SPENCERLAB DIGITAL COLOR LABORATORY

Final Report

Comparative Study: Kodak Professional 8500 Digital Photo Printer *vs.* **Olympus P-400** and **Epson Stylus Photo 2000P** Printers

The *SpencerLab* Digital Color Laboratory, a division of Spencer & Associates Publishing, Ltd, has conducted independent comparative testing and evaluation of the new Kodak dye-sublimation printer.[1] The comparison evaluated ***Cost-per-Print*** and ***Print Quality*** of the **Kodak Professional 8500 Digital Photo Printer** and the **Olympus P-400** dye-sublimation printers, and the **Epson Stylus Photo 2000P** color inkjet printer,[2] utilizing representative real-world images.

Overview

The Kodak 8500DP provides a significant Cost-per-Print benefit over both the Olympus P-400 and the Epson Stylus Photo (SP) 2000P, providing lowest Cost-per-Print on both images – up to 34% lower per page. In the area of Print Quality, the Kodak 8500DP excels in blends and images, offering well-rendered, linear blends and sharp, generally smooth images.

Lowest Cost-per-Print combined with competitive Print Quality positions the Kodak 8500DP to provide users with exceptional cost-effective photographic output.

Both Cost-per-Print and Print Quality are discussed in detail in the following sections.

Cost-per-Print Analysis

Summary

The Kodak 8500DP has the lowest Cost-per-Print for both of the representative photographic prints: *Castle,* an outdoor scenery image selected from the *SpencerLab* Printer Test Suite, and *Bride,* an indoor portrait image as might be taken by a wedding photographer.

SpencerLab's test and analysis showed that both the Olympus P-400 and the Epson Stylus Photo 2000P are more expensive to use than the Kodak 8500DP; the Epson SP 2000P tested as the most expensive on both files.

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[1] The *SpencerLab* Digital Color Laboratory is an independent test laboratory with a broad base of industry clients. Although this project was conducted under Kodak sponsorship, *SpencerLab* believes these test results maintain its reputation for the integrity of its procedures and analyses. Results stated herein are based upon testing of actual products believed to be representative.

[2] A single printer of each manufacturer model was used in analysis, and the printers are assumed to be representative of production units. The Kodak 8500DP was acquired from Eastman Kodak Company prior to commercial release.

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The overall results of the *SpencerLab* Cost-per-Print analysis are summarized in the following table. Results were compiled by adding the costs of inks or ribbon (dependent on the technology) and media for each print.

COST-PER-PRINT	Kodak 8500DP	Olympus P-400	Epson Stylus Photo 2000P
Castle	**$1.800**	**$2.459**	**$2.723**
Bride	**$1.800**	**$2.459**	**$2.697**

Methodology

Although Cost-per-Print combines the costs of inks or ribbon and media for each print, the precise method is technology dependent, differing for dye-sublimation and inkjet printers.

The process for determining the Cost-per-Print for the dye sublimation printers is straightforward. Since the ribbon roll provides a set number of prints regardless of coverage, the cost of the ribbon for one print is simply the total cost of the ribbon divided by the number of color sheet sets per roll. Similarly, the cost of the media is the total cost of the media as sold divided by the number of sheets of media in the package. The sum of these ribbon and media costs is the Cost-per-Print.

The method of determining Cost-per-Print for color inkjet printers is more complex and time consuming. The task is to first determine ink yield in Pages-per-Cartridge, the number of pages between individual ink cartridge replacements – averaged over a span of multiple cartridges. Once an average number of Pages-per-Cartridge is established for both black and color, this is divided into the cost of each cartridge to compute the Cost-per-Print; the sum of the black and color ink costs plus the media costs is the Cost-per-Print. However, there is a further complexity in that the amount of ink varies with print content. It is therefore appropriate to select multiple print samples representative of the intended use, and to measure the multiple samples. In this study, determination of Pages-per-Cartridge and Cost-per-Print is performed for each of two test images.

