Pigment Selection for an Inkjet Ink Set with Balanced Lightfade Performance

Howard Doumaux, Katie Burns, David Mahli
Hewlett-Packard Company
San Diego, California

Abstract

Careful pigment selection for an inkjet printer can achieve balanced lightfade performance. When a print fades from light exposure, commonly each colorant fades at a different rate. This results in an unwanted hue shift in addition to the overall loss in density. In a balanced system, each colorant fades at approximately the same rate. As a result, the amount of hue shift is reduced. The faded print is perceived as less objectionable to the user when the original hues are maintained. In order to create a balanced system, samples are printed with pigment and pigment blend candidates on a variety of media types. Those samples are exposed in a lightfade chamber, and density changes are measured over time. This data is used to select candidates with similar lightfade performance for each colorant of the system. Instead of attempting to maximize the lightfade performance of each colorant, other desirable performance attributes can be considered, such as chroma and cost. The achievement of a balanced lightfade system results in a more complete solution to the customer.

Introduction

Print permanence is an increasingly desirable property in existing and emerging inkjet printing markets. Some exemplary markets include: professional, especially wedding, photography, digital fine arts, and home photography. Pigmented ink systems are known to be capable of providing excellent indoor lightfastness.[1] However, some recently introduced pigment-based inkjet systems have targeted maximum color gamut, with light fade permanence similar to high-quality dye-based prints.[2] While this trade-off is acceptable to some users, it does not make the best use the available pigment technology to improve print permanence while maintaining high image quality. In this paper, we describe the approach used in designing the pigment system for the HP Photosmart Pro B9180. The printer uses up to eight inks depending upon the selected media and print mode. A matte black ink was included to enhance black optical density on matte, digital fine art, and plain paper media. The other inks are the two shades each of neutral gray, cyan, and magenta, with a single yellow. The advantages of neutral gray inks have been described in detail elsewhere by Kabalnov et al.[3] The most important advantages are: enhanced neutrality control and robustness, reduced metamerism, and enhanced image quality.

Delivering high print permanence with minimal gamut trade-off was a key design goal of the B9180. Print permanence attributes were studied across several media to ensure good performance across a variety of media. The tested media are all HP commercial or developmental products, and included: glossy, two digital fine art media, and a heavy weight matte media. Permanence attributes studied included: indoor and window lightfastness and ozone-fastness. This paper will focus on the indoor lightfastness testing and results.

Experimental

Indoor light fade was conducted using Hewlett-Packard's Image Permanence Lab.[4] Two, internally designed, chambers were used. In each chamber, temperature and humidity were targeted at 24 °C and 60 % RH. Light intensities from Cool White fluorescent bulbs ranged from 70-90 klux. Print samples were glass-covered during light exposure. Wilhelm Imaging Research failure criteria version 3.0 and daily exposure assumptions were used to determine sample lifetimes. One year of indoor exposure was taken to be 1971 klux-hours, based upon 12 hours of 450 lux illumination per day.

Results and Discussion

Lightfade performance of pigmented systems is mainly controlled by the selection of the yellow pigment, especially in extreme exposure environments where even moderate amounts of UV light are present. This bluish, near UV light is strongly absorbed by the yellow ink and is relatively energetic, leading to decreased permanence. Enhanced UV light content is present in a proposed illuminant under ISO-WG5/Task Group 3, namely filtered Xenon-arc light. UV light exposure is also significantly higher when prints are displayed in direct sunlight, for example, in a window. We have conducted testing which has shown that the results discussed here are in-line with those from these harsher environments. Yellow is also a focus point due to the very good permanence of traditional cyan, magenta, and black pigments utilized in most desktop and large format water-based inkjet printers; namely, copper phthalocyanine-based cyans, quinacridone-based magentas, and carbon black-based blacks. The permanence characteristics of these basic colorants are determined by other printer design requirements, for example: gloss, transparency, chroma, hue, and pigment dispersibility.

In designing the HP Photosmart Pro B9180, it was desired to allow the user the option of printing a black and white image without using composite black, while still providing excellent image quality. The printer uses two photo black inks and one matte black ink. The photo inks were tinted with other colorants to make their hue when printed substantially neutral. The use of neutral gray inks can decouple the lightfastness failure of the neutral axis from the failure of the primary colorants, depending upon the level of composite black used by the selected printmode. Given these desired printer and ink properties, a significant focus of our investigation was the colorant composition of the neutral gray ink and the yellow pigment selection.

The differences in lightfade of the primary colors are driven by several mechanisms, including: media chemistry, ink-media interactions, and printmode differences such as the utilization of light and dark inks between the media types. The effect of media type on pigmented ink print permanence has been demonstrated in other printers, so we took this factor into account when we were selecting the composition of our neutral gray inks and our yellow pigment.[5]

The permanence performance of two neutral gray light and dark ink compositions is shown in Figure 1. In this figure longer bars indicate a longer time to failure. There are four media types presented in the chart; DFA-1 and DFA-2 are two types of digital fine art paper, glossy is an HP developmental microporous photopaper, and matte is a heavyweight coated matte paper. The colorants used to produce the neutral gray inks are different in composition 1 and 2. There are also formulation differences between the light and dark inks. Please note that neutral gray inks based upon composition 2 have higher lightfastness across multiple media than those based on composition 1. Ink compositional differences between the light and dark inks and the interaction of those differences with the different colorants also drive differences in the light and dark ink permanence.

