

Summary Report

Print Quality Study Comparison: *HP Color LaserJet 9500*

vs. Heidelberg QuickMaster DI, Hewlett-Packard Indigo Press 3000, Canon CLC 1140, Canon CLC 5000, Xerox DocuColor 12 and Xerox DocuColor 2060

This report summarizes an independent Print Quality comparative test and evaluation of the **Hewlett-Packard Color LaserJet 9500 digital printer with its internal Raster Image Processor (RIP)**, and the Heidelberg QuickMaster DI and Hewlett-Packard Indigo Press 3000 digital presses, as well as the Canon CLC 1140, Canon CLC 5000, Xerox DocuColor 12 and Xerox DocuColor 2060 digital color printers, each with external RIPs. Each digital press or printer was evaluated with a particular RIP in an RGB workflow, recommended by an associated print-for-pay supplier.^{1,2}

The objective of this Print Quality analysis was to comparatively evaluate the HP Color LaserJet (CLJ) 9500 as a potential in-house alternative for printing office documents that might otherwise require a central reproduction facility or outsourcing to obtain appropriate print quality. This usage is enabled, in part, by its ability to print on HP High Gloss Laser Paper. *Although it is commonly assumed that offset is the best overall print quality users can get, this study concluded that the CLJ 9500 is an excellent alternative.*

This independent evaluation was conducted by the *SpencerLab* Digital Color Laboratory, a division of Spencer & Associates Publishing, Ltd.³ Analysis examined print quality demonstrated on high-quality recommended glossy paper with test files and from the *SpencerLab* Printer Test Suite⁴ that highlight a variety of printing requirements representative of the office environment.

Executive Summary

This comparative Print Quality evaluation concluded that overall print quality of the CLJ 9500 shared the top rating with the HP Indigo Press 3000. The CLJ 9500 ranked above the Xerox DocuColor 12 and 2060 printers, and substantially above the Canon CLC 1140 and 5000 printers as well as the Heidelberg QuickMaster DI press.

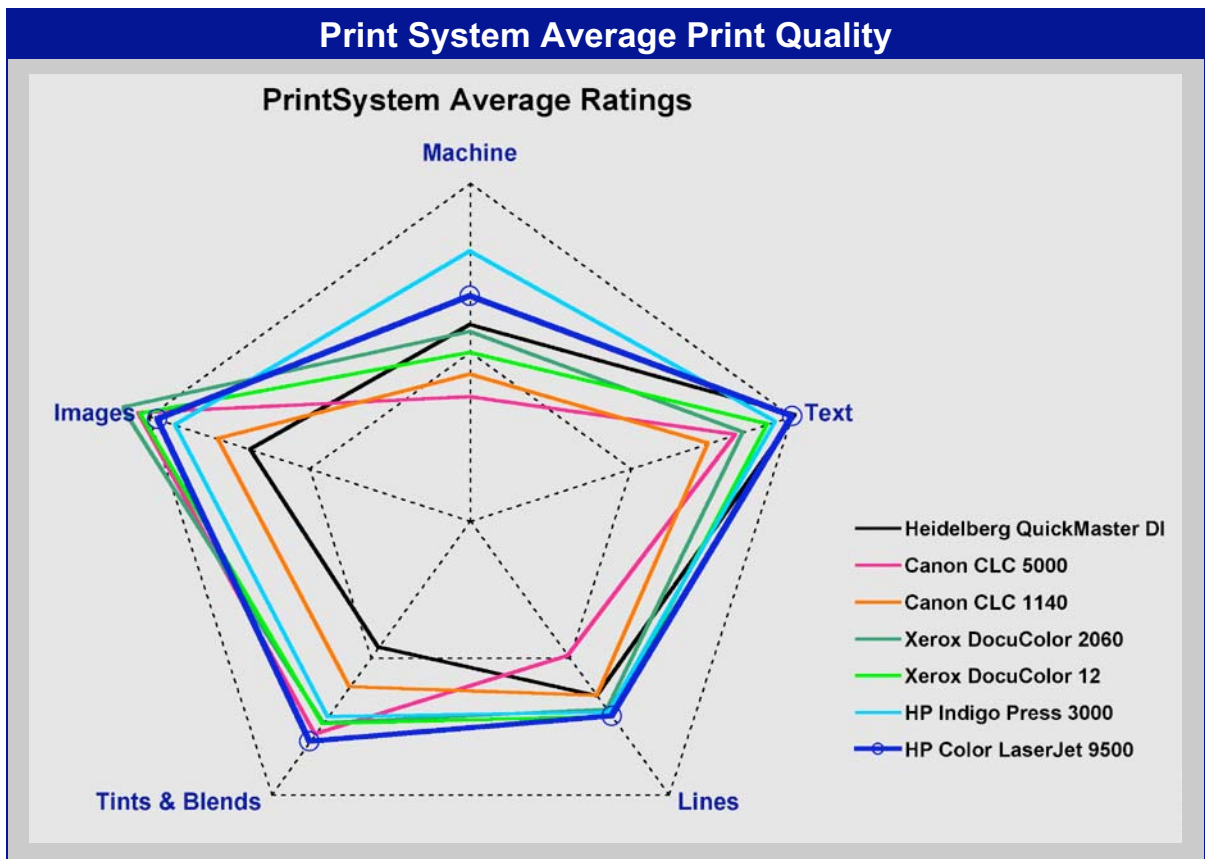
An important, but unexpected, understanding from this research is that the embedded state-of-the-art RIP of the CLJ 9500 assures proper RGB color processing and eliminates quality variability seen in many of the other evaluated printer/RIP combinations. As such, an untrained user can obtain excellent output consistently on the CLJ 9500, whereas outsourcing may be a Pandora's box of printing issues.