In the *SpencerLab* methodology, precise measurements of the weight of the ink cartridge (including its remaining ink) are made periodically while printing is paused. From these measurements the rate of ink consumption is monitored to assure the reliability of the test results. The measurement of cartridge yield requires a method of determining when cartridges are empty. In this testing, the Epson SP 2000P printer employs mechanisms that alert the operator to an ink-out situation, a reliable and generally acceptable indicator.

In a printer such as the Epson SP 2000P there are multiple ink cartridges. The printer design does not allow printing when any one of the ink cartridges is empty. As is often the case, different ink cartridges have different page-per-cartridge yields. Therefore, testing must proceed on all inks until reliable, multi-cartridge yield data has been obtained on the highest-yield cartridge – the cartridge that prints the largest number of pages in the test.

As noted, the computation of Cost-per-Print on all printers in the test includes ink/ribbon and media costs. The Kodak 8500DP has two ribbon types available, Glossy and Satin; pricing is equal for both ribbon types. Both the Kodak 8500DP and the Olympus P-400 offer only one type of media; however, the Epson offers four types. For this test, the two types listed in the chart below were deemed comparable to those of the Kodak 8500DP and the Olympus P-400.

Cost-per-Print calculations are based upon manufacturer suggested retail prices (MSRPs) below.[3]

INK / RIBBON MSRP	Kodak 8500DP	Olympus P-400	Epson Stylus Photo 2000P
Ink Cartridge			**$34.20/Color $29.70/Black**
Ribbon Sheets	**$112/100 sheets**	**$60/50 sheets**	
Media Sheets	**$68/100 sheets**	**$125.95/100 sheets**	**Premium Luster Photo Paper $35/50 sheets Premium Semi-Gloss Photo Paper $15/20 sheets**

Workstation Configuration

All testing was performed in a Windows 2000 Professional operating system environment, with printers directly connected to the workstation. Print files were created from Adobe Photoshop 6.0 using vendor-supplied Windows 2000 Professional drivers. These print files were downloaded to each printer repeatedly to initiate each print run.

Cost-per-Print testing was conducted with each of the printers in modes according to the following table.

[3] Epson and Olympus manufacturer suggested retail prices were reported by their respective websites as of July 2, 2002. Kodak manufacturer list prices were received directly from Kodak, as the products are not yet released.

SETTINGS	Kodak 8500DP	Olympus P-400	Epson Stylus Photo 2000P
Castle	Ribbon type: Glossy, Extra Life: On	Default	PQ: Photo, Super X: On, Color Controls (Gamma:1.8), Mode: Photorealistic, Premium Luster Photo Paper
Bride	Ribbon type: Matte, Extra Life: On	Default	PQ: Photo, Super X: On, Color Controls (Gamma:1.8), Mode: Photorealistic, Premium SemiGloss Photo Paper

Test Documents

Cost-per-Print was evaluated across two application-based test images deemed to be representative of this printer market. File size was customized to allow “apples-to-apples” comparison among the three printers. Kodak’s 8.5" x 12" and Epson’s 8.5" x 11" media can print images up to 8" x 10"; however, the Olympus’ A4-size media only allows printing up to 7.64" x 10". Therefore, this size was chosen as the maximum dimensions for the printed images. The *Castle* and *Bride* were printed in sizes of 7.6" x 10" and 7" x 10", respectively.

