80	0.77	0.73	0.70	0.64	Yellow 55	3.75	8.75	12.50	20.00
Yellow 5	0.07	0.09	0.08	0.09	0.08	Yellow 5	-28.57	-14.29	-28.57	-14.29
Years:	0.00	9.87	17.54	25.26	32.65		9.87	17.54	25.26	32.65
Black 100	2.41	2.35	2.24	2.12	2.10	Black 100	2.49	7.05	12.03	12.86
Black 55	0.85	0.83	0.81	0.78	0.79	Black 55	2.35	4.71	8.24	7.06
Black 5	0.10	0.09	0.10	0.10	0.09	Black 5	10.00	0.00	0.00	10.00
Years:	0.00	9.87	17.54	25.26	32.65		9.87	17.54	25.26	32.65
Black 100 Y	2.16	2.14	2.06	2.01	2.00	Black 100 Y	0.93	4.63	6.94	7.41
Black 100 M	2.39	2.39	2.30	2.30	2.28	Black 100 M	0.00	3.77	3.77	4.60
Black 100 C	2.67	2.55	2.37	2.05	2.02	Black 100 C	4.49	11.24	23.22	24.34
Years:	0.00	9.87	17.54	25.26	32.65		9.87	17.54	25.26	32.65
Black 55 Y	0.84	0.83	0.81	0.81	0.79	Black 55 Y	1.19	3.57	3.57	5.95
Black 55 M	0.82	0.82	0.82	0.80	0.79	Black 55 M	0.00	0.00	2.44	3.66
Black 55 C	0.89	0.85	0.79	0.74	0.72	Black 55 C	4.49	11.24	16.85	19.10
Years:	0.00	9.87	17.54	25.26	32.65		9.87	17.54	25.26	32.65
Black 5 Y	0.07	0.07	0.09	0.11	0.09	Black 5 Y	0.00	-28.57	-57.14	-28.57
Black 5 M	0.11	0.10	0.11	0.10	0.09	Black 5 M	9.09	0.00	9.09	18.18
Black 5 C	0.13	0.11	0.11	0.10	0.10	Black 5 C	15.38	15.38	23.08	23.08
Base Y	0.04	0.05	0.06	0.07	0.06					
Base M	0.08	0.08	0.07	0.08	0.07					
Base C	0.10	0.08	0.08	0.09	0.08					

APPENDIX D.17

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 17 FOR ACCELERATED FADE TEST