This research concluded that *the addition of the CLJ 9500 is a superb alternative to outsourced color document printing solutions.*

The CLJ 9500 produced top-level Text. With excellent screening and smoothness, the CLJ 9500 delivered exceptional Color Text that was of higher quality than both digital presses and all tested competitive printers.

- ◆ The CLJ 9500 produced the highest quality Lines. Color Lines were excellent and higher quality than both digital presses and all tested competitive printers.
- ◆ The CLJ 9500 produced the highest quality Tints and Blends. Color Tints and Blends were remarkable and of higher quality than both digital presses and all tested competitive printers. Excellent saturation, screening and color fidelity were key.
- ◆ The CLJ 9500 ranked higher than the QuickMaster DI and other tested systems on overall Machine issues. With tight registration and superb trapping capabilities, the CLJ 9500 scored high in this category.
- ◆ The CLJ 9500 embedded RIP assured proper color management, eliminated quality variability, and offered ease-of-use within the office environment.

The following chart displays the average print quality evaluation for each analyzed category. The size of each pentagon is indicative of the printer's total quality, with the distance of each printer's category point from the center corresponding to its higher quality in that category.



(The full report may be downloaded at <http://www.spencerlab.com>)

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¹ Throughout this report the term "printers" is used to denote complete print systems – digital press or printer and RIP combination – including driver and media.

² Results stated herein are based upon testing of individual product samples, and the results assume each is representative of its type.

³ Although this research was performed under HP sponsorship, SpencerLab is an independent test laboratory with a broad base of industry clients, and believes that this report maintains its reputation for the integrity of its test procedures and analyses.

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

About This Research

Office users typically produce documents from common office application software in an RGB color space. In the Print-for-Pay environment, competency in dealing with RGB documents varies widely among vendors today. Press-oriented Print-for-Pay houses prefer to receive CMYK customer files, despite possessing printers and RIPs which might be fully capable of handling typical office RGB source files. Others have not invested in more modern RIPs that effectively handle RGB workflows. As RGB workflow demand increases, Print-for-Pay vendors develop workarounds, apparently driven by the preference of incremental investment in labor over one-time investment in equipment modernization. The availability of various RIPs for the same print engine exacerbates the issues; different RIP options can yield varying quality output from the same print engine, and the adoption of good color management practices is disjointed.

While the output devices in this study are capable of high quality output, their variability is considerable and dependent upon the skill of the operating staff – there is still craft involved in at least some of these print systems. Even vendors with positive reputations who claim to be capable of satisfying office user requirements may deliver results below the inherent capabilities of the output device, especially for RGB documents. Alternatives include: being resigned to accept the limitations of these Print-for-Pay vendors and avoiding any expectation of controlling color when creating RGB documents; providing CMYK files; or finding another vendor. Establishing a customer-vendor relationship in order to gain the ability to control color satisfactorily may involve the office employing a graphics-trained staff – not a desirable solution.

Identifying printers in this research by print engine only is potentially misleading, because each of these systems must be paired with a RIP that is capable of operating in various color modes. While mode settings are under some level of control, the print buyer has little influence over the type of RIP that a vendor acquires with their print system. Therefore, this research is limited to the RIPs that were available in Print-for-Pay houses that offered the desired printing engines (within project time/resource constraints).

We believe that as this market continues to mature, improvements in the RGB color handling by RIPs and the acceptance of RGB workflows by the Print-for-Pay industry may yield a significant upgrade in the competitive landscape. Perhaps the important lesson is that the embedded state-of-the-art RIP of the CLJ 9500 assures proper RGB color processing and eliminates the quality variability seen in the other evaluated printer/RIP combinations. As such, an untrained user can obtain excellent output consistently on the CLJ 9500, whereas outsourcing may be a Pandora's box of printing issues. This research demonstrated that print quality is determined at least as much by the RIP and expertise of the operator, as by the print engine.

Print Quality Analysis

Methodology

SpencerLab selected some of the latest versions of test documents from the *SpencerLab Printer Test Suite* (now in Beta; originally developed as part of the *Color Hardcopy Quality Factors* study series), representing a variety of Print Quality issues and printing requirements.

PostScript and PDF test files:

- *Color Spectrum / Color Graphic Calibrated RGB*
- *Color Spectrum / Color Graphic Device RGB*
- *Enhanced Graphic (device gray) / 75%/25% CMY Tints*

Tiff photographic images:

- *Castle*
- *Covered Bridge*
- *Composite Image (including La Boca, Isle, Woman's Face, and Babies)*



Print Quality was analyzed by element type (*e.g.*, Machine issues, Text, Lines, Tints & Blends, and Images) across these test documents. Although all tested print systems are capable of CMYK workflows, most offices use RGB workflows for applications ranging from office suites (word processing, spreadsheets, presentations, etc.) to images (digital cameras, office scanners); in fact, today's Windows OS's natively only support RGB. Offices are increasingly unwilling to support specialists to creating CMYK versions of RGB documents, just for the print systems. Therefore RGB test files and workflows were used to replicate typical office documents and workflows.