Cost-per-Print Results

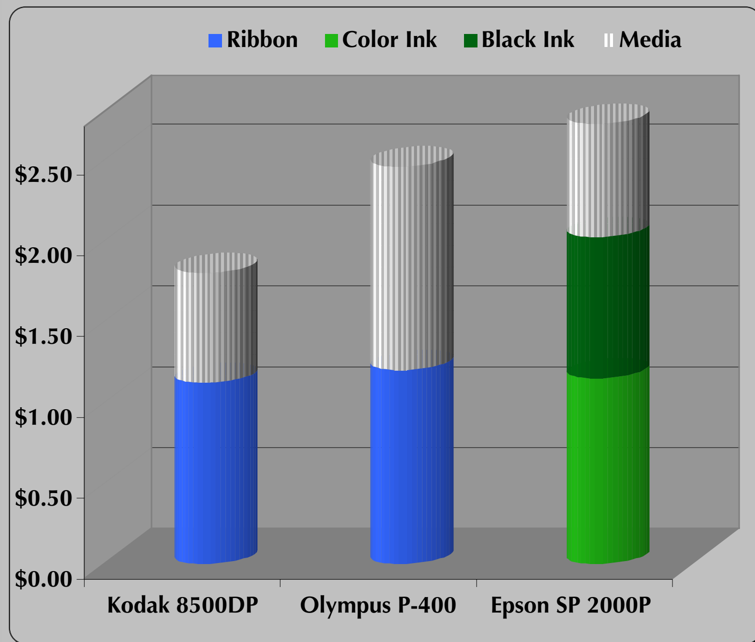
As noted above, the Kodak 8500DP has the lowest Cost-per-Print for both images, the *Castle* and the *Bride*. The Olympus P-400 and Epson SP 2000P were up to 37% and 51% more expensive, respectively, than the Kodak 8500DP.

In testing with the *Castle* image, the Kodak 8500DP showed the lowest Cost-per-Print at $1.80 per print, with the other two printers notably more expensive. The Olympus P-400 at $2.46 per print was 37% more expensive than the Kodak 8500DP. The Epson SP 2000P at $2.72 per print was 51% more expensive than the more economical Kodak 8500DP.

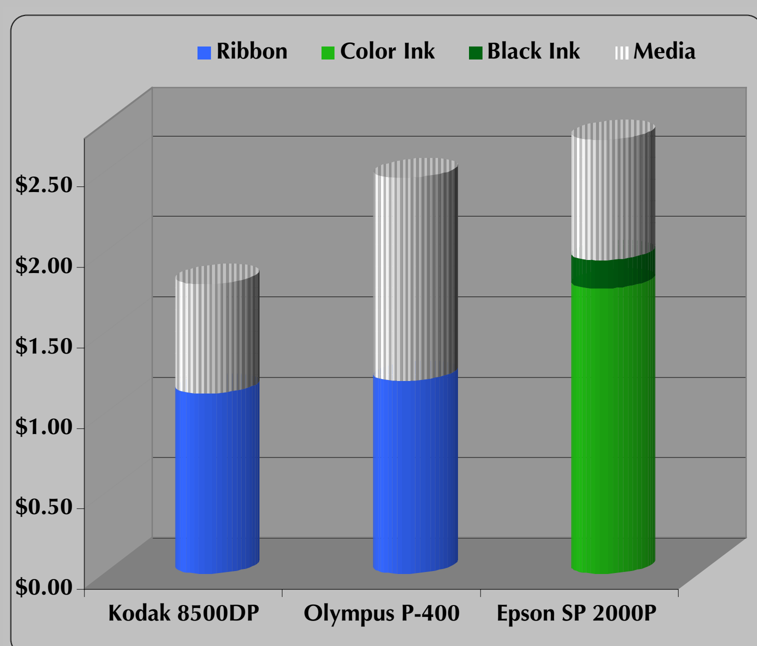
In testing with the *Bride* image, the Kodak 8500DP again showed the lowest Cost-per-Print at $1.80 per print, with the other two printers notably more expensive. The Olympus P-400 at $2.46 per print was again 37% more expensive than the economical Kodak 8500DP, while the Epson SP 2000P at $2.70 per print was 50% more expensive.