PRINT NUMBER:	17

Fuji Crystal Archive Lustre Type 1 Paper for Frontier
Printer: Fuji Frontier

Density values						**% Density decrease**				
Years:	0.00	2.61	10.33	17.72	25.31		2.61	10.33	17.72	25.31
Cyan 100	1.54	1.48	1.45	1.31	1.19	Cyan 100	3.90	5.84	14.94	22.73
Cyan 55	0.88	0.84	0.82	0.79	0.76	Cyan 55	4.55	6.82	10.23	13.64
Cyan 5	0.13	0.12	0.12	0.11	0.12	Cyan 5	7.69	7.69	15.38	7.69
Years:	0.00	2.61	10.33	17.72	25.31		2.61	10.33	17.72	25.31
Magenta 100	1.84	1.85	1.85	1.79	1.74	Magenta 100	-0.54	-0.54	2.72	5.43
Magenta 55	0.86	0.87	0.85	0.82	0.78	Magenta 55	-1.16	1.16	4.65	9.30
Magenta 5	0.10	0.10	0.10	0.09	0.09	Magenta 5	0.00	0.00	10.00	10.00
Years:	0.00	2.61	10.33	17.72	25.31		2.61	10.33	17.72	25.31
Yellow 100	1.55	1.56	1.48	1.39	1.30	Yellow 100	-0.65	4.52	10.32	16.13
Yellow 55	0.74	0.73	0.72	0.71	0.69	Yellow 55	1.35	2.70	4.05	6.76
Yellow 5	0.04	0.04	0.08	0.09	0.08	Yellow 5	0.00	-100.00	-125.00	-100.00
Years:	0.00	2.61	10.33	17.72	25.31		2.61	10.33	17.72	25.31
Black 100 Y	2.13	2.13	2.09	2.06	2.03	Black 100 Y	0.00	1.88	3.29	4.69
Black 100 M	2.35	2.35	2.35	2.33	2.31	Black 100 M	0.00	0.00	0.85	1.70
Black 100 C	2.57	2.55	2.08	1.92	1.91	Black 100 C	0.78	19.07	25.29	25.68
Years:	0.00	2.61	10.33	17.72	25.31		2.61	10.33	17.72	25.31
Black 55 Y	0.80	0.80	0.79	0.79	0.78	Black 55 Y	0.00	1.25	1.25	2.50
Black 55 M	0.84	0.84	0.84	0.83	0.82	Black 55 M	0.00	0.00	1.19	2.38
Black 55 C	0.89	0.88	0.83	0.81	0.80	Black 55 C	1.12	6.74	8.99	10.11
Years:	0.00	2.61	10.33	17.72	25.31		2.61	10.33	17.72	25.31
Black 5 Y	0.05	0.05	0.12	0.10	0.07	Black 5 Y	0.00	-140.00	-100.00	-40.00
Black 5 M	0.10	0.09	0.10	0.09	0.09	Black 5 M	10.00	0.00	10.00	10.00
Black 5 C	0.12	0.12	0.11	0.10	0.10	Black 5 C	0.00	8.33	16.67	16.67
Base Y	0.03	0.03	0.10	0.08	0.07					
Base M	0.08	0.08	0.09	0.08	0.08					
Base C	0.10	0.09	0.09	0.09	0.10					

APPENDIX E.1

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 8 FOR RECIPROCITY TEST

PRINT NUMBER: 8 Exposed at 6 Klux.

Agfa Prestige Digital Glossy CN510

Printer: Agfa D-Lab 2.

Density values at 6 Klux / **% Density decrease**

Years:	0.00	0.60	2.68		0.60	2.68
Cyan 100	2.76	2.83	2.81	Cyan 100	-2.54	-1.81
Cyan 55	0.78	0.78	0.79	Cyan 55	0.00	-1.28
Cyan 5	0.12	0.12	0.13	Cyan 5	0.00	-8.33
Years:	0.00	0.60	2.68		0.60	2.68
Magenta 100	2.10	2.14	2.14	Magenta 100	-1.90	-1.90
Magenta 55	0.60	0.61	0.61	Magenta 55	-1.67	-1.67
Magenta 5	0.09	0.10	0.10	Magenta 5	-11.11	-11.11
Years:	0.00	0.60	2.68		0.60	2.68
Yellow 100	1.91	1.94	1.93	Yellow 100	-1.57	-1.05
Yellow 55	0.62	0.62	0.62	Yellow 55	0.00	0.00
Yellow 5	0.07	0.07	0.07	Yellow 5	0.00	0.00
Years:	0.00	0.60	2.68		0.60	2.68
Black 100 Y	2.14	2.16	2.14	Black 100 Y	-0.93	0.00
Black 100 M	2.38	2.42	2.40	Black 100 M	-1.68	-0.84
Black 100 C	3.38	3.16	3.06	Black 100 C	6.51	9.47
Years:	0.00	0.60	2.68		0.60	2.68
Black 55 Y	0.64	0.64	0.64	Black 55 Y	0.00	0.00
Black 55 M	0.70	0.69	0.70	Black 55 M	1.43	0.00
Black 55 C	0.74	0.74	0.76	Black 55 C	0.00	-2.70
Years:	0.00	0.60	2.68		0.60	2.68
Black 5 Y	0.08	0.07	0.07	Black 5 Y	12.50	12.50
Black 5 M	0.11	0.11	0.11	Black 5 M	0.00	0.00
Black 5 C	0.12	0.12	0.13	Black 5 C	0.00	-8.33

APPENDIX E.2

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 6 FOR RECIPROCITY TEST

PRINT NUMBER: 6 Exposed at 6 Klux.

