# Photoquality PQ and Durability Constraints For Inkjet Media

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## Abstract

The composite, long term storage stability of inkjet prints is influenced by four factors that can be separated and quantified. In this paper, lightfastness, darkfastness and color bleed of inkjet prints are discussed. No mention is made in this paper to the fourth IJ degradation factor of waterfastness. Specifically in this paper, the kinetics of the lightfastness degradation process is described. Globally, pseudo first order kinetics for the color degradation process is obeyed by most, but not all, ink and media combinations examined for short exposure times to strong light sources. In the absence of a concrete first order kinetic model, the confluence of temperature and light flux on the image degradation process is discussed. In addition, information about the long term deleterious effects of image bleed are presented. In the opinion of the authors, these three image degradation processes need significant control in order for inkjet photo printing to continue approaching that of traditional color photography.

## Introduction

Inkjet printing involves the direct writing of spots of liquid onto a media surface. The complex, and often ill defined, chemical interactions of various components of the multitude of inks and media choices play the key role in determining resultant imaging quality and long term stability of the images. Great advances have been made in the past few years in color inkjet printing throughput and so-called “photorealism”. Without doubt, the future for inkjet printing is growing and dynamic.

This paper will examine the role of temperature, light source, time and ink/media interactions on common photoquality inkjet print attributes as dark fade and light fade. In addition, the very long term storage stability issue of bleed and it’s proposed phenomenological origins will be presented and discussed. The degradation of photo print quality of IJ prints as a function of bleed, lightfastness and darkfastness is then presented in unison.

## Experimental

### Sample Preparation

Glossy photobase large format inkjet media were acquired from various commercial, and non-commercial sources, including Arkwright, and were imaged on ENCAD commercially available inkjet plotters using various commercially available dye based ink-sets. Two photobase media were further characterized as being primarily hydrophilic cellulose type, and are referred to as such throughout the body of the paper.

### Lightfade

Lightfade is the ability of imaged, and unimaged, media to withstand the degradation effects of UV/VIS spectral radiation. Lightfade information was generated by exposing inkjet printed media samples to the light of a Xenon bulb in an Atlas Sunchex ® instrument. The dosage was of 0.35 $W/M^2$ at 340nm.

### Darkfade

Darkfade is described by changes in color density, color gamut and other parameters, as a function of time, in the absence of an overwhelming stimulus like strong light flux. Darkfade measurements were made by placing imaged media samples into forced air ovens at the temperatures and times noted.

### Bleed

Bleed is the degradation of image edge acuity and dot resolution as a function of time. Often, as will be discussed in this paper, bleed can be greatly influenced by ambient moisture. A brief discussion of the effect of high boiling solvent in IJ inksets as a significant factor in the bleed process is also presented.

### Measurements and Calculations

All colorimetry measurements were made with an X-Rite 918. Gamut calculations were made via utilization of the excellent model described by Kapple.[1] GC/MS measurements were made utilizing an HP 5890 GC/MS system. Thermogravimetric measurements used to estimate the amount of retained solvents for long-term stored inkjet prints, were done utilizing a TA instruments TGA-2950 with $N_2$ purge.

## Results and Discussion

### Lightfade

Imaged inkjet photobase media samples exposed to high pressure Xenon arc light show the effects of the incident radiation. These effects vary by both media type and ink type, as has been discussed previously. [2-3]

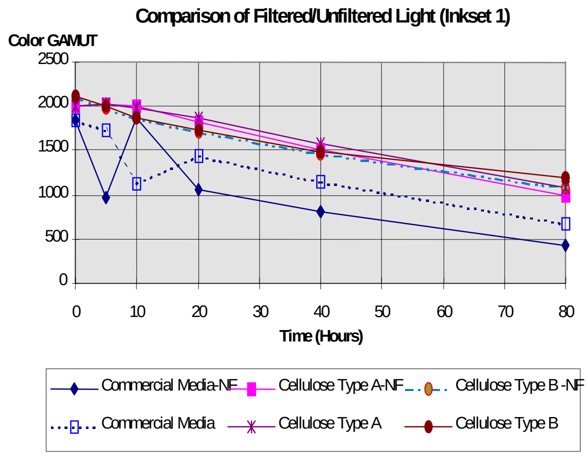


*Figure 1a. Light Fade as a function of exposure time for a variety of media types for commercial dye based IJ ink (inkset 1). NF in the legend indicates non-filtered (bare bulb) light.*