Competitive print systems were evaluated utilizing Print-for-Pay providers in the New York City area. In some cases, additional print samples were requested from alternate vendors to ensure that the output used for evaluation was somewhat representative of the print systems. On both the Heidelberg QuickMaster DI and Canon CLC 1140 prints, multiple sets of prints were obtained after it was deemed that those obtained in initial runs might not be representative of what the print system was able to output. *SpencerLab* contracted additional vendors to produce print sets and the print quality analysis was performed on the better of two sets. Xerox Print-for-Pay providers delivered quality deemed to be reasonably representative. Hewlett-Packard, under direct supervision of *SpencerLab* personnel, supplied both the CLJ 9500 and Indigo 3000 print samples. All vendors were made aware that we were performing a test for an undisclosed client (such as an office end-user) and wanted to acquire the best print quality of which their equipment was capable.

One of the key factors enabling the CLJ 9500 to be considered a viable print quality alternative for printing office documents that might otherwise require outsourcing is its ability to image on very high quality paper. Our testing of the CLJ 9500 was performed on 32 lb. HP High Gloss Laser Paper, which has a Brightness rating of 95. Testing of all other print systems used comparable premium glossy paper or as recommended by the respective manufacturer or service supplier. Printer/RIP settings for sRGB source documents were used in printing and prints were run after a maintenance cycle or color calibration was performed on each print system. Full specs and print locations are listed in the chart on the following page.

In performing print quality analyses since 1989, *SpencerLab* has developed and refined a hierarchical understanding of the elements that comprise overall color print qual-

ity. These elements may be categorized into the areas of Text, Lines, Tints & Blends, Images, and general Machine issues. Since these areas are not equally important in all user environments, a weighting is applied to the elements and areas that is appropriate to the targeted market at the specified time.

SpencerLab print quality evaluators analyze the print samples by element type. Depth and insight are obtained by performing a detailed analysis of each element – those that are merely average as well as those that are good and bad. These analyses are scaled in accordance with the evaluator’s expertise, aggregated, and carefully reviewed. Any differences are resolved by discussion and further analysis, until an effective consensus is reached under the guidance of senior staff. This methodology requires extensive test targets, specifically designed for this purpose; the *SpencerLab* Printer Test Suite, in development since 1990, supports this robust methodology.⁵

Print System	RIP	Paper	Print Mode	OutSource Location
Hewlett-Packard CLJ 9500	Embedded	HP High Gloss Laser Paper	Default	Hewlett-Packard (Boise, ID)
Heidelberg QuickMaster DI	Rampage PrePress	HP High Gloss Laser Paper	sRGB source; Photographic Intent	Cosmos Communications ⁶ Commercial Printer (Long Island City, NY)
Hewlett-Packard Indigo 3000	IPTech TurboRIP	StoraEnso 4CC Art Sheets	sRGB source; Photographic Intent Presentation Intent	Hewlett-Packard (Boise, ID)
Canon CLC 1140	KPG Professional Matchprint Professional Server ColorPASS-Z400e ⁷	StoraEnso 4CC Art Sheets ⁸	sRGB source; Manual Calibration	QuadRight Graphics Pre-press Service Bureau (New York, NY)
Canon CLC 5000	ColorPASS- Z5000	Canon Glossy Brochure Paper	sRGB source; Photographic Intent	Sterling Group Advertising Agency (New York, NY)
Xerox DocuColor 12	Fiery XP12 PS	Xerox Digital Color Gloss Paper	sRGB source; Photographic Intent	Alpina Digital Digital Quick Printing Shop (New York, NY)
Xerox DocuColor 2060	Fiery DocuColor 2000	Xerox Digital Color Gloss Paper	sRGB source; Photographic Intent	Alpina Digital Pay-for-Print Shop (New York, NY)

Machine Issues

Machine issues are complex, in that elements of this attribute have a cascading effect within print quality analysis. If an element within Machine issues – such as registration, edge effects, gloss, or smoothness – is less than acceptable, then other elements within Text, Lines, Tints & Blends, and Images may be adversely affected.

Registration issues will surface in the reproduction of sharp color Text and Lines, Tint, and Image sharpness. Edge effects may produce additional defects in Tint boundaries, confounding trapping algorithms. Differential Gloss consequences may range from Text legibility to Image detail. Smoothness defects – including graininess, mottling, and banding – may yield visible distractions in numerous elements, especially in large areas of grayscale or color Tints & Blends and even low-detail Image area. Although the Machine issues are evaluated independently, there is a symbiotic relationship with many other Print Quality elements.

HP Color LaserJet 9500

The CLJ 9500 produced very high quality output with a smooth, uniform, low gloss appearance. With just slightly higher differential gloss than the Indigo 3000 or QuickMaster DI, black and color toners have a similar non-distracting uniform appearance. Trapping was exceptional, perhaps some of the highest quality seen. While registration errors were not evident, minor xerographic edge effects were visible around high-contrast black-and-white borders and between pairs of saturated color objects. Pure black toner was used for printing black and neutral grays that are specified using RGB values in non-image based objects. Negligible mottle was present, but some graininess was visible in neutral grays and light pastels.

Heidelberg QuickMaster DI

The QuickMaster DI produced output that suffered from poor registration, visible mottling and banding. Our second vendor's use of the Rampage RIP, which incorporated in-RIP trapping, reduced the effect of the poor registration. Some print samples exhibited double-printing of the black plate, appearing to overprint itself. The absence of xerographic edge effects and the low level of differential gloss were exceptional, as might be expected from a lithographic offset press. Banding was visible in large gray areas and mottling was problematic in both grayscale and color. Grain was slight in gray areas, but areas of color were very smooth. White artifacts seen in some solid single color objects and particularly noticeable on the *Enhanced Black* file may have been due to inadequate environmental control of dust.