Epson Premium Glossy Photo Paper

Printer: Epson 1200.

Ink: MIS Archival CFS inkset

Density values / **% Density decrease**

Years:	0.00	0.62	1.92	3.17	4.45		0.62	1.92	3.17	4.45
Cyan 100	1.01	1.00	0.99	1.01	1.02	Cyan 100	0.99	1.98	0.00	-0.99
Cyan 55	0.70	0.70	0.70	0.70	0.71	Cyan 55	0.00	0.00	0.00	-1.43
Cyan 5	0.16	0.17	0.17	0.17	0.17	Cyan 5	-6.25	-6.25	-6.25	-6.25
Years:	0.00	0.62	1.92	3.17	4.45		0.62	1.92	3.17	4.45
Magenta 100	1.03	1.00	0.98	0.98	0.96	Magenta 100	2.91	4.85	4.85	6.80
Magenta 55	0.75	0.73	0.72	0.71	0.71	Magenta 55	2.67	4.00	5.33	5.33
Magenta 5	0.12	0.12	0.12	0.12	0.12	Magenta 5	0.00	0.00	0.00	0.00
Years:	0.00	0.62	1.92	3.17	4.45		0.62	1.92	3.17	4.45
Yellow 100	1.02	1.01	0.99	0.98	0.97	Yellow 100	0.98	2.94	3.92	4.90
Yellow 55	0.51	0.49	0.49	0.50	0.49	Yellow 55	3.92	3.92	1.96	3.92
Yellow 5	0.04	0.04	0.04	0.03	0.03	Yellow 5	0.00	0.00	25.00	25.00
Years:	0.00	0.62	1.92	3.17	4.45		0.62	1.92	3.17	4.45
Black 100 Y	2.03	1.97	1.97	1.97	1.88	Black 100 Y	2.96	2.96	2.96	7.39
Black 100 M	2.24	2.17	2.17	2.18	2.08	Black 100 M	3.13	3.13	2.68	7.14
Black 100 C	2.06	2.05	2.08	2.10	2.03	Black 100 C	0.49	-0.97	-1.94	1.46
Years:	0.00	0.62	1.92	3.17	4.45		0.62	1.92	3.17	4.45
Black 55 Y	0.71	0.70	0.71	0.70	0.68	Black 55 Y	1.41	0.00	1.41	4.23
Black 55 M	0.83	0.82	0.81	0.80	0.79	Black 55 M	1.20	2.41	3.61	4.82
Black 55 C	0.92	0.90	0.91	0.90	0.90	Black 55 C	2.17	1.09	2.17	2.17
Years:	0.00	0.62	1.92	3.17	4.45		0.62	1.92	3.17	4.45
Black 5 Y	0.03	0.03	0.03	0.03	0.02	Black 5 Y	0.00	0.00	0.00	33.33
Black 5 M	0.11	0.10	0.10	0.10	0.10	Black 5 M	9.09	9.09	9.09	9.09
Black 5 C	0.13	0.13	0.14	0.14	0.14	Black 5 C	0.00	-7.69	-7.69	-7.69

APPENDIX E.3

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 17 FOR RECIPROCITY TEST

PRINT NUMBER:	**17**	**Exposed at 6 Klux.**

Fuji Crystal Archive Lustre.
Printer: Fuji Frontier.