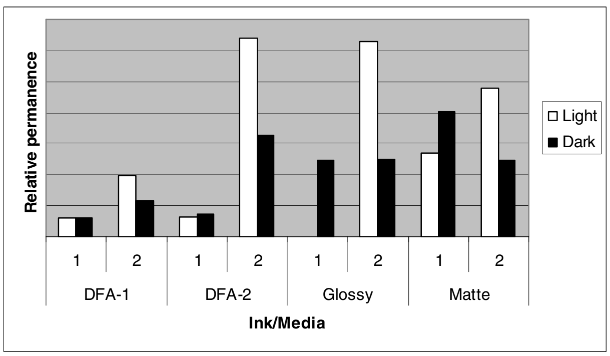

Figure 1: *Comparative lightfastness of two different neutral gray inks using two different colorant formulations.*

Yellow ink selection is a somewhat more complicated task. There are several well-known, very lightfast pigments available today. However, these pigments have generally poor color strength, requiring high pigment loadings and potentially significant yellow, red, and green chroma trade-offs. They also tend to be comparatively expensive and are difficult to disperse. However, the very lightfast pigments intended for automotive and outdoor use tend to be "over-performers" when exposed to indoor light. Their lightfade performance can be so good, that they are no longer limiting the system performance, and hence the additional performance being paid for in terms of reduced gamut and increased ink usage is not fully taken advantage of.

Selection of the yellow pigment involved consideration of many attributes in addition to color and lightfastness, these criteria included: gloss, transparency, suitability for inkjet, and dispersibility, amongst others. A range of suitable yellow pigments was identified for consideration. Figures 2a and 2b shows the color strength and ultimate chroma of several candidate pigments on glossy and digital fine arts type 1 (DFA-1) media. The ink amount goes to the media limit, so the differences observed in the middle of the figure are more important for a practical print system. Similar performance is seen across the other digital fine arts and matte media. The lightfastness results of these pigments are shown in Figure 2c.

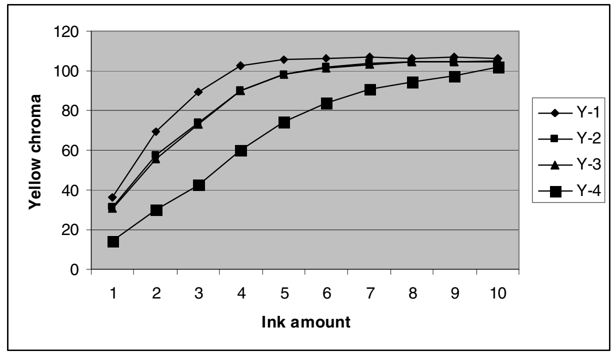

Figure 2a: *Comparative color strengths of selected yellow pigment candidates when printed on glossy media.*

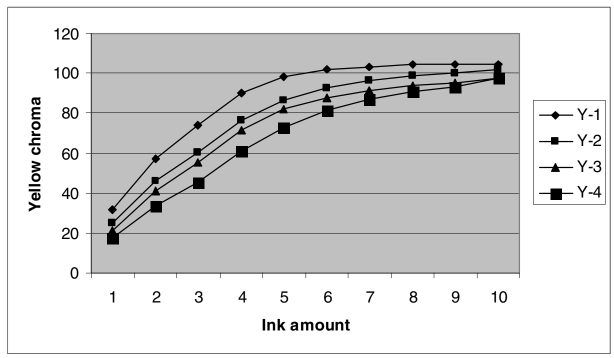

Figure 2b: *Comparative color strengths of selected yellow pigment candidates when printed on type 1 DFA media.*

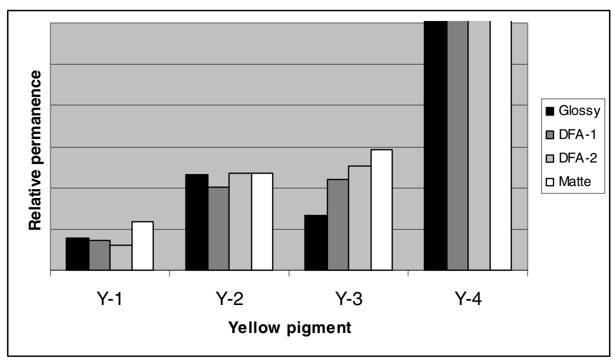

Figure 2c: *Comparative lightfastness of selected yellow pigment candidates.*

If we examine the charts in Figure 2 as a group, we see that there are three groups of pigments: very good color strength and poor fastness, good color strength and good fastness, and poor color strength with excellent fastness. Hence, Y-1 would significantly reduce print permanence while providing increased gamut. Similarly, a print system utilizing pigment Y-4 would sacrifice significant gamut, while providing little additional lightfastness. Therefore, yellow pigments Y-2 and Y-3 are desirable pigment choices as they deliver good chroma and good lightfastness.