HP Indigo 3000

Printing on the Indigo Press 3000 generates top quality prints that are well-registered and smoothly rendered. The Indigo 3000's proprietary ink appears smooth and has an even, non-distracting low gloss finish. Samples appear finely registered, although it was thin and not used on all colors. Xerographic edge effect was minimal and the absence of banding, mottling, and graininess was noteworthy. Neutral gray tones defined using equal RGB values are printed as process neutrals, however pure black was used when printing R=G=B=0.

Canon CLC 1140

Output from the CLC 1140 using the Kodak Professional Matchprint Server was overall smooth, but suffered from excessive gloss differential and xerographic edge effects. Of all evaluated print systems, it was ranked the lowest in the Machine category. Samples exhibited minor banding and significant fuser oil streaking. The glossiness of saturated

colors, heavy process neutrals, and pure black was very disturbing and unnatural in image shadow areas. Registration was good, with some misregistration in cyan and magenta. The controller does not perform in-RIP trapping, but not much was warranted. The CLC 1140 was virtually mottle and grain-free, with very minor grain seen only in high-light areas.

Canon CLC 5000

Like the CLC 1140, output from the CLC 5000 exhibited very noticeable xerographic edge effects and excessive differential gloss. The differential gloss of solid black and heavily saturated colors was distracting in Text, and detracts from image quality as well. The controller does not perform in-RIP trapping, and misregistration was seen between black and cyan. Some banding and grain was seen in neutral areas, but overall smoothness was good.

Xerox DocuColor 12

The most obvious Machine issues of the tested DocuColor 12 were excessive banding and differential gloss. Banding was most evident on the *Enhanced Black* and *75%/25% CMY Tint* test pages and to a lesser degree on the color test files. Differential gloss was distracting, but less so than on the Canon systems. The controller does not perform in-RIP trapping, and minor mis-registration was seen in cyan and yellow, along with very minor xerographic edge effects. Minor mottling was present in tints, but with little noticeable grain.

Xerox DocuColor 2060

On overall Machine issues, the DocuColor 2060 ranked comparably to the Quick-Master DI. Though controller does not perform in-RIP trapping, registration was good and edge effects are minimal. Differential gloss issues were present, but less than on the Canon print systems. Banding was minor, but noticeable on the *75%/25% CMY Tint* file; mottling was present in some lighter pastels, and graininess was nominal.

Text Quality

Black Text represents the most common use of an office printer, and is primarily comprised 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. 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 four-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 with point size to even the most casual reader.

Uniform character stroke weights and spacing provide “typographic color”, the perceived overall uniform darkness of the text. This enhances effective communication when successful, but may detract significantly when distorted and uneven. Font details such as fine serifs, thin strokes, and uniform kerning can easily be lost due to poor reproduction.

Color can be used to highlight or emphasize particular words or phrases, and is being utilized more often in the office environment, as color printing becomes more accessible and affordable. The improper rendering of color can shift the emphasis from the key idea to the lack of adequate print quality. Because most colors (all but pure CMYK primaries and secondaries) require some halftoning even at full saturation, text quality is often decreased further due to the sparse halftone cells.

Although less significant than other print attributes for many applications, reverse text represents a specific use that some printers tend to reproduce poorly due to enlarged spot size, toner splatter, and other causes of poor modulation transfer function. Typically, thin lines and fine font fills are dimmed or dropped out completely.

HP Color LaserJet 9500

The CLJ 9500 rendered top-level Text, ranking equivalent to the digital presses and DocuColor 12 and higher than the other xerographic printers analyzed. Black Text was legible down to 2-point, and dropout free down to 6-point. Splatter, while not visible to the naked eye, was evident under magnification, resulting in soft character edges. Typographic color was even and consistent. Color Text was ranked very highly and comprised of smooth and legible characters. Screening was excellent and rarely visible, even in colors such as orange or brown. Color Text was legible and sharp at 2-point, though it appeared somewhat heavy. Grayscale Text offered excellent legibility, but midrange grays were a bit too dark, yielding less distinction across the darker shades. In Reverse Black Text, legibility was good down to 4-point, with minor fill-in occurring at 8-point. Reverse Color Text was trapped and was legible down to 2-point.

Heidelberg QuickMaster DI

The QuickMaster DI produced high quality Text comparable to the CLJ 9550. Dropouts were very minor, seen only at 4-point and below. Black Text had excellent typographic color, was splatter-free, and legible down to 2-point. Characters were rendered with very smooth edges, possibly enhanced by the dot gain inherent in the blanket-transfer process. Color Text was rendered well, with good legibility; however, screening was visible. Grayscale Text was screened well, but rendered a bit dark in the lighter and midtone shades. Reverse Text was legible down to 4-point, exhibiting fill-in at 8-point and below.

HP Indigo Press 3000

The Indigo 3000 produced high-end Text, comparable to the QuickMaster DI and the DocuColor 12. Black Text was excellently rendered: sharp, crisp, splatter-free, legible down to the smallest point sizes, and without dropouts. Color Text was legible down to 2-point, but screening was visible in tertiary colors, such as brown and orange. Grayscale Text was also rendered well, with good distinction between shades. Reverse Text exhibited fill-in at 8-point and was legible down to 4-point.

Canon CLC 1140

The tested CLC 1140 ranked lowest overall in Text, mainly due to issues with Black Text and Reverse Text. Black Text displayed uneven, broken character shapes with noticeable dropouts at point sizes as large as 14-point. Legibility suffered as a result and 2-point text was unreadable. No splatter was visible, but Black Text at 8-point and below was rendered too light. Color Text was rendered well, but suffers from character distortions and dropouts, even at higher point sizes, perhaps reflecting the printer's 400 DPI base resolution. Grayscale Text exhibited good shade gradation, but irregular character edges were noticeable in the lighter shades. Reverse Text was legible down to 2-point, but fill-ins become noticeable at 8-point. As noted under Machine, differential gloss rendered text distracting.