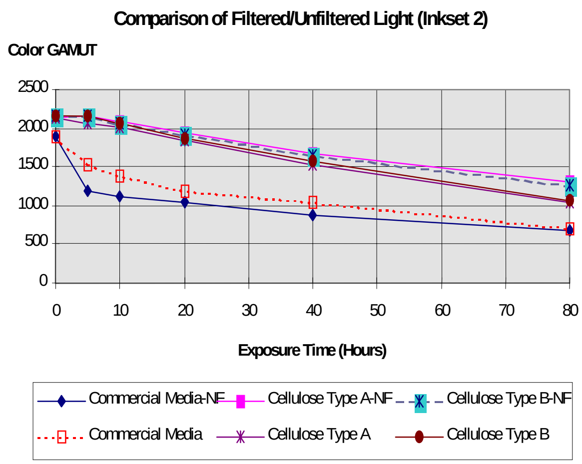


*Figure 1b. Light Fade as a function of exposure time for a variety of media types for commercial dye based IJ ink (inkset 2).*

Typically, color density reduction has been described as a function of exposure time, i.e. light dose. This degradation of image density is reported here as color Gamut reduction. However, closer inspection of the curves in *Figure 1* reveal some non-linear points. Interestingly, the commercial media gave images which were most prone to light fading in this analysis.

For some inkjet media and ink combinations, the colors initially fade, and then revert, within relatively short exposure times. Such information suggests the presence of competing reaction pathways in the color fading process. It is unlikely for the colorants to be regenerated within the light fading process. Therefore, it may be possible that certain dyes dissolve within different domains of the polymeric based media. Such mechanisms have been suggested for several stability processes involving polymeric material and small molecules in the presence of strong light sources.[4] Heat might be anticipated to increase such an effect. However, no non-linearity was noted for darkfade measurements made over a similar reduction of color Gamut.

The effect of filtering the low end UV component of the light from the incident fading radiation shows a marked difference based on the media. For relatively light stable cellulose based IJ media, little, if any, effect is seen. However, for the commercially available media used in this study, the overall Gamut is reduced by about 10%. The rate of lightfade based on the media and ink combinations used does vary, often considerably, as shown in *Figures 1a and 1b*. As demonstrated, for the similar cellulose based media (type A and type B) the rate of fading is strongly ink dependent.

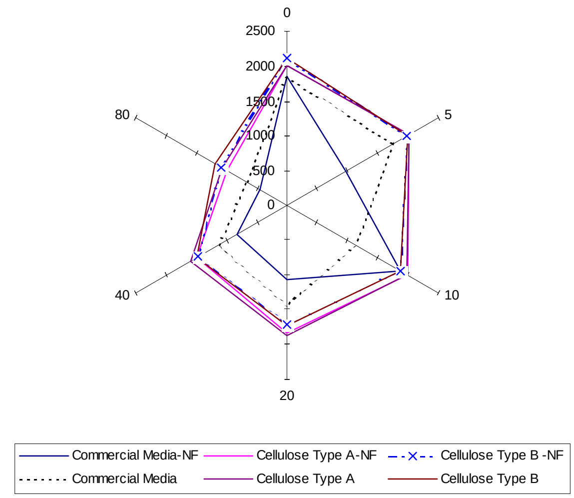


*Figure 1c. Color Gamut comparisons for filtered and unfiltered Xenon light for inkset 1.*