These results are shown graphically on the following page:

CASTLE



BRIDE



Print Quality Analysis

Summary

The Kodak 8500DP offers very good image quality, with outstanding sharpness. Blends are smooth and well rendered. Although tints, blends, and images are well saturated and generally smooth, overall print quality is limited by banding, evident in areas of water and sky on the images. Color fidelity is superior to the Olympus P-400. Image quality of the Epson SC 2000P is slightly inferior to both. Although unimportant for this market, text lacks some sharpness and exhibits dropouts at lower point sizes.

Methodology

A range of test documents from the *SpencerLab* Printer Test Suite[4] was printed on each of the printers in a range of print modes, after printer setup and alignment. These test documents included current versions of the *Color Spectrum, Graphic,* and *Graphic RGB* PostScript programs (originally developed as part of the *Color Hardcopy Quality Factors* study series). Also included was the *Enhanced Graphic* PostScript program (originally developed as part of the *Hardcopy Quality Enhancement* study) and a range of images and application test documents from the suite, covering a variety of printing requirements. Print Quality was analyzed by element type (*e.g.*, black, color, and reverse text, tints, blends, and images) across these test documents. As these printers are targeted towards the photo market segment, elements effecting image quality hold greater importance in overall print quality.

Print Quality Results

Text

While text, both black and color, represents the most common use of an office printer, this is not the scenario with photo printers. Therefore, while this attribute was evaluated, it carries minimal weight in this market segment of photo printers. Neither of the tested dye-sublimation printers produced very high quality text.

Black and Color Text

Text is comprised primarily of thin, filled solid regions. As the principal vehicle for communicating ideas, text is designed to be very legible while being unobtrusive to the reader. Color can be used to highlight or emphasize particular words or phrases – improper rendering of such color can shift the emphasis from the purpose of the document to the lack of adequate print quality

[4] The *SpencerLab* Printer Test Suite, now in ßeta3, is an extension of Spencer & Associates' Color Hardcopy Quality Factors test suite, a de facto industry standard since 1990.

itself. Because most colors require some halftoning, even at full saturation, text quality is strained by the limited halftone cell availability for all but pure primaries and secondaries. Print quality limitations can cause distractions that subtract from the effectiveness of the communication; in the worst case, they can render text illegible.

Because of the limited number of addressable dots with which to render a font character, small text poses the greatest challenge to legibility. Two- and 4-point text is often used in situations where legibility is crucial but precise artistic accuracy is not necessary; the sophistication of font design increases at 6 points and larger as the visibility of fine details improves to even the most casual reader.

Uniform character stroke weights and spacing provide uniform “typographic color”, the perceived overall darkness of the text. This enhances effective communication when successful, but detracts significantly when distorted and uneven. Fine serifs, thin strokes, and narrow kerning represent font details that can easily be lost due to poor reproduction.

The Kodak 8500DP produces Black and Color Text, in both RGB and CMY that appears “fuzzy”, especially in the Black text. Curved segments in characters also appear faceted and characters lack uniformity in thickness. Text also exhibits drop-outs at the smaller sizes of 10-points and below, and 4-point is marginally useable. Black text lacks apparent density, and all colors are very desaturated.

On the Olympus P-400, the Black Text has a green cast, and all curved character segments are faceted – more so than that of the Kodak 8500DP. Drop-outs are present at 10-point and below, rendering the text mostly useless at 4-point. Intra-character thickness is not uniform, character edges are jagged and serifs are dropping-out.

On the Epson SC 2000P, Black Text in CMY color space is rendered in four-color which causes color halos to appear at 4-point and below; 2-point is severely affected. However, in RGB color space, Black text is rendered pure and thus does not suffer from the halos. All text in RGB color space is excellent; sharp, well formed at all point sizes, and splatter-free. Minimal drop-out and jaggedness begin to appear at 2-points. In general, Matte paper appears slightly rougher at larger point sizes, but at 2-point Matte is noticeably better. Overall, the texture and gloss of the Epson Premium Luster Photo Paper and Premium Semi-Gloss Gloss Photo Paper are very distracting and at many angles, reduce legibility.

