spencer*LAB*
DIGITAL COLOR LABORATORY

Color Cartridge Reliability Comparison Study – 2014

HP LaserJet Color Toner Cartridges vs. Xerox Brand

The *spencerLAB* DIGITAL COLOR LABORATORY has conducted a cartridge reliability comparison testing of Hewlett-Packard [HP] LaserJet color toner cartridges and non-HP Xerox brand of color toner cartridges. The test included CE400A/X (Black), CE401A (Cyan), CE402A (Yellow), and CE403A (Magenta) cartridges for the HP LASERJET Enterprise 500 color Printer M551n.

The analysis compared the Reliability, Print Quality (PQ), and Color Fidelity throughout the life of the toner cartridges tested. Cartridge Reliability was evaluated, determining the total number of Problem Cartridges that were Dead-on-Arrival (DOA). User Interventions due to poor Print Quality were also tracked for each brand. Print samples and color test charts were collected from each cartridge brand at regular intervals over the life of each cartridge set. Print samples were sorted using a Print Quality acceptance scale generated from a psychometric research study. The four PQ levels were – External Use (all uses including distribution outside the company), Internal Use (distribution inside company), Individual Use, and Unusable. The color charts were measured to evaluate Color Fidelity. [See definitions in Appendix 4]

KEY FINDINGS

- *Original HP color toner cartridges tested showed no Problem Cartridges, whereas 15% of Xerox brand color cartridges tested were Dead-on-Arrivals.*

- *Original HP color toner cartridges experienced no user Interventions due to print quality problems, whereas 33% of the Xerox color cartridge sets required user Intervention(s) to correct for poor print quality.*

- *Xerox color cartridges exhibited poor Color Fidelity with inaccurate color rendition over the life of the cartridge sets compared to colors produced by Original HP color cartridge sets.*

- *Original HP color cartridges had the largest percentage (99%) of External Use Print Quality samples, clearly surpassing the quality of Xerox cartridges where only 59% of the samples inspected were acceptable for External Use.*
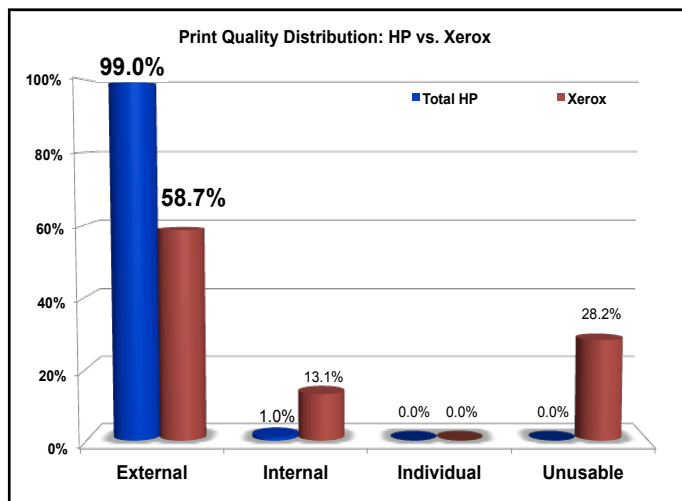
TEST RESULTS

CARTRIDGE RELIABILITY

HP cartridges were more reliable than the Xerox cartridges; none of the HP cartridges were deemed Problem Cartridges. All HP cartridge sets reached the end of test and did not require any user Interventions due to poor print quality before test completion.

The Xerox cartridges exhibited Reliability issues. Out of the 26 procured Xerox cartridges, 15% were deemed as Problem Cartridges. One-third (33%) of the tested Xerox cartridge sets required user Intervention(s) to attempt a recovery due to poor print quality.

Problem Cartridges and Print Quality Problems		
Cartridge Brand	**Problems Cartridges**	**PQ Problems**
	Dead-on-Arrival	Interventions
HP	0%	0%
Xerox	15%	33%

PRINT QUALITY DISTRIBUTION

HP cartridges produced significantly[*] greater number of pages with higher Print Quality than Xerox cartridges. HP cartridges produced a total of 99.0% of print samples categorized as good for External Use. Comparatively, Xerox cartridges produced only 58.7% of pages that were good for External Use.
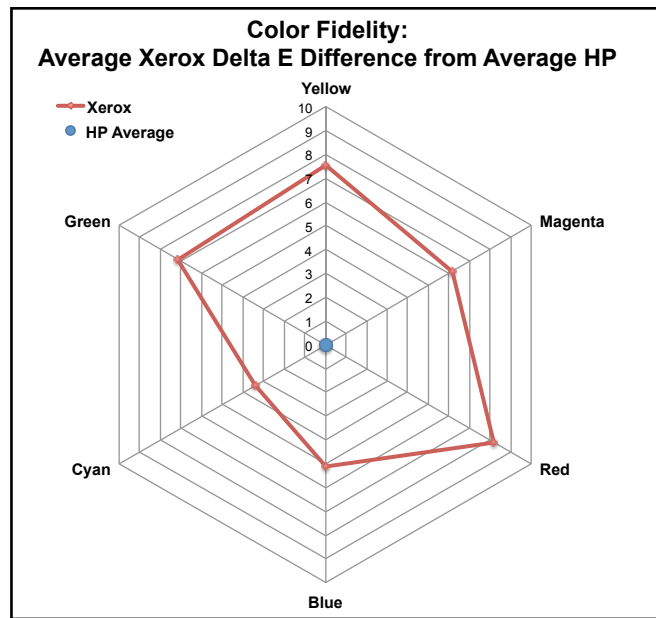

Print Quality Distribution: HP vs. Xerox

HP cartridges produced only 1% Internal Use pages; whereas, Limited Use (with PQ categorized as either Internal Use, Individual Use, or Unusable) pages accounted for 41.3% of Xerox output. Xerox Limited Use pages exhibited print quality defects such as vertical and horizontal Streaks (74.5%), Fade (9.8%), and Color shift (7.8%).

* Statistically significant at 95% confidence level

COLOR FIDELITY

Xerox cartridges exhibited overall poor Color Fidelity. The Xerox cartridges rendered noticeably[†] inaccurate colors when compared to the colors produced by the Original HP cartridges which was used as benchmark. Xerox cartridges showed an average of 6.3 delta E on six color patches (Red, Green, Blue, Cyan, Magenta, and Yellow). The largest difference from the HP average was noted on the Xerox Red color patch with an average of 8.2 delta E. The average color difference (delta E) between color values printed by Xerox and HP cartridge sets for each of the six color patches is shown in the spider chart.

Color Fidelity:
Average Xerox Delta E Difference from Average HP

Xerox
HP Average

Yellow, Magenta, Red, Blue, Cyan, Green
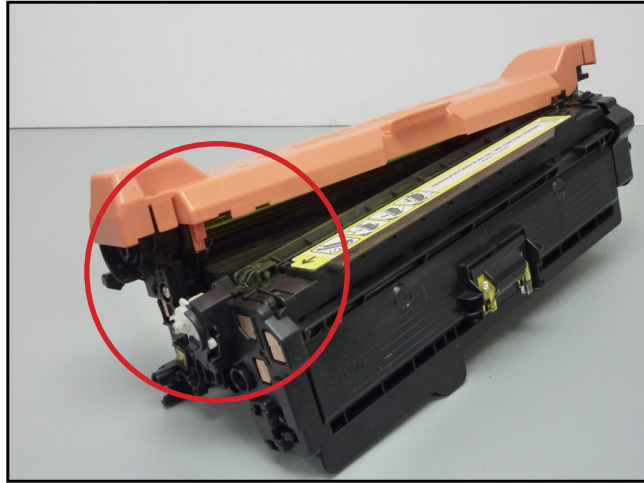

THE *spencerLAB* DIGITAL COLOR LABORATORY

Celebrating more than 25 years of industry service, SPENCER & ASSOCIATES PUBLISHING, LTD. has earned an international reputation for expertise in Color Print Quality and Consumable Yield/Cost-per-Print. *spencerLAB* DIGITAL COLOR LABORATORY, its independent test division, is recognized as a leader in unbiased, third-party digital image testing. Leading vendors also rely on *spencerLAB* to benchmark Running Cost, Throughput Performance, Reliability and Usability, and Productivity metrics for a wide variety of printing technologies – inkjet, laser/LED, thermal, and photographic, etc. *spencerLAB* provides leadership in quantitative and qualitative comparisons – test and evaluation services, focus group management, compliance certifications, benchmark test software/hardware, and custom consulting.
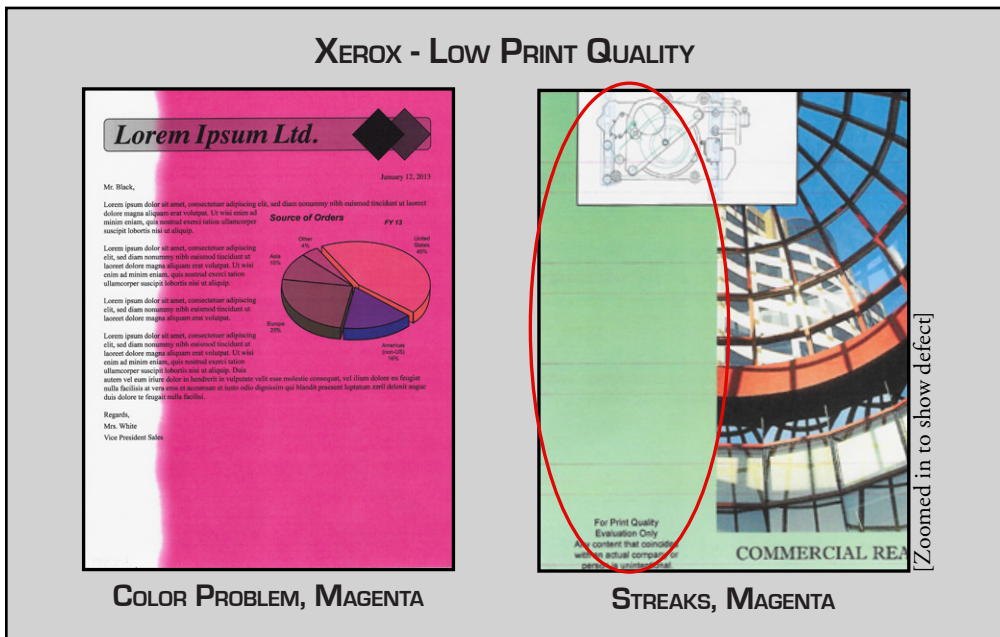
For more information, please visit www.spencerlab.com.

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RELIABILITY TESTED

[†] One (1) delta E (1976) is considered as Just Noticeable Difference

Appendix 1: Problem Cartridge Photos - Xerox Brand

Broken Cartridge, Yellow

Xerox - Low Print Quality

Color Problem, Magenta

Streaks, Magenta

[Zoomed in to show defect]

Note: Images may not be accurately reproduced when printed from this report.

APPENDIX 2: METHODOLOGY

TEST PARAMETERS

The test included CE400A/X (Black), CE401A (Cyan), CE402A (Yellow), and CE403A (Magenta) color cartridge models for the HP LASERJET Enterprise 500 color Printer M551n.

Original HP Black, Cyan, Magenta, and Yellow cartridges were acquired from multiple retail vendors in the USA. Xerox brand cartridges were acquired from multiple online vendors within the USA and Canada.

Three (3) new HP Color LaserJet printers were assigned to Xerox cartridges in order to avoid cross-contamination of brands and to minimize printer-to-printer performance variation. Original HP cartridges were assigned four (4) printers to test one cartridge set on each printer. Two (2) of these printers were used to test cartridge sets using CE400A (Black) cartridges and the other two (2) printers were used to test cartridge sets using CE400X (Black) cartridges. Original HP starter cartridges in all test printers were depleted prior to the target cartridges being installed for testing.

A staggered start was assigned to each set to simulate typical user behavior of changing a toner cartridge only when that color cartridge is depleted. Once all cartridges were

TEST SUITE: PRINT QUALITY & COLOR TEST FILES

changed in a test printer then that set of four cartridges (CMYK) was considered a Cartridge Set. Additional spare cartridges were purchased to accommodate the staggered start and for use as spares when any of the Cartridge Test Set cartridges failed. A total of 26 cartridges were tested for each brand. At the end of test, all unused spare cartridges were tested to check if they passed the DOA test.

All test supplies, such as printers, toner cartridges, and paper, were acclimated to the testing environment of 23C° +/- 2C° and 50% +/-10% RH for at least 12 hours.

The five (5) Print Quality files and one (1) Color TC9.18 RGB file [see Page 5] comprised the Test Suite and was printed using Windows 7 operating system. Test files were printed in printer default mode for plain paper, on Hammermill Fore Multi-Purpose 20lb., 96 Brightness, office paper. Printing of the Test Suite was alternated with printing of approximately 500 copies of a Low Coverage file. All test printing was performed by *spencerLAB.*

Printing was performed in a semi-continuous manner, with 3-page jobs and a pause, with stops for paper replenishment, overnight, etc., until toner cartridges reached End-of-Test. [See definition in Appendix 4]

CARTRIDGE RELIABILITY TESTING

Prior to printing, all cartridges were carefully unpacked and inspected for any toner leakage and/or broken parts; all DOAs were noted and photographed. [See definition in Appendix 4]

PRINT QUALITY ASSESSMENT

Overall Print Quality was evaluated for a maximum of 130 print samples from each toner cartridge set. All cartridge sets were expected to reach End-of-Test by providing at least 130 print quality samples. If a cartridge set failed to reach the End-of-Test mark and provided less than 130 print quality samples for grading, the remainder of the print samples were categorized as Unusable pages. The 130 print samples comprised of twenty-six five-page Print Quality files printed and collected at pre-determined intervals over the life of the cartridge set.

Using the psychometric Print Quality acceptance scale, three *spencerLAB* evaluators independently assessed and graded the overall Print Quality of each of the samples by categorizing them into one of four Print Quality levels: External Use, Internal Use, Individual

Use, and Unusable. The Print Quality level of each print sample was determined by the average of the three evaluators' grades, with defects noted.

As a part of evaluator training, the Print Quality evaluators graded a set of twenty print samples, three times each. Consistency of grading was measured among the evaluators, as well as among each evaluators' three grades for a sample. This exercise was repeated until all evaluators had acceptable consistency in grading among each other and among their three trials per sample. During evaluation of the test print samples, the Print Quality assessment by evaluators was continuously monitored to ensure consistency. Each evaluation session lasted one hour with a thirty minute break between sessions.

The Print Quality scale samples, determined during psychometric testing, were mounted in front of evaluators' workstations for reference. Print Quality evaluation was performed in a neutral environment with uniform lighting and no external lights (no windows). Lighting with a color temperature of 5000˚K +/- 500 and luminance of 550 lux +/- 50 was used in both psychometric and print sample evaluation study.

Color Fidelity Analysis

The Color TC9.18 RGB file was printed along with the five (5) page Print Quality files. The printed Color file samples were measured using an X-rite i1 iSis spectrophotometer with i1Profiler software version 1.5.0, XRD version 2.3.1.4, in single scan (M2) mode. The CIELAB ($L^*\,a^*\,b^*$) measurements of each color patch were averaged over the life of the cartridge, from beginning to End-of-Test, for each brand.

Non-HP cartridge Color file measurements were then evaluated against HP average values for Color Fidelity analysis. With HP cartridge average $L^*\,a^*\,b^*$ values as reference, the overall color difference (Delta E 1976) was calculated for six color patches – Cyan, Magenta, Yellow, Red, Green, and Blue.

APPENDIX 3: PSYCHOMETRIC STUDY – PRINT QUALITY SCALE

A psychometric study of color office printing users was conducted by *spencerLAB* in the greater New York City area (Hicksville, New York), to establish a Print Quality acceptance scale. Participants who printed color documents for personal, internal, and external use, were recruited from a range of professions and business sizes, from micro business (1-49 employees) to enterprise business (> 500 employees). A total of thirty-three business printing users participated in the exercise.

TEST SUITE

SpencerLAB collaborated with HP to design a representative business-user test suite. *SpencerLAB* then utilized the test suite pages to simulate common Print Quality defects such as banding, streaks, dark and light density, color shifts, ghosting, etc. A total of fifteen test sets were created and each test set had a range of twelve variations (based on severity of defect) for a single defect type.

Test sets were printed on a HP LASERJET Enterprise 500 color Printer M551n using Windows 7 operating system. Test samples were printed in printer default mode for plain paper on Hammermill Fore MP 20lb., 96 Brightness, plain office paper. All printing was performed by *spencerLAB* and test sets were reviewed by *spencerLAB* to ensure that the test samples were rendered as intended.
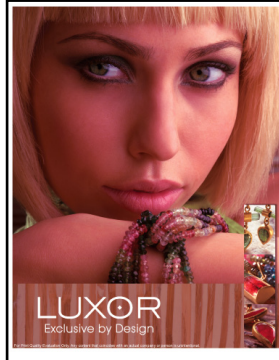
BUSINESS USER FOCUS GROUPS

The focus group participants judged fifteen sets of print samples and sorted the samples into four Print Quality levels based on their acceptance level of Print Quality. The test samples were rated in a neutral environment with uniform lighting and no external lights.
Participants sorted all the test samples into four Print Quality acceptance levels:

- External Use – acceptable for all uses, including distribution outside a company to customers, vendors, etc.

- Internal Use – acceptable for distribution inside a company, but not acceptable for distribution outside a company

- Individual Use – usable as a copy to read, file, or mark-up in the office, but not acceptable for distribution, either within or outside a company

- Unusable – not acceptable for any business purpose

SpencerLAB used proprietary sorting and analysis algorithms to calculate the average Print Quality rating of each sample for each test set. The resulting score was used to determine the rank order of samples in each test set.
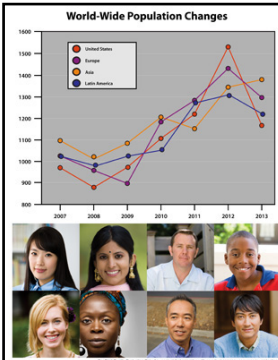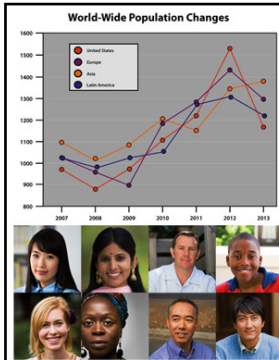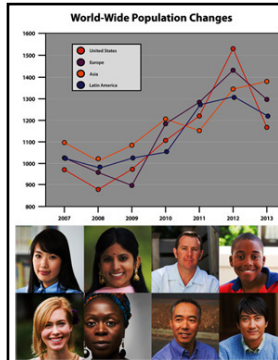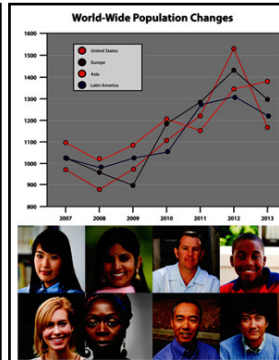
COLOR SHIFT TEST SET SAMPLE

EXTERNAL REFERENCE	EXTERNAL/INTERNAL BOUNDARY	INTERNAL/INDIVIDUAL BOUNDARY	INDIVIDUAL/UNUSABLE BOUNDARY
	LOWER PQ - INTERNAL	LOWER PQ - INDIVIDUAL	LOWER PQ - UNUSABLE

COLOR SHIFT TEST SET SAMPLE

EXTERNAL REFERENCE	EXTERNAL/INTERNAL BOUNDARY	INTERNAL/INDIVIDUAL BOUNDARY	INDIVIDUAL/UNUSABLE BOUNDARY
	LOWER PQ - INTERNAL	LOWER PQ - INDIVIDUAL	LOWER PQ - UNUSABLE

DARK DENSITY TEST SET SAMPLE

EXTERNAL REFERENCE	EXTERNAL/INTERNAL BOUNDARY	INTERNAL/INDIVIDUAL BOUNDARY	INDIVIDUAL/UNUSABLE BOUNDARY
	LOWER PQ - INTERNAL	LOWER PQ - INDIVIDUAL	LOWER PQ - UNUSABLE

Examples above are the boundary samples from three of the fifteen test sets.

NOTE: IMAGES MAY NOT BE ACCURATELY REPRODUCED WHEN PRINTED FROM THIS REPORT.

APPENDIX 4: TEST TERMS AND DEFINITIONS

Terms	Definitions
End-of-Test (EOT)	EOT for HP and non-HP cartridge sets was determined by the average Very Low page count of all HP cartridge sets. Very Low is a printer notification that a cartridge is at the estimated end of its useful life.
Dead on Arrival (DOA)	A cartridge failure determined by one of four mechanisms: 1. A cartridge that has at least 50% of the handling surface covered in leaked toner, before or during the installation process and/or toner visibly spilled in the plastic bag containing the cartridge and/or on the exterior of the cartridge. 2. A cartridge that within the first six (6) pages has at least one page categorized as Individual Use or Unusable, and does not improve during the recovery process. If at least