9-ink Printing Using Vivera Inks: Image Quality and Permanence on Photo and Visual Arts Media

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Abstract

The HP Photosmart 8750 printer is a new 9-ink dye-based printer introduced by Hewlett-Packard in 2005. The 9 inks utilized by the 8750 are contained in three tri-chamber print cartridges which include the traditional CMY cartridge, a three-gray ink cartridge, and a new cartridge that contains light cyan, light magenta, and blue ink (cmB). The light- and ozonefastness of the HP Photosmart 8750 output was evaluated on a variety of photo and artistic ink-jet media. High permanence, in parity with pigment based systems, was measured on HP Premium Plus Photo Paper. Un*coated artistic media were also found to provide good light and ozone stability for images with or without protection by glass. However, all tested* coated *artistic media do require glass protection to ensure image stability against ozone and light.*

Introduction

In spring 2005, Hewlett Packard introduced a new printer, the Photosmart 8750. The 8750 is a B+-sized, 9-ink photo printer that utilizes three print cartridges, HP 97 (CMY), HP 101 (cmB) and HP 102 (gGZ). This printer has been primarily designed for use with HP photo media, such as HP Premium Plus Photo Paper (high gloss or soft gloss), on which it produces high-quality photographic images in both color and black-and-white.

One of the special features of the printer is the usage of the HP 102 three ink gray photo print cartridge which enables high quality black-and-white output. The cartridge contains light gray (g), dark gray (G), and photo black (Z) inks. These inks were carefully formulated to yield hues on specific photo media that are truly neutral because human visual perception is very sensitive to small variations in shade along the neutral axis. The gray photo ink cartridge has no global hue shift due to drop volume variation or differential dot spreading across media types. The two gray ink intensities are evenly placed on the perceptual scale with intermediate gray levels achieved by dot on dot techniques and digital halftoning algorithms. The darkest OD points are reached through blending of the dark gray and the special photo black ink, resulting in a very smooth spectral reflectance curve for the black (Figure 1a). Through the design of the gray inks and the printing system, the metamerism (color constancy) of the neutral scale is one of the lowest in digital image printing (Figure 1b).

In addition to neutrality and low metamerism, the three levels of gray allow seamless transitions in the levels of lightness (L*) while conserving the broad dynamic range. Having three inks with evenly spaced levels of darkness produce high quality, grain-free images. Specifically, the black ink (Z) can be used to make very dark (very low in L*) without the trade-off in grain, Figure 1c.

Although the benefits of the gray photo print cartridge are mostly attributed to black-and-white prints, significant benefits are also seen on color images where the light and medium gray inks are used extensively in pastel and light colors (e.g. sky, skin tones). For example, using light and medium gray in clouds and sky reduces hue shift that can be present when magenta, cyan and yellow are combined to make composite gray. In dark and shadowed areas of an image, utilization of the inks in the gray photo cartridge results in dark, more saturated colors, and greater detail through reduction of the total ink flux when compared to composite black.

Several high-end HP photo printers support CMYgGZcm 8-ink printing. The 8-ink configuration adds two gray inks to the typical 6-ink CMYK set, plus light cyan, and light magenta inks. This configuration presented the opportunity to add a 9th ink to the printing system for the HP 8750. A highly chromatic blue ink was selected to give targeted gamut expansion in an important region of the color space. HP released the new HP 101 blue photo print cartridge containing the light cyan, light magenta, and chromatic blue inks together in a tri-chamber inkjet cartridge.

Blue was selected as the most important region for color gamut expansion after a review of the gamut size and shape of silver halide prints, along with analysis of the gamut differences between digital photographs and the 8-ink printer gamut. Figure 2 compares the spectral reflectance curve of the printed blue ink with the process blue from the prior 8-ink printing configuration.

This additional blue reflectance results in up to 20% more chroma for vivid blue colors in inkjet prints. Unlike the gray inks, not all photo prints will benefit from the blue ink. This is a targeted solution, and the subset of photos that contain rich blue, azure, and violet colors will more correctly reproduce the vividness of the original image.

As a dye-based printer, the Photosmart 8750 provides an excellent gamut and dynamic range and does not suffer from the bronzing and gloss uniformity issues often seen with pigmented inks. Historically, pigmented inks have had some advantage over dyes in the area of image permanence. The Vivera inks were formulated to not only give the desirable photo attributes of dye based inks, but also to address image permanence by providing good light and ozone stability common to pigmented inks. For example, the light stability of the Photosmart 8750 color output on HP Premium Plus Photo Paper is rated at 108 years when the image is displayed under glass.[1]

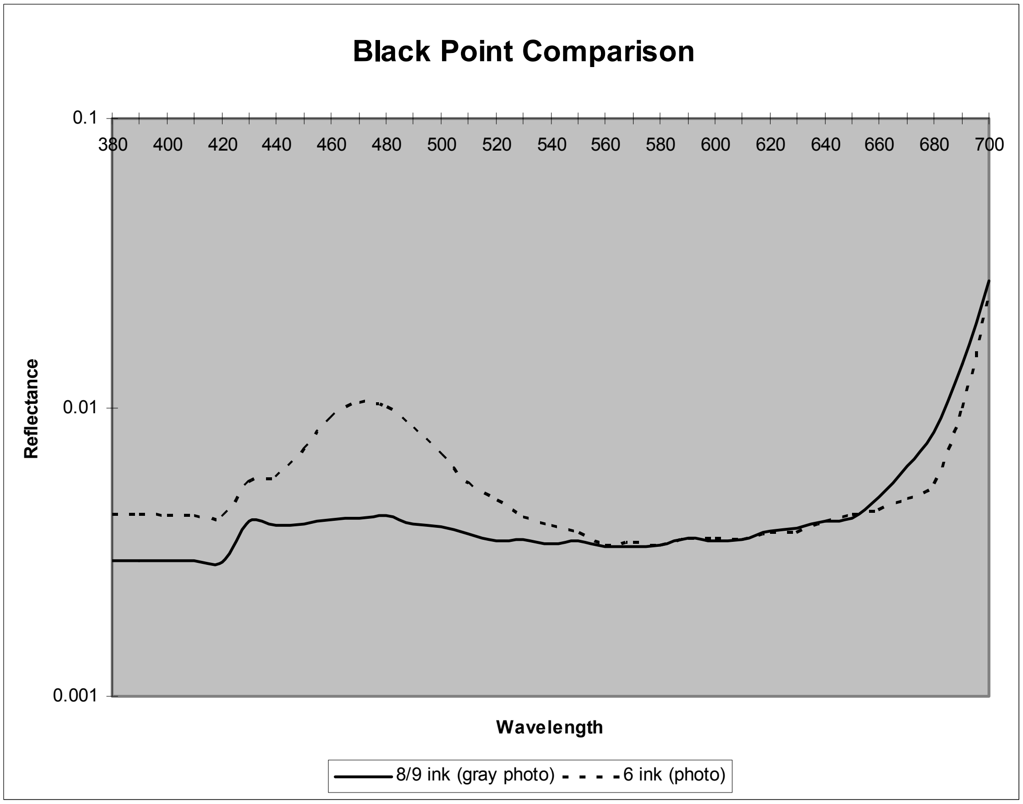

Figure 1a. Spectral reflectance curves for the 9-ink black output of Photosmart 8750 with HP 102 print cartridge (solid line) versus 6-ink output of HP 99 cartridge (dashed line)

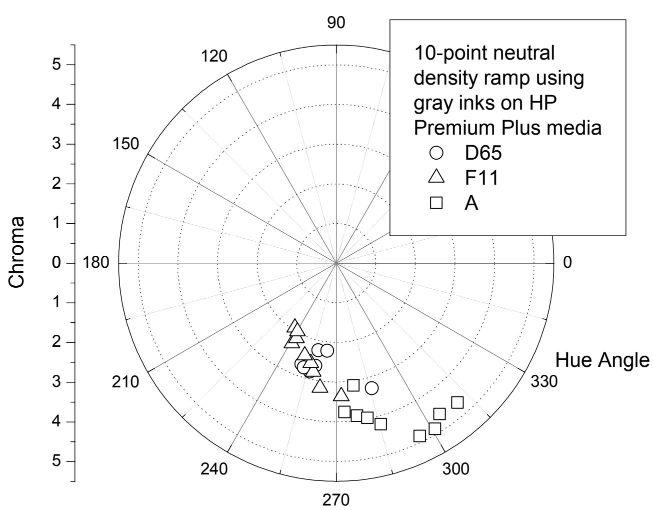

Figure 1b. Chroma (left axis) and hue angle of the gray ramp of Photosmart 8750 under different illuminants.

Figure 1c. Schematic of ink use for light gray, medium gray and photo black as a function of L for HP 102 print cartridge*

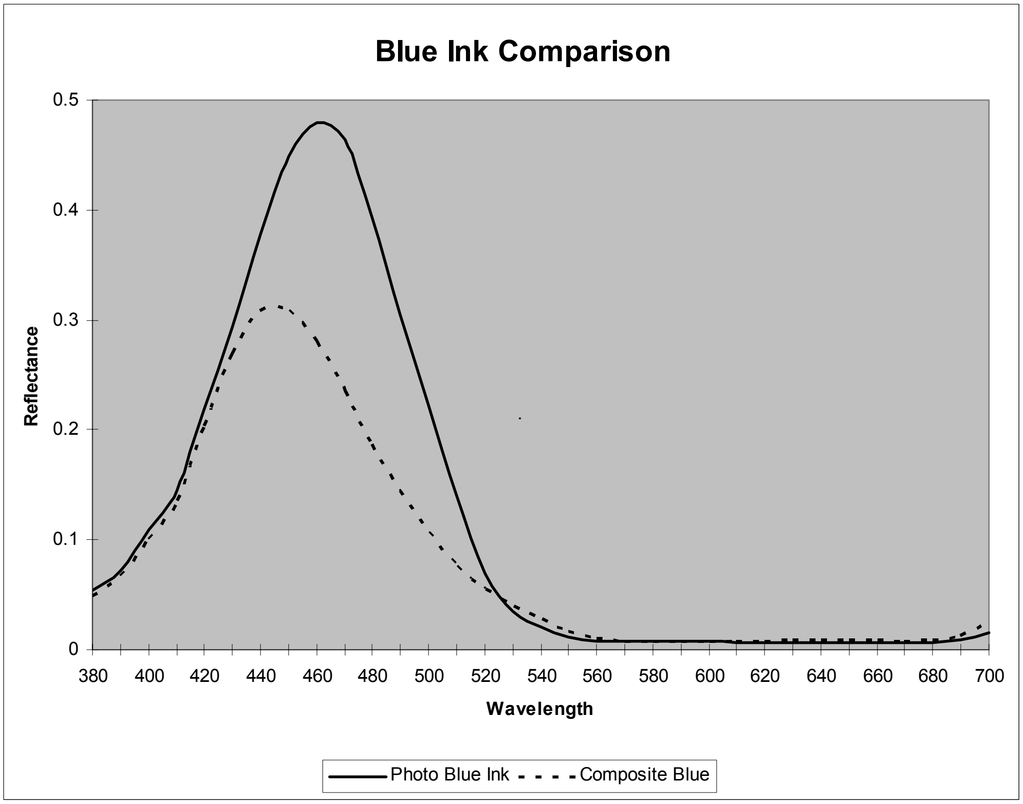

Figure 2. Spectral reflectance curves for photo blue ink (solid line) versus composite blue (dashed line) for PhotoSmart 8750

Inkjet photo media are not the only media type used by photographers and artists. There is substantial interest in printing on canvas, photo rag, and watercolor media. These clay-coated or uncoated media are offered by many vendors such as Arches, Somerset, and Hahnemuhle. The media coating immobilizes colorants closer to the surface of the print, thereby producing more vivid colors and darker blacks. Unfortunately, this gamut expansion is often accompanied by poorer image permanence because the colorants are more exposed to light and atmospheric gases. In particular, the exposure to traces of atmospheric ozone has been known to cause the degradation of colorants on ink-jet photo porous media.[2] Therefore, the performance of the Photosmart 8750 on artistic media was evaluated to compare the image quality and permanence tradeoffs with traditional inkjet photo media.

Experimental

Media

There is a substantial number of different visual arts media available. In this study, the media sampler pack suggested by Inkjet Art Solutions, Utah (www.inkjetart.com) was used. Out of the fifteen media in the sampler pack, eleven media were tested, five of them non-coated and six coated (Table 1). Some of the non-coated media were of heavier stock and required using the rear feed mechanism of the printer.

Print Sample Generation and Color Measurement

The prints were generated using the Photosmart 8750 inkjet printer configured with the HP 97, HP100, and HP101 print cartridges. Note that inks in the HP95 and HP97 cartridges are identical, as well as the inks in the HP100 and HP102. Therefore, the permanence ratings are not expected to change if these print cartridges are interchanged. Printing was done through the HP-provided Windows XP printer driver using the “HP Premium Plus Photo Paper” media setting and the “best” quality setting. Fade targets containing cyan, magenta, yellow, red, blue, and black ramps were printed, dried over 2 weeks, and subjected to light fade and ozone fade tests. Unless otherwise indicated, color (D65, 2°) and ANSI Status A optical densities were measured using Gretag-MacBeth Spectrolinos. Additional color measurements were also determined using the D50, 2° setting.

Table 1: Visual Arts Media Tested

Brand	Name	Type	Weight (gsm)	Weight (lbs)
Arches	Cold Press	Non-coated		140
Arches	Hot Press	Non-coated		90
Arches	Infinity Smooth	Coated	230	
Arches	Infinity Textured	Coated	230	
Hahnemuhle	Photo Rag	Coated	308	
Lanaquarelle	Cold Press	Non-coated	300	
Lanaquarelle	Hot Press	Non-coated	185	
Osprey	Giclee	Coated	250	
Somerset	Textured P.E.	Coated	225	
Somerset	Velvet P.E.	Coated	225	
Somerset	Velvet	Non-coated	250	

Light Fade Experiment

Light fade experiments were conducted internally at Hewlett Packard. The conditions were similar, although not identical, to the ones used by Wilhelm Imaging Research, Iowa, USA (Table 2). HPUV Indoor Actinic Exposure Systems (Atlas Material Testing Technology LLC) were used, which utilize cool white light at an intensity of 60 – 70 kLux. Wilhelm's WIR v3.0 Endpoint Criteria set and assumptions for the daily light exposure were used in the analysis.[3] The system lifetime is defined as the time to reach the first endpoint criteria. The optical densities of the C, M, Y, K, red, green, blue, and neutral color patches with an initial 0.6 and 1.0 OD's were monitored during the tests. One year of light exposure was taken as 1971 klux-hr, based on a daily illumination of 450 lux per 12 day.

Table 2: Conditions of Lightfade Experiment

Conditions	HP internal	Wilhelm Imaging Research
Temperature	28 ± 1° C	24° C
Relative Humidity	30 ± 2 %	60%
Light intensity/source	60 – 90 kLux, cool white light	35 kLux, cool white light
Air gap between the sample and the glass	No air gap; glass on top of the sample	5 mm
Sample dry-down before the test	2 weeks	2 weeks
Failure criteria	WIR v3.0 Endpoint Criteria set [3]	*Same*

Comparison with historical data on photo media has indicated that internal Hewlett Packard data are similar to those of Wilhelm Imaging Research, with the deviations not exceeding 30%.

Ozone Fade

The fade setup was similar to the one described previously.[4] Testing was done in a Hampden 903 ozone test chamber (Hampden Test Equipment Ltd) at 50% relative humidity, 30°C, and 1.0 ppm of ozone. The yearly exposure to ozone was taken as 40 ppm-hr.[5] Wilhelm's WIR v3.0 Endpoint Criteria set was used to approximate sample lifetimes.[3]

Results and Discussion

Gamut Volume and Dynamic Range on Visual Arts Media

Table 3 lists the gamut volumes and the lightness of the darkest black for a variety of media, including HP Premium Plus Photo Paper as a reference. The gamut volume in this Table represents a simple 8-point gamut estimate as based on D65 L*a*b* volume of RGBCMY-White-Black octahedron. Note that L*min covers the range from 11 to 22.3 L* units. The gamut volume varies between 220,000 and 440,000 L*a*b* volume units. As expected, the gamut on the coated media is substantially expanded and reaches or exceeds the gamut seen on photo media.

Note that despite the fact that the gamut on non-coated media is substantially decreased compared to photo media, it is still large compared to US Web Uncoated gamut. Figure 3 shows the overlap of PhotoSmart 8750 output on Arches Cold Press Watercolor media as the wireframe and US Web Uncoated gamut (D50 2 degree data) as the solid color. One can see a substantial expansion in the gamut over blue, red, and yellow areas. This means that the user can generate visual arts prints that surpass the gamut of traditional offset prints.

Table 3: Gamut Volume and L*min of PhotoSmart 8750 on Visual Arts Media

Media	media type	L*min	V
Lanaquarelle Hot Press	non-coated	22.3	220,159
Arches Cold Press	non-coated	22	221,522
Arches Hot Press	non-coated	21.6	224,139
Somerset Velvet 250 gsm	non-coated	26.1	224,818
Lanaquarelle Cold Press	non-coated	23.9	228,326
Osprey Giclee	coated	24.3	245,544
Arches Infinity Textured	coated	19.8	333,849
Arches Infinity Smooth	coated	17.7	348,943
Somerset Textured P.E.	coated	16.8	357,767
Somerset Velvet P.E.	coated	15.0	383,959
Hahnemuhle Photo Rag 308 gsm	coated	11	440,258
HP Premium Plus Photo Paper Glossy	swellable	9.3	424,114

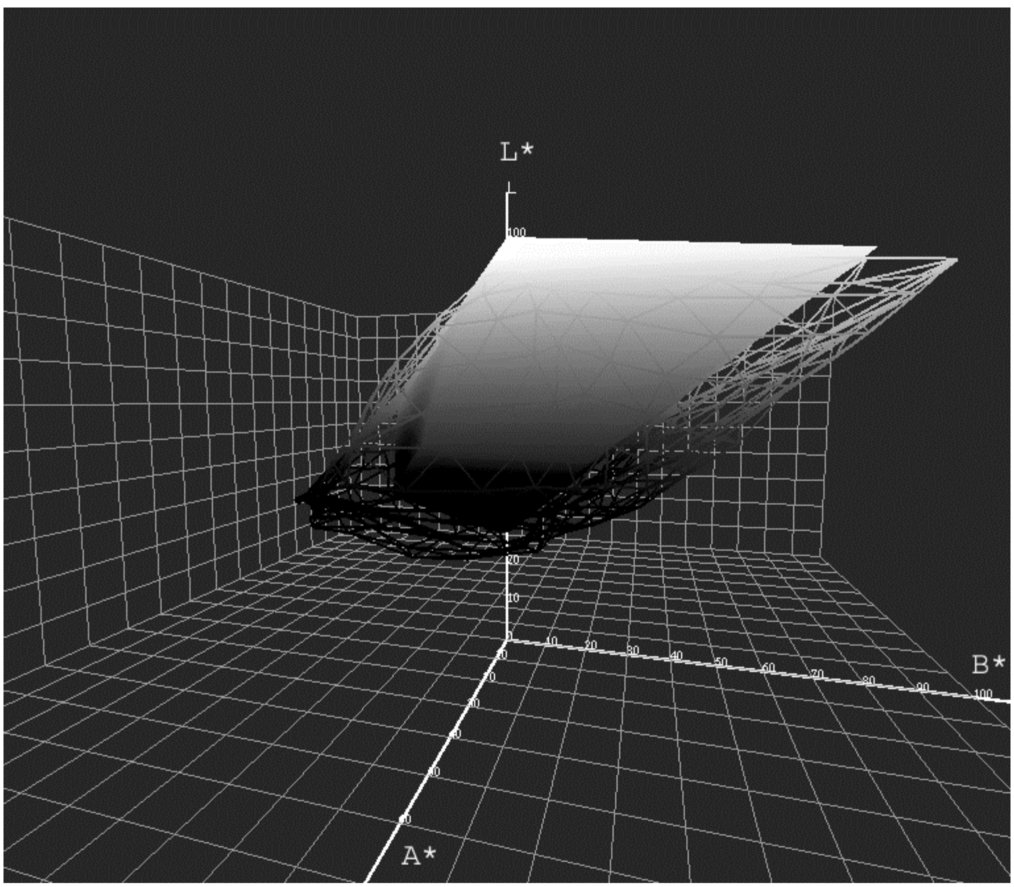

Figure 3. Overlap of the US Web Uncoated gamut space (solid color, full volume V = 188,182) with the PhotoSmart 8750 output on Arches Cold Press media (wireframe, full volume V = 288,566). D50 illuminant, 2 degrees.

Image Permanence

As expected for Vivera inks, the HP Photosmart 8750 provides excellent permanence on HP photo media. As shown in Table 4, good image permanence is also obtainable on visual arts media. It is readily apparent that most non-coated media have better permanence than coated media. However, some coated media and photo-enhanced (P.E.) media do provide permanence that is comparable to Kodak Edge silver halide.

Another mode of use for prints on visual arts media is the non-protected display. Indeed, it is when this media is unprotected that the texture becomes truly visible. Table 5 lists the permanence data with respect to ozone fade and light fade for unprotected display. Note that if the images are exposed to light and ozone at the same time, an interaction between the failure mechanisms may occur. No effort was made to account for this possible effect. One can clearly see that for non-protected display, none of coated media provide acceptable permanence. However, for uncoated media, much better permanence is observed.

Table 4: Predicted Time-to-Reach-Endpoint for Photosmart 8750 Outputs on Artistic Media versus Ink-Jet Photo Media and AgX for Exposure Under Glass*

Media	media type	LF under glass, years
Silver halide photography		
Kodak Edge Generations	AgX	19**
Fuji Crystal Archive	AgX	40**
Photosmart 8750		
HP Premium Plus Photo Paper Glossy	photo swellable	108**
Arches Cold Press	non-coated	37
Arches Hot Press	non-coated	35
Lanaquarelle Hot Press	non-coated	27.9
Lanaquarelle Cold Press	non-coated	23.8
Hahnemuhle Photo Rag 308 gsm	coated	21.6
Somerset Textured P.E.	coated	16.4
Somerset Velvet 250 gsm	non-coated	15.9
Somerset Velvet P.E.	coated	13.2
Osprey Giclee	coated	8
Arches Infinity Textured	coated	7.8
Arches Infinity Smooth	coated	3.9

*Internal Hewlett Packard data unless marked otherwise ** WIR data, Refs.1 and 6

Table 5: Predicted Time-to-Reach-Endpoint for Photosmart 8750 Outputs on Artistic Media for Unprotected Exposure to Light and Ozone*

Media	media type	ozonefade, years	LF bare, years
Somerset Velvet P.E.	coated	0.1	0.8
Arches Infinity Smooth	coated	0.12	1.1
Hahnemuhle Photo Rag 308 gsm	coated	0.15	1.4
Arches Infinity Textured	coated	0.135	1.5
Somerset Textured P.E.	coated	0.1	2
Osprey Giclee	coated	1.3	2.5
Concorde Rag	coated	0.13	5.2
Somerset Velvet 250 gsm	non-coated	7.7	9.4
Lanaquarelle Cold Press	non-coated	>17.7	14
Lanaquarelle Hot Press	non-coated	>17.7	14
Arches Hot Press	non-coated	>17.7	15.7
Arches Cold Press	non-coated	>17.7	16

*No interaction between the lightfade and ozonefade assumed

Conclusions

The Photosmart 8750 inkjet photo printer provides excellent gamut and dynamic range on photo and visual arts media. A very large gamut and good neutrality of gray is produced on HP Premium Plus Photo Paper. For coated visual arts media, the gamut is large and approaches that of HP Premium Plus Photo Paper. For non-coated media, the gamut and dynamic range are reduced.

A very high level of lightfastness is achieved on HP Premium Plus Photo Paper, with the Wilhelm Imaging Research data predicting a display life of 108 years. For visual arts media, out of 11 media tested, 4 non-coated media show superior lightfastness and ozonefastness relative to traditional AgX prints. These media are robust for prolonged image display, protected or unprotected. The 6 coated media exhibit relatively poor ozone stability, although good permanence can be achieved in some cases when prints are stored under glass.

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Author Biography

Alexey Kabalnov holds a PhD degree in chemistry from Moscow State University, Russia with the specialization in colloids and surface chemistry. Since 1998, he has been working for Hewlett Packard Company in Corvallis, Oregon and San Diego, California, primarily on the formulation of color inks. He authors about 50 scientific publications and patents. He is a member of the American Chemical Society and is a member of NIP Image Permanence Committee.