Canon CLC 5000

The tested CLC 5000 rendered Text somewhat better than the CLC 1140 and was more comparable to the DocuColor 2060. Black Text was thick and saturated, making 2-point text illegible. While no dropouts or splatter were visible, heavy toner application contributed to a blurry character appearance. Overall, Color Text was very good, except for minor misregistration and visible screening. Grayscale Text had irregular edges and screening resulted in unevenly rendered in light gradients. Reverse Black Text fill-ins were visible in text as large as 12-point. Reverse Text fill-ins were problematic even at larger point sizes, due to thick rendition and legibility was poor below 6-point. As on the CLC 1140, differential gloss was distracting.

Xerox DocuColor 12

The DocuColor 12 Text quality ranked similarly to the Indigo 3000. Black Text was sharp and smooth with few quality issues. It was virtually free from dropouts and splatter and was legible down to 2-point. Color Text was rendered well, but minor misregistration was visible within characters. Grayscale Text was evenly screened with good shade gradation. Reverse Text was legible down to 4-point, but fill-in was noticeable in 8-point and below. As seen on the Canon printers, differential gloss was distracting.

Xerox DocuColor 2060

The DocuColor 2060 produced Text ranked comparably to the CLC 5000. Black Text quality was good, with no observable splatter or dropouts. Text, while legible down to 2-point, was faint; magnification reveals minor character edge jaggedness. The screening of Color Text was visible, as in the DocuColor 12. Overall Color Text character weight was thin. Grayscale Text was excellent, with good gradation. Reverse Black Text exhibited some fill-in starting at 8-point and was legible down to 2-point; Reverse Color Text was legible down to 4-point. As seen on the DocuColor 12 and Canon printers, differential gloss was distracting.

Line Quality

As a graphical element, lines are critical in representing data, providing visual separation of document sections, and contributing to artistic graphics; in fact, the prevalence of

lines in printed material is overwhelming and nearly as common as text. Of these, the most common are vertical and horizontal ruled lines – fortunately the simplest to render on a rectilinear grid. Because of the geometry of such a grid, diagonal lines are subject to an increase in minimum thickness; a printer system's ability to maintain line thickness between the thinnest straight and diagonal lines is a tradeoff between offering thinner straight lines or greater uniformity.

While this uniformity issue is often of minor importance for discrete lines of different angles, curved lines require that they do not appear to vary in thickness. In transitioning along curved lines from vertical or horizontal orientations to the angles between, many rendering algorithms will create noticeable artifacts that emphasize the jaggedness of the pixel grid.

In addition to width non-uniformity, lines often illustrate deficiencies such as drop out and ghosting, halftoning issues (some halftone algorithms are designed for use over large areas, but also employed in thin line situations), and color registration problems perpendicular to the orientation of the line.

HP Color LaserJet 9500

The CLJ 9500 ranked highest in overall Line reproduction. Thin angled Black Lines were produced consistently at most angles, with the sole exception of 45° lines that are very thinly rendered on the Radial pattern. Line thicknesses exhibited some errors, such as 300 DPI lines being thicker than 1/4-point lines. Horizontal and vertical hairlines of the same called-for weight were not rendered the same thickness, such as 1/1200th-inch horizontal lines being thicker than 1/1200th-inch verticals. Near-Horizontal and -Vertical Lines appeared slightly broken, thickening at joints. Black Curved Lines appeared slightly jagged into and out of curves. Slight toner splatter smoothed the overall appearance. While lines were a bit thick, thin lines were rendered at equal width in the black Mazda drawing, resulting in detail loss and decreasing its three-dimensional appearance. Thin gray lines of the car were pure Black gradients, not process. Color Lines, horizontal, vertical, and those in the Mazda drawing were rendered quite well, with a very smooth appearance in part due to line thickness.

Heidelberg QuickMaster DI

The resolution of the second tested QuickMaster DI, at 2540dpi, was significantly higher than any other print system evaluated; however, its overall Line rating was within the lower half of the printers. Black Line rendition was near perfect; printed line weights matched expectations for the request, and horizontal and vertical lines of equal weight were produced at the same thickness. Curved lines were sharp and well defined, and Near-Horizontals and -Verticals were consistent and very smooth. Closely spaced, thin Reverse black lines, and lines within the Radial pattern suffered detail loss. The black Mazda drawing was extremely well rendered; the fine detail preserved by distinct rendering of varied thin line weights. Dropouts and loss of detail from halftone screening detracted from the quality of thin process Color Lines. Very thin color lines, as in the Mazda drawing, were seen as individual color components.

HP Indigo press 3000

Overall Line rendition of the Indigo 3000 was comparable to the DocuColor 12 and 2060 printers. Black Line weights were rendered as expected down to $1/600^{\text{th}}$ thickness, beyond where the vertical appeared thinner than the horizontal line of the same specified weight. Near-Horizontal and -Vertical lines were very smooth, clean and appear straight. Thin Reverse Lines were not visible in the Reverse Radial pattern, which may be due to excessive spot size, as also seen on the QuickMaster DI. Curved lines showed some jaggedness going into and out of the curve. Fine detail was well defined and the impression of depth was preserved nicely in the monochrome Mazda drawing. The Indigo 3000's screening pattern contributed to dropouts in thin Color Lines, especially orange. Thin color lines in the Mazda line were rendered as color components.