Reverse Text

Although less significant than other print attributes for many applications, and photo printers in particular, reverse text represent a specific use that inkjet and thermal printers tend to reproduce poorly due to enlarged spot size, satellite ink drops, and other causes of poor modulation transfer function. Typically, thin lines and fine font fills are dimmed or dropped out completely.

On the Kodak 8500DP, Reverse Text appears “fuzzy”, an apparent result of thermal bleed. Reverse white text is affected at all sizes. All Reverse Text exhibits fill-ins at the smaller sizes of 10-points and below, where 4-point is marginally useable. Characters also lack uniformity in thickness.

The Olympus P-400 produces Reverse text that is jagged. Fill-ins begin at 14-point and are evident in the smaller point sizes. However, reverse white text is clear of thermal bleed seen on the Kodak 8500DP, thereby rendering whiter looking characters on the Olympus.

On the Epson 2000P, the Reverse Text appears generally well rendered at most sizes, but fill-in is apparent at 8-point and below, and 2-point text is difficult to discern from the background. Reverse color text is slightly worse than reverse white text.

Tints

Unlike solid printing, tints introduce an increased sensitivity to resolution and mechanical issues. A tint is a large area of a single unsaturated color, such as pink, sky-blue, or brown. Therefore, it is also sensitive to hue color errors.

Continuous-tone technologies such as dye sublimation are able to print up to 256 levels of each primary at rated resolution. However, many technologies are limited to very few levels, and must average colors printed at high resolution to achieve the desired color tone. Ink jet is such a technology. The technique of averaging limited high-resolution colors to achieve the desired tone at lower resolution is called dithering or screening.

Traditional screening creates a tradeoff between resolution and the number of available intermediate colors that may be unfavorable. To enhance the number of colors a printer can produce, vendors have often introduced superpixel dithering over traditional screening – even though this runs some risk of introducing pattern artifacts and moiré effects that can be annoyingly visible. Stochastic screening modulates the placement between high-resolution dots (spatial frequency modulation), minimizing most artifacts; however, this technique requires good color registration and may yield grainy highlights.

The Kodak 8500DP produces well-saturated tints that are generally smooth. However, horizontal banding is visible throughout most shades, appearing to be caused by feed limitations. Some thermal bleed is seen on Blues, Greens, Reds and Black in both monochrome and process tints. The process Black appears to have a reddish-gray cast, instead of a being rendered as a pure Black.

The Olympus P-400 produces vibrant RGB tints, but its CMY tints are less vibrant in Cyan shades, as in the Blues, Greens, and Purples. Like the Kodak and Epson, Olympus does not produce a dark process Black. There is some minor horizontal banding and thermal bleed, most notably in saturated Blues and Reds. While there is banding and bleed, it is less noticeable on the Olympus than on the Kodak 8500DP. Overall, smooth tints are produced.

On the Epson SP2000, the RGB tints are rendered accurately and are well saturated. The CMY tints, however produce a 100% Green that is too Blue; while the 100% Blue is produced overly dark. Having to rely on screening techniques, patterning is also apparent in the darker shades. Process Black does not appear as Black, but instead is rendered as a reddish-gray. The NO COLOR ADJUSTMENT driver setting produces CMY tints that are very dark.

Blends

Blends are smooth transitions between two or more colors. While incorporating all the issues of tint generation, Blends additionally require an abundance of color levels, smooth transitions between these colors, and perceptual linearity of hue, saturation, and lightness ramps.

Highlights and shadows often deteriorate blend quality. This is due to the difficulties involved in providing accurate differentiation of shades in heavily toned regions, and in providing a sufficient number of light pastel shades to smooth the transition to paper white.

The Kodak 8500DP produces well-rendered Blends that are smooth and linear. However, blend ramps possess a muddy, desaturated appearance. As with tints, banding is noticeable and distracting throughout the blends.