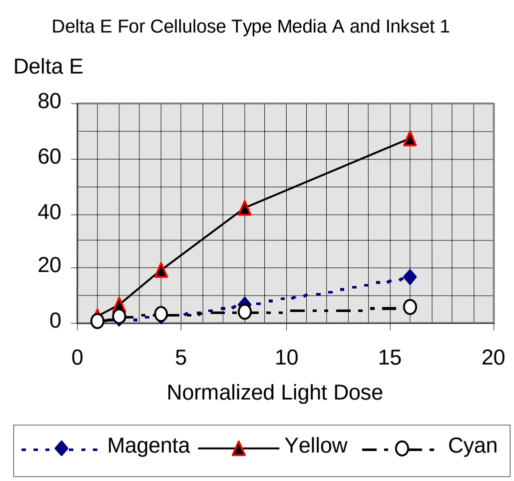


*Figure 2. Delta E values for a cellulose type A media as a function of light dose.*

The rate of fading of various dyes within a particular media combination is not linear as is shown in *Figure 2*.

Within this experiment the yellow dye(s) showed a much greater fading rate. The rate of fading of magenta and cyan is significantly reduced. However, the overall kinetic order of the fading reactions are different for each inkset, as well as the rate as shown below in *Figure 3*.

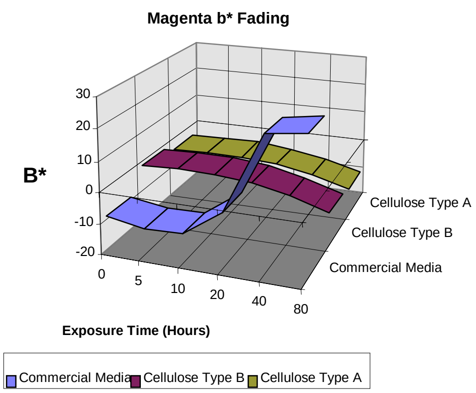


*Figure 3. b* values for magenta showing the effect of media type on the fading process. For the commercially available material the order is second order.*

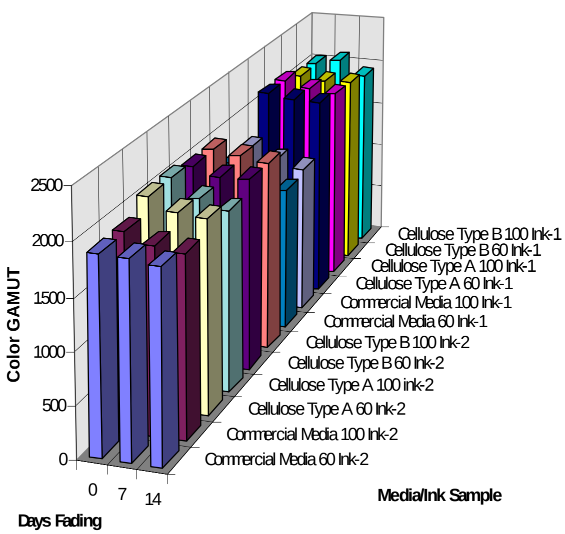


*Figure 4. Dark fading of various inks and media at 60℃ and 100℃.*

## Darkfade

The effect of temperature in the absence of strong incident light is shown in *Figure 4*. The effect of temperature on the fading process is more pronounced for the cellulose type B product. Such rates of reaction are complex and do not lend themselves to careful mechanistic study.

## Long-Term Storage Bleed

As has been previously alluded to, the effect of high boiling solvent, often used in inkjet inks, on image bleed is often dramatic. These effects can produce long term image degradation effects. In *Figure 5*, the long term effects of bleed on image edge acuity is shown.