Density values at 6 Klux				**% Density decrease**		
Years:	0.00	1.09	2.37		1.09	2.37
Cyan 100	1.54	1.50	1.51	Cyan 100	2.60	1.95
Cyan 55	0.88	0.86	0.86	Cyan 55	2.27	2.27
Cyan 5	0.13	0.13	0.12	Cyan 5	0.00	7.69
Years:	0.00	1.09	2.37		1.09	2.37
Magenta 100	1.84	1.85	1.84	Magenta 100	-0.54	0.00
Magenta 55	0.86	0.86	0.87	Magenta 55	0.00	-1.16
Magenta 5	0.10	0.10	0.09	Magenta 5	0.00	10.00
Years:	0.00	1.09	2.37		1.09	2.37
Yellow 100	1.55	1.57	1.56	Yellow 100	-1.29	-0.65
Yellow 55	0.74	0.75	0.74	Yellow 55	-1.35	0.00
Yellow 5	0.04	0.04	0.04	Yellow 5	0.00	0.00
Years:	0.00	1.09	2.37		1.09	2.37
Black 100 Y	2.13	2.11	2.13	Black 100 Y	0.94	0.00
Black 100 M	2.35	2.32	2.33	Black 100 M	1.28	0.85
Black 100 C	2.57	2.51	2.46	Black 100 C	2.33	4.28
Years:	0.00	1.09	2.37		1.09	2.37
Black 55 Y	0.80	0.80	0.80	Black 55 Y	0.00	0.00
Black 55 M	0.84	0.84	0.84	Black 55 M	0.00	0.00
Black 55 C	0.89	0.88	0.88	Black 55 C	1.12	1.12
Years:	0.00	1.09	2.37		1.09	2.37
Black 5 Y	0.05	0.04	0.05	Black 5 Y	20.00	0.00
Black 5 M	0.10	0.10	0.09	Black 5 M	0.00	10.00
Black 5 C	0.12	0.12	0.12	Black 5 C	0.00	0.00

APPENDIX F.1

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 8 FOR DARK TEST

Printer: Agfa D-Lab 2

Density values					**% Density decrease**			
Years:	0.00	7.73	15.11	22.69		7.73	15.11	22.69
Cyan 100	2.76	2.77	2.81	2.81	Cyan 100	-0.36	-0.36	-1.81
Cyan 55	0.78	0.76	0.79	0.79	Cyan 55	2.56	2.56	-1.28
Cyan 5	0.12	0.12	0.12	0.12	Cyan 5	0.00	0.00	0.00
Years:	0.00	7.73	15.11	22.69		7.73	15.11	22.69
Magenta 100	2.10	2.13	2.14	2.14	Magenta 100	-1.43	-1.43	-1.90
Magenta 55	0.60	0.58	0.66	0.66	Magenta 55	3.33	3.33	-10.00
Magenta 5	0.09	0.10	0.11	0.11	Magenta 5	-11.11	-11.11	-22.22
Years:	0.00	7.73	15.11	22.69		7.73	15.11	22.69
Yellow 100	1.91	1.92	1.93	1.92	Yellow 100	-0.52	-0.52	-0.52
Yellow 55	0.62	0.59	0.64	0.63	Yellow 55	4.84	4.84	-1.61
Yellow 5	0.07	0.12	0.09	0.11	Yellow 5	-71.43	-71.43	-57.14
Years:	0.00	7.73	15.11	22.69		7.73	15.11	22.69
Black 100 Y	2.14	2.20	2.18	2.14	Black 100 Y	-2.80	-2.80	0.00
Black 100 M	2.38	2.46	2.44	2.40	Black 100 M	-3.36	-3.36	-0.84
Black 100 C	3.38	3.19	3.03	3.00	Black 100 C	5.62	5.62	11.24
Years:	0.00	7.73	15.11	22.69		7.73	15.11	22.69
Black 55 Y	0.64	0.62	0.67	0.66	Black 55 Y	3.13	3.13	-3.13
Black 55 M	0.70	0.70	0.75	0.74	Black 55 M	0.00	0.00	-5.71
Black 55 C	0.75	0.73	0.75	0.76	Black 55 C	2.67	2.67	-1.33
Years:	0.00	7.73	15.11	22.69		7.73	15.11	22.69
Black 5 Y	0.08	0.08	0.09	0.08	Black 5 Y	0.00	0.00	0.00
Black 5 M	0.11	0.11	0.11	0.12	Black 5 M	0.00	0.00	-9.09
Black 5 C	0.12	0.12	0.12	0.13	Black 5 C	0.00	0.00	-8.33