Canon CLC 1140

Overall Line quality from the CLC 1140 was mid-range within the printers evaluated. Prints exhibited thicker vertical than horizontal Lines below $1/600^{\text{th}}$ -inch lines. Near-Horizontal and -Vertical angles appeared jagged, and exhibited thinning at the joints. Radial Lines were good, but suffered from moiré artifacts. Curved Lines were very smooth, with good blending for this resolution printer. The black Mazda image showed good detail and depth, although lines occasionally appeared broken. Screening artifacts were evident in Color Lines and an annoying differential gloss detracted from quality. The color Mazda drawing appeared sharp overall, but thick Black and Blue lines were too rich and details were lost.

Canon CLC 5000

Overall Lines were ranked lowest for the CLC 5000. Black Lines suffered from excessive thickness; and weights thinner than $1/600^{\text{th}}$ -inch appeared to be rendered equally. As a result, the ability to convey subtle detail, as in the radiator grille of the black Mazda drawing, was lost. As seen on other printers, below $1/600^{\text{th}}$ inch vertical lines were thicker than horizontal. Near-Horizontals and -Verticals were thick and exhibited some jaggedness. The Radial Line pattern displayed a moiré pattern, indicating screening of angled lines. Curved lines were consistent and well rendered. Color lines also appeared heavy with screening artifacts with some colors appearing darker and thicker than others. Lines in the Mazda car are thick and overpowering, resulting in a loss of 3-D effect. As on the CLC 1140, the differential gloss on both Black and Color lines is distracting.

Xerox DocuColor 12

The DocuColor 12 ranked comparable to the Indigo 3000 and the DocuColor 2060 on overall Lines. Both Black and Color Lines were rendered well. Horizontal Black Lines $1/600^{\text{th}}$ -inch and thinner were rendered at the same thickness, as were vertical lines thinner than $1/1200^{\text{th}}$ -inch; vertical lines, $1/1200^{\text{th}}$ -inch and smaller, appeared thinner than the same requested weight Horizontal Lines. Stepping was visible in Near-Horizontal and Near-Vertical lines, but Radial Lines appeared straight, smooth and consistent. The black Mazda drawing showed good detail and the thickness of very fine lines was distinct, maintaining a good illusion of depth. Color lines were solidly rendered, with some minor

screening evident. Though lines were slightly thick, fine details were maintained in the color Mazda drawing.

Xerox DocuColor 2060

The DocuColor 2060 was comparable to the Indigo 3000 and DocuColor 12 on overall Lines. Black Lines were rendered well, but as seen on other printers the thin verticals were thinner than the corresponding horizontals. Minor jaggedness was apparent in Near-Horizontal and -Vertical lines. Radial Lines were clean and well formed, with some detail loss in the Reverses. Some break-up going into and out of thin Curved Lines was noticeable, but generally were well rendered. Excellent detail was maintained in the thinnest lines of the black Mazda drawing. Color Lines were of good quality, but exhibited some minor screening patterns and thin gray lines were seen as component colors. Color Lines in the Mazda car were smooth, with a satisfactory level of detail and depth.

Tint & Blend Quality

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. Binary printers must use screening to achieve tints. Tints are also sensitive to hue color errors.

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 super-pixel 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 among high-resolution dots (spatial frequency modulation), minimizing most artifacts; however, this technique requires small spot size and may yield grainy pastels.

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 color space conversion from RGB to CMY involves many opportunities for error, and the ability to produce high-quality RGB blends may be more important than the RIP vendor realized.

HP Color LaserJet 9500

The overall Tints and Blends of the CLJ 9500 was rated highest of all systems. With excellent color screening frequency, good saturation and high color fidelity the CLJ excelled in the Color elements. Grayscale screen grain was visible, especially in highlights as

the 30% and 40% patches. Gray monochrome blends were smooth, but exhibited dark shadow and midtone areas, reaching full saturation at 80% on the Wedge. Wedge highlights were moved through quickly and appeared washed out. Color screening was excellent, slightly visible in the lighter pastel shades and neutral grays. Color Wedges were smooth and with consistent hue, except in Magenta and Cyan. Wedges had extended shadow and midtone ranges with limited highlight ranges. The Saturated Blends were exceptional; smooth and saturated, but the Purple to Magenta transition was harsh. Highlight and Shadow Blends were produced well, but exhibited some non-linearities in Green, Blue, and Cyan. Color fidelity was excellent with vibrant and saturated colors where expected. However saturated colors of similar, but different hues (*e.g.* the “LO” in “COLOR SPECTRUM”), were not distinct. The 3-D Pie Chart was of highest quality, displaying excellent saturation and contrast.

Heidelberg QuickMaster DI

The QuickMaster DI ranked at the bottom of the overall Tint and Blend category. Screening was at a slightly lower frequency (150 lpi) than that of the CLJ 9500, even though the resolution was considerably higher. The pure Black Wedge had dark shadows and midtones, with a harsh jump out of highlights and non-linearities present. Color screening was good, with a classic moiré pattern sometime visible. The Color Wedges feature a good midtone range, but contained harsh transitions in the shadow regions. The Cyan area of the Saturated Blends was full of non-linearities, and the Highlight and Shadow Blends had non-linearities in Purple, Blue, Green and Red. Color Fidelity was acceptable, except for a purplish Blue. The 3-D Pie Chart was well balanced; however, the colors – especially Red – were dull.

HP Indigo press 3000

The Indigo 3000 produced high quality overall Tints and Blends. The Grayscale Wedge exhibited excellent highlights, an extended midtone range that was light and flat, and a limited shadow range. Grayscale screening was handled well. Screening in Color Tints was visible, yet smooth and non-distracting. The process Black gradient appeared darker, but smoother than the pure Black Wedge that barely reached full saturation. While smooth, Color Wedges had visible screening and exhibited an extended midtone range. Saturated Blends were excellent, with a slight Purple to Magenta jump. Minor non-linearities were seen in the Highlight and Shadow Blends in Purple, Magenta, Red and Cyan. The 3-D Pie Chart was rendered with limited contrast and sharp transitions.

Canon CLC 1140

Overall the CLC 1140 was rated low on Tints and Blends. Screening in grayscale tints was visible and the pure Black Wedge had a very narrow shadow range that barely reached full saturation. Overall, large Color tints were smooth and uniform; the line screen pattern was noticeable, but consistent and not distracting. The process Black Wedge was smooth, but had a bluish tint in the highlight areas and non-linearities in the shadows. Color Wedges were smooth, but had extended shadow ranges, while the Cyan was light Blue and the Magenta was Purple. Hue shifts were seen in the Color Wedges

when using the KPG RIP (these were not present with the earlier ColorPASS controller). The Saturated Blends displayed harsh transitions from Blue to Cyan to Green, and non-linearities in the Magenta region. Highlight and Shadow Blends exhibited abrupt hue changes in Magenta and Cyan, and non-linearities in Purple, Red, and Magenta. The 3-D Pie Chart had good saturation, but exhibited xerographic “white gap”.

Canon CLC 5000

Overall, the CLC 5000 performed highly in the category of Tints and Blends. Gray-scale Tints were a bit dark in the midrange and shadow areas, but had an excellent high-frequency line screen. The Color Wedges exhibited some mottling in the highlight areas, but colors were richer than those of the Indigo 3000. Lightness bumps were visible in the midtone and shadow areas of the Color Wedges, and the Wedges moved quickly through the midtone range. The Saturated Blends were vivid and saturated, but with severe non-linearities in the Cyan region that was also very narrow. The Highlight and Shadow Blends were excellent, with non-linearities seen again in Cyan. Color Fidelity was excellent with nice contrast, but limited variation among the darker (>75%) tints. The 3-D Pie Chart had good color contrast, even with limited Red; if not for white gap the CLC 5000 would be on par with the CLJ 9500 in this subset.

Xerox DocuColor 12

The DocuColor 12 rated highly in the overall Tint and Blend category, with good Color screening and saturation. Grayscale line screening was visible in 10% to 70% Tints and non-linearities were numerous on the Grayscale Wedge, while color was consistent. Color Screening was excellent and Color Wedges, while overall good, showed little variation between 75% and 100%, and had a limited highlight range. The process Black Wedge reached full saturation early and had a slight Magenta cast in the midrange. Most Wedges were smooth, but there was a hue jump in the Blue Wedge, the Cyan was Blue and the Magenta was Purple, and full intensity was reached too rapidly. The Saturated Blends were smooth, but contained an extended Green region and some non-linearities in the Cyan to Green. The Highlight-Shadow Blends exhibited non-linearities in the Cyan, Blue and Green, but transitions overall were smooth. The Red slice of the 3-D Pie Chart was very vivid compared to the surrounding colors, while Cyan and Green were too pastel, detail was lost in shadow areas, and white gap was present.

Xerox DocuColor 2060

Overall, the DocuColor 2060 also produced high quality Tints and Blends, very similar to the DocuColor 12. Grayscale highlights were rendered very well, with good screening. The pure Black Wedge was smooth, with only minor noise. Color screening was fairly smooth with some slight mottle. Color Wedges were very smooth, with good highlight and midrange, but reach full saturation at 75%. The process Black Wedge was also smooth, but had a Magenta cast. The Saturated Blends were very smooth, with an extended Green region that did not reach full saturation. The Highlight-Shadow Blends were excellent, with only minor non-linearities in Yellow and Green and an extended Cyan highlight area. As on the DocuColor 12, Color Fidelity was acceptable; there was

little variation between 75% and 100% tints. The 3-D pie chart Red slice, also like the DocuColor 12, was very vivid compared to the surrounding slices and there was limited shadow detail.

Image Quality

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; even if only at the time of product selection; therefore, a printer must produce high quality images.

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, skin tones, wood browns, and neutrals 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. Another demand for image color fidelity is matching a color-corrected photograph such as a calibrated image file with an associated profile or in a standardized color space such as sRGB. Although sometimes causing conflict, both objectives are important.

High spatial frequency within an image reflects a printer's ability to provide high quality detail. 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.

HP Color LaserJet 9500

The CLJ 9500 ranks highly in the overall area of Images. Blue sky areas were very realistic and well represented. Minor contouring was noticeable in the highlight areas of clouds in the *Castle* file and surface of the water in the *Covered Bridge* file. Other memory colors, such as the green trees and the neutral stone walls in the *Castle* image were less realistic due to magenta and bluish casts, respectively. The monochrome headshot on the *Enhanced Graphic* pages was rendered too dark and with contouring and judged to be of lower quality than the other printers. Skin tones were generally good, but had a slight Magenta cast. Screening was very smooth, with only minor graininess noticeable in highlights, and no visible artifacts. Images were very vivid and highly saturated, which resulted in a loss of preferred color depth and contrast. Image Exposure was rated positively, but subject matter appeared darker and with less contrast than on the Indigo 3000, Canon 5000, and DocuColor 12 and 2060. All images were sharp and clear.

Heidelberg QuickMaster DI

Images from the QuickMaster DI were the least preferred in this overall area. Workflows at the two vendors who supplied output differed – although the initial vendor converted from sRGB in Photoshop and then sent CMYK to their Harlequin RIP, the replacement vendor sent the images to the Rampage RIP as sRGB and then on to the printer as CMYK DCS files. Although skin tones were very realistic and natural, the QuickMaster DI (with Rampage RIP) did not perform as well on other memory colors. Sky areas were rendered with good soft highlights, but had an overall purple cast, and grass areas were somewhat desaturated and dark, but with accurate hues. Some minor graininess was seen in highlight areas and in monochrome images, but no artifacts were visible. Contrast was a bit high, with some loss of shadow detail. Images appeared less vivid and lacked the depth of the digital printers. Overall, the print quality of the QuickMaster DI was exceeded by that of the CLJ 9500 in the Image subsets of realism, smoothness, richness, exposure and sharpness.

HP Indigo press 3000

The Indigo 3000 produced overall Images comparably ranked to the CLJ 9500. Clouds were rendered with realistic detail, but blue skies appeared dull and pastel, with a slight Magenta cast. The green foliage in the *Castle* and *Covered Bridge* images, while less vibrant than on other printers, was very realistic. Skin tones also appeared desaturated and washed out, but without noticeable color casts. Neutrals were rendered very light, but were extremely smooth. Images were smooth, with the absence of artifacts and grain. Minor contouring appeared in monochrome shadow areas. Overall, the images of the Indigo 3000 were less saturated than those of the CLJ 9500, with loss of sharp detail in the highlight areas, as well as a loss of image depth.

Canon CLC 1140

The CLC 1140 ranked lowest in the overall category of Images, lower than the CLC 5000 (a real-world result, most likely attributable to its RIP). Images lacked realism, with the over-saturated, yellow-cast greens. Blue skies looked natural, but white cloud highlight areas exhibited some posterization and graininess. Highlight areas were too bright with blown-out details. Skin tones exhibited contouring and had slightly high contrast and a shift to Yellow. Neutrals were rendered light and exhibited contouring. Fuser oil marks were visible on the output, but graininess was minimal. Images were overly vivid, with excessive contrast, resulting in detail loss in the shadow and highlight areas. Differential gloss detracted from the overall image quality.

Canon CLC 5000

Overall Images from the CLC 5000 were ranked highly. Images were sharp, smooth and composed of vivid, rich, and strong colors. Overall contrast was very good, but some highlight areas appeared de-saturated. Blue skies were rendered purplish and green grass was a bit light. Skin tones were similar to the CLJ 9500, but with less contrast. Neutral memory colors were slightly dark, but the rendition was very good as evidenced in the monochrome headshot. Of two sets of prints run, one exhibited banding, while the other

had noticeable streaking. Graininess due to screening was slightly noticeable in skin tones, and quite noticeable in grayscale images. Images were sharp, but highlight seemed overexposed. Banding and differential gloss also detract from image quality. Overall, the CLC 5000 was rated just slightly above the CLJ 9500 in the area of image quality.

Xerox DocuColor 12

The DocuColor 12 ranked very highly on overall Images. Images were smooth and sharp. Somewhat dark exposure gave some loss of detail in the shadow areas. Blue skies had slight purple-tinged shadows but green foliage was rendered realistically. The neutral stone walls in the *Covered Bridge* and *Castle* and the monochrome headshot were excellently rendered. Skin tones were over-saturated with a Magenta cast. Banding was slight, as was the differential gloss, and graininess in highlight areas. Pastel highlight areas, such as white clouds or the stucco walls of *La Boca* were rendered smoothly, and did not exhibit contours. Images had good exposure and contrast, but were a bit over-saturated with some loss in shadow detail.

Xerox DocuColor 2060

The DocuColor 2060 ranked highest in overall Images, with excellent vividness and contrast. The greens of foliage were the most realistic and the blue sky was rendered with a slight purple cast. Skin tones lacked some contrast and were overly Magenta. Neutrals were excellent rendered, like those on the DocuColor 12, but had slight contouring. Minor banding was visible in the sky of the *Castle* image. Colors were vivid, with good depth and contrast was excellent. While there was some loss of definition in the shadow areas, overall sharpness was good. As on the DocuColor 12 differential gloss was present, but was not as distracting as on the Canon printers.

⁵ *SpencerLab* employs alternate top-down methodologies in focus groups, where there are a large number of evaluators who are users within the target market and have limited time and experience. Evaluators may be asked to perform a gestalt analysis of the print quality of a sample, and subsequently to explain which areas contributed to their evaluation. While this method may limit the depth of understanding, it is an important check on the realities of the user environment.

⁶ Earlier samples from another vendor printed with a Harlequin RIP, at 1270 DPI, were judged to be inferior quality and additional prints were run at Cosmos at 2540 DPI.

⁷ Again noting quality issues, two sets of prints were obtained; analyses were conducted on the print set that exhibited the best print quality of that attribute being evaluated.

⁸ Recommended by outsource vendor to offer better print reliability than our supplied Canon Glossy Brochure Paper.

About *spencerLAB*

The *SpencerLab* Digital Color Laboratory is an independent printer evaluation facility 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, ink and toner cartridge yield and cost-per-page/TCO, 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 IT 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.

For more information, please contact *SpencerLab* by email at info@spencerlab.com, by telephone at 631-367-6655, by fax at 631-367-2878, or on the web at www.spencer.com and www.spencerlab.com.

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