On the Olympus P-400, the RGB Ramps are smooth, linear, and well rendered. The CMY Ramps, however, show some non-linearities in Cyan and Green. Both the CMY and RGB Rainbow Blends have harsh transitions in Green and demonstrate non-linearities in Blue. The Red region also shows a sudden jump in saturation on the CMY rainbow.

On the Epson SP 2000, the CMY blends are inferior, exhibiting abrupt jumps in saturation in the Cyan, Magenta and Green ramps. The rainbow blend appears generally smooth, except for a very narrow Blue to Magenta transition, and a Yellow to Red transition that exhibits some non-linearities. The Highlight-Shadow Blends are also generally good, but have minor non-linearities throughout. The RGB Rainbow Blend lacks saturation in the Red region and has a harsh transition in the Green region. The Cyan and Green Highlight-Shadow blends also exhibit similar harsh transitions.

Images

Unlike computer-generated graphics, images are the result of sampled raster data and seamlessly combine the quality elements of graphics, tints, and blends. Because of the wide range of potential subject matter in an image, a printer's ability to produce realistic, high-quality images is extremely difficult, but critical to the user's quality perception; therefore, all printers should produce high quality images, and this is particularly true in this photographic market segment.

The use of photographic data sources for images leads to a high demand for color fidelity. This includes accurate reproduction of memory colors – those with which users are heuristically familiar, without requiring an original for comparison. Natural greens, sky blues, wood browns, and flesh tones represent common memory colors that can tax a printer's color rendering ability due to color gamut restrictions, imprecise color balance, or sub-optimal colorants.

High-frequency, high-contrast detail within an image reflects a printer's ability to provide high quality text and graphics. The device resolution is used to carry the high level of fine detail. In areas of little variation (low spatial frequency), process noise and screen artifacts (in the case of non-continuous-tone printers) can be readily apparent. Finally, smoothly varying regions require blend linearity in order to accurately capture the realistic appearance and visual depth of the original.

On the Kodak 8500DP, flesh tones are rendered generally smooth but appear to have an orange cast. The *Covered Bridge* image is rendered too yellow and appears overly "hot". Details, however, are rendered sharp – as seen on the quite legible bridge sign. Horizontal banding can be observed in the sky and water areas of the *Castle, Covered Bridge* and *Isle* images. The sky color in the *Castle* image lacks realism, as it appears slightly gray.

On the Olympus P-400, flesh tones are rendered too yellow, and some contouring is evident in the shadows. The *Covered Bridge* image is sharp with good color rendition. The *Castle* image however, has an overall Yellow cast and the sky appears dull. Slight banding is also evident in the sky area.

On the Epson SP 2000P, images are rendered somewhat muted in the default COLOR CONTROL setting, but are adequately corrected with the sRGB setting. Flesh tones are good and mostly smooth, but some graininess appears in shadows. The sky color is pleasing, however the covered bridge is too bright and overly orange. Objects appear out-of-focus, as can be seen in the grass areas. There is no noticeable grain or mottling in the skies; overall, images are generally pleasing. Epson media lacks the smooth, glossy finish consumers can receive through traditional silver halide photo processing.

About *spencer*LAB

The *SpencerLab* Digital Color Laboratory is an independent printer evaluation laboratory that provides services to vendors and corporations for whom color printing is mission-critical. The Laboratory follows strict guidelines in the integrity of both methodology and reporting; vendor-sponsored studies do not guarantee favorable results. *SpencerLab* has developed industry-standard test software, and performs print quality, throughput speed, cost-per-print and ink and toner cartridge yield, and ease-of-use analyses for color and monochrome printers in all technology classes, from inkjet and laser printers to digital color presses.

SpencerLab is operated by Spencer & Associates Publishing, Ltd., a premier information technology consulting boutique specializing in the application of Digital Color Technology to all aspects of color imaging. For over a dozen years Spencer & Associates has been providing strategic support to manufacturers in product planning, development, and launch. Color printing workflow analysis, print system selection, and usage optimization services are provided to corporate users.

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