APPENDIX F.2

DATA SHEET OF TEST PRINT REFLECTION DENSITIES FOR PRINT 17 FOR DARK TEST

PRINT NUMBER:	**17**	**DARK TEST**

Fuji Crystal Archive Lustre Type 1 Paper for Frontier

Printer: Fuji Frontier

Density values / **% Density decrease**

Years:	0.00	10.39	17.77	25.35		10.39	17.77	25.35
Cyan 100	1.54	1.54	1.53	1.52	Cyan 100	0.00	0.65	1.30
Cyan 55	0.88	0.87	0.87	0.88	Cyan 55	1.14	1.14	0.00
Cyan 5	0.13	0.13	0.12	0.13	Cyan 5	0.00	7.69	0.00
Years:	0.00	10.39	17.77	25.35		10.39	17.77	25.35
Magenta 100	1.84	1.87	1.87	1.86	Magenta 100	-1.63	-1.63	-1.09
Magenta 55	0.86	0.87	0.87	0.87	Magenta 55	-1.16	-1.16	-1.16
Magenta 5	0.10	0.10	0.10	0.10	Magenta 5	0.00	0.00	0.00
Years:	0.00	10.39	17.77	25.35		10.39	17.77	25.35
Yellow 100	1.55	1.57	1.58	1.57	Yellow 100	-1.29	-1.94	-1.29
Yellow 55	0.74	0.76	0.77	0.76	Yellow 55	-2.70	-4.05	-2.70
Yellow 5	0.04	0.05	0.05	0.04	Yellow 5	-25.00	-25.00	0.00
Years:	0.00	10.39	17.77	25.35		10.39	17.77	25.35
Black 100 Y	2.14	2.11	2.14	2.12	Black 100 Y	1.40	1.40	0.93
Black 100 M	2.38	2.35	2.37	2.35	Black 100 M	1.26	1.26	1.26
Black 100 C	3.38	2.61	2.58	2.60	Black 100 C	22.78	22.78	23.08
Years:	0.00	10.39	17.77	25.35		10.39	17.77	25.35
Black 55 Y	0.80	0.81	0.82	0.81	Black 55 Y	-1.25	-2.50	-1.25
Black 55 M	0.84	0.85	0.86	0.85	Black 55 M	-1.19	-2.38	-1.19
Black 55 C	0.89	0.90	0.89	0.90	Black 55 C	-1.12	0.00	-1.12
Years:	0.00	10.39	17.77	25.35		10.39	17.77	25.35
Black 5 Y	0.05	0.05	0.06	0.05	Black 5 Y	0.00	-20.00	0.00
Black 5 M	0.10	0.10	0.10	0.10	Black 5 M	0.00	0.00	0.00
Black 5 C	0.12	0.12	0.12	0.13	Black 5 C	0.00	0.00	-8.33

APPENDIX G

LIST OF PAPERS TESTED FOR BASE DENSITIES

Comparison of paper base densities

Print No.	Paper
1	Epson Premium Glossy Photo Paper S041286
7	Somerset Velvet Radiant White M8FZ1041
8	Agfa Prestige Digital Glossy CN510
10	Epson Photo Quality Ink Jet Paper S041061
12	Epson Enhanced Matte Paper S041341
16	Fuji Crystal Archive Glossy Type 1 Paper for Frontier
17	Fuji Crystal Archive Lustre Type 1 Paper for Frontier

APPENDIX G.1

DENSITY CHARTS FOR COMPARISON OF PAPER BASE DENSITY CHANGES CAUSED BY LIGHT AND TEMPERATURE

Comparison of paper base densities.

Effects of light and temperature.