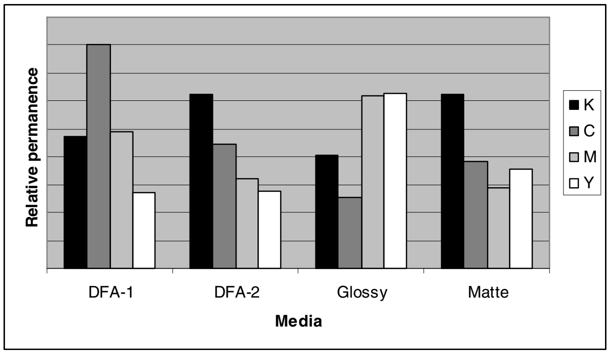

Figure 3: *Comparative lightfastness results across several media for a B9180 prototype system, which is very similar to the final printer.*

The relative performance of a near final prototype system across several media types is shown in Figure 3. The neutral gray photo ink type 2 is representative of the black ink used in the prototype system. Similarly, the relative performance of yellow pigments Y-2 and Y-3 is similar to that of the yellow ink shown in Figure 3. It is clear from Figure 3 that the print permanence of the primary colors is strongly dependent upon the media type, while the overall print lifetime is reasonably constant. The limiting primary color varies with media type. Internal Hewlett-Packard Image Permanence Lab testing of competing printers utilizing high chroma yellow pigments has shown that pure yellow or yellow color balance in composite black is consistently the failure mechanism. This failure occurs substantially sooner than the cyan or magenta and is not a strong function of media type. This behavior is very different from the colorant system employed in the HP Photosmart Pro B9180. The design approach Hewlett-Packard used has resulted in indoor lightfastness results of over 200 years for color images, and over 250 years for black and white images in preliminary testing.[6]

Conclusion

Design considerations for a photo printer with excellent permanence and very good color performance have been laid out. In order to optimize a printer for both excellent color gamut and print permanence, it is necessary to examine the component lightfade performance across media, locate the areas for improvement, and select appropriate colorants for consideration. In the design of the HP Photosmart Pro B9180, various options for increasing lightfastness were taken into account while providing good color gamut. The neutral gray inks and the yellow inks were the key design areas. The combination of good chroma and good, balanced, lightfastness combine to make what Hewlett-Packard considers to be an outstanding photo printer solution.

References

[1] Wilhelm Imaging Research; Hewlett-Packard Designjet 5000 and 5500 – Print Permanence Ratings, http://www.wilhelm-reseach.com/hp/WIR_HP5000_2003_07_31.pdf and http://www.wilhelm-reseach.com/hp/WIR_HP_5500_2005_06_30.pdf.

[2] Wilhelm Imaging Research; Hewlett-Packard Designjet PS 130 and Photosmart 8750 – Print Permanence Ratings, http://www.wilhelm-research.com/hp/WIR_HP_130_2005_06_30.pdf and http://www.wilhelm-research.com/hp/WIR_HP_8750_2005_02_18.pdf.

[3] A. Kabalnov, L. Rolly, and J. Gondek, Proc. IS&T NIP 21 2005, 364-370.

[4] Hewlett-Packard Company; Light fade testing methods: HP Image Permanence Labs & Wilhelm Imaging Research, http://www.hp.com/products1/printpermanence/pdfs/light_fade_testing_methods_Aug242004_final.pdf.

[5] Wilhelm Imaging Research; Epson Stylus Pro 4800 – Print Permanence Ratings, http://www.wilhelm-research.com/epson/WIR_Ep4800_2005_09_03.pdf.

[6] Wilhelm Imaging Research; Hewlett-Packard Photosmart Pro B9180 – Print Permanence Ratings, http://www.wilhelm-research.com/hp/WIR_HP_B9180_2006_02_23.pdf.

Author Biography

Howard Doumaux received his BS in Chemical Engineering from Lehigh University (1989), and his PhD in Chemical Engineering from the University of Minnesota (1995). Howard has worked at Hewlett-Packard as an ink chemist since 1997. While at Hewlett-Packard Howard has worked with a wide range of ink chemistries utilizing both dye and pigment colorants. Howard has been awarded eight US patents.

Katie Burns received her BS in Imaging and Photographic Technology from RIT (1998). Katie has eight years of development experience with inkjet printers. Her focus has been on image quality, durability, and lightfade performance. Prior to coming to Hewlett-Packard as an engineer in 2003, Katie worked at Phogenix Imaging, and Lexmark International.

David Mahli received his BS in Biology from the University of Minnesota (1997) and his PhD in Polymers and Coatings at North Dakota State University (2003). David has worked at Hewlett-Packard as an ink chemist since 2003