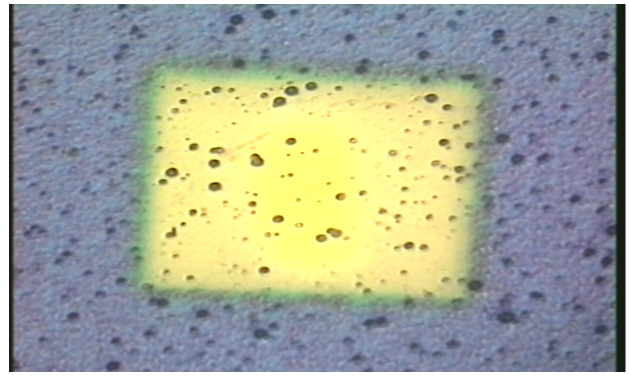

*Figure 5.Long term storage bleed. Blue to yellow bleed shows edge acuity issues.*

In order to demonstrate the presence of the organic solvent in the media after such a long term storage, the prints were subjected to some thermal and GC/Mass spectral analysis. As shown in *Figure 6*, even after 3 years of ambient storage, a significant amount of high boiling solvent is still retained in the imaged inkjet media.

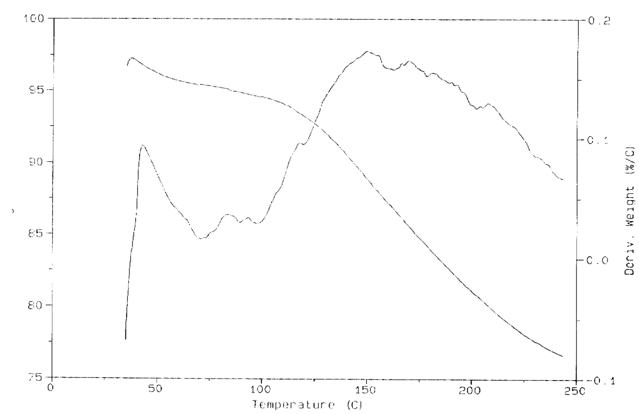


*Figure 6. After three years aging under office ambient conditions, an inkjet print still has a significant amount of high boiling ink vehicle present in the imaged media, as shown in this thermogravimetric analysis.*

It is likely that the relatively non-volatile ink vehicles act as solvents for the various dyes used in the inkjet inks within the inkjet media matrix Over time, dye diffusion processes would cause uniform blurring of the image and degradation of the image quality.

## Conclusion

Active aging of an inkjet print would involve exposure of the printed media to an external stimulus like heat, UV/VIS radiation or humidity. Therefore, active aging includes lightfade and waterfastness measurements. Arrhenius models are often relied on to correlate the effects of temperature on reaction rates, as is well known in the photographic arts.[6-7] Inactive aging involves print defect caused by chemistry present within the inkjet media upon imaging with inkjet ink. Darkfade and long-term storage bleed are always present in modern inkjet ink and media combinations.

Darkfade, lightfade and bleed are processes that exist simultaneously in inkjet media as demonstrated in this paper. Darkfastness and lightfastness act on the overall color quality of the media. Due to the rapidly changing nature of inkjet ink and media development, long term storage information and durability information is difficult to develop and often obsolete when gathered. It is clear, however, that the long-term effects of light, temperature and inclusive high boiling solvents in inkjet inks will have a strong influence on image print quality. As shown in this paper, similar materials often give very different responses for the various aging phenomena. Any claims of long-term inkjet media/ink stability need to be viewed independently in terms described in this paper.

## Acknowledgement

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## References

1. W. D. Kapple,. *IS&T NIP13*, 470, (1997).
2. S. Yuan, S. J. Sargeant, J. Rundus, N. Jones and K. Nguyen, *IS&T NIP13*, 414-417, (1997).
3. S. J. Sargeant; S. Yang; M. Huang; D. Atherton, and K Sun, *SPIE Proceedings*, 2413, (1995).
4. K. Horie; I. Mita, “Reactions and Photodynamics in Polymer Solids”, in *Advances in Polymer Science* 88, Springer-Verlag, (1989).
5. H. Wilhelm, “A Survey of the Light Fading Stability of Digital Pictorial Reflection Prints” *IS&T 48th Annual Conference*, (1995).
6. S. Benson, The Foundation Of Chemical Kinetics, McGraw Hill, (1960), pp66-70.
7. K. B. Hendriks, “The Stability and Preservation Of Recorded Images”, in *Imaging Processes and Materials, 8th ed.*, (1989).