Epson Premium Glossy Photo Paper S041286

Years:	0.00	9.87	17.54	25.26	32.65
Base Y	0.00	0.00	0.00	0.00	0.00
Base M	0.04	0.05	0.04	0.04	0.05
Base C	0.07	0.07	0.07	0.07	0.07

Agfa Prestige Digital Glossy CN510

	0.00	2.61	10.33	17.72	25.31
Agfa Base Y	0.06	0.06	0.07	0.11	0.11
Base M	0.08	0.09	0.09	0.10	0.10
Base C	0.10	0.10	0.10	0.10	0.10

Epson Photo Quality Ink Jet Paper S041061

Years:	0.00	7.42	15.72	25.60
Base Y	0.00	0.03	0.03	0.03
Base M	0.08	0.08	0.07	0.08
Base C	0.10	0.08	0.09	0.09

Epson Enhanced Matte Paper S041341

	0.00	7.42	15.72	20.78
Base Y	-0.01	0.02	0.01	0.02
Base M	0.03	0.04	0.03	0.04
Base C	0.05	0.04	0.06	0.05

Fuji Crystal Archive Lustre Type 1 Paper for Frontier

Years:	0.00	2.61	10.33	17.72	25.31
Fuji Base Y	0.03	0.03	0.10	0.08	0.07
Base M	0.08	0.08	0.09	0.08	0.08
Base C	0.10	0.09	0.09	0.09	0.10

APPENDIX G.2

DENSITY CHARTS FOR COMPARISON OF PAPER BASE DENSITY CHANGES CAUSED BY TEMPERATURE ONLY

Comparison of paper base densities.

Effects of temperature only.

Epson Premium Glossy Photo Paper S041286

	0.00	6.25	16.16	39.99
Base Y	0.00	0.00	0.00	0.00
Base M	0.04	0.04	0.05	0.05
Base C	0.07	0.07	0.06	0.07

Agfa Prestige Digital Glossy CN510

Years:	0.00	7.73	15.11	22.69
Base Y	0.06	0.06	0.07	0.07
Base M	0.08	0.09	0.09	0.09
Base C	0.10	0.10	0.10	0.11

Epson Photo Quality Ink Jet Paper S041061

Years:	0.00	6.25	16.16	39.99
Base Y	0.00	0.00	0.00	0.00
Base M	0.07	0.07	0.07	0.08
Base C	0.09	0.09	0.08	0.08

Epson Enhanced Matte Paper S041341

Years:	0.00	6.25	16.16	39.99
Base Y	-0.01	-0.01	-0.01	0.00
Base M	0.03	0.03	0.03	0.03
Base C	0.05	0.05	0.04	0.05

Fuji Crystal Archive Lustre Type 1 Paper for Frontier

Years:	0.00	10.39	17.77	25.35
Base Y	0.03	0.04	0.05	0.04
Base M	0.08	0.08	0.08	0.08
Base C	0.10	0.10	0.09	0.10

APPENDIX G.3

TABLE OF TEMPERATURES MEASURED IN ACCELERATED FADE UNIT

<u>TEMPERATURE of Accelerated Fading Unit</u>

Temperatures in Degrees Celsius of Print Surface Area

Position	08-Oct-03	27-Oct-03	05-Nov-03	17-Nov-03
1	no print	no print	no print	no print
2	35.3	36.5	36.1	36.4
3	40.5	41.1	40.6	41.2
4	46.5	46.4	45.7	45.9
5	no print	no print	no print	no print
6	38.2	37.9	37.5	38.9
7	44.9	44.5	44.9	45.0
8	42.1	40.8	41.2	42.8
9	no print	no print	no print	no print
10	38.0	36.5	36.7	37.2
11	36.4	35.1	35.6	36.6
12	37.5	36.1	36.9	37.3
Average	39.9	39.4	39.5	40.1

39.7 Average temperature.

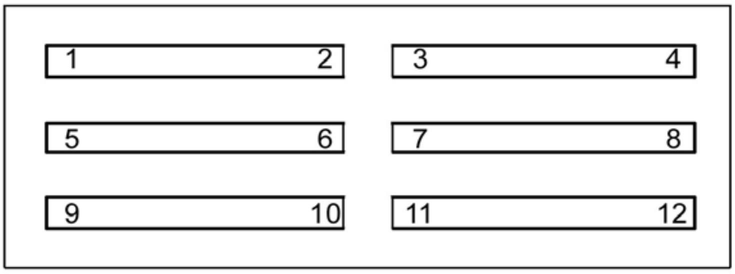


Figure 3.3 Positions of illuminance and temperature measurement points on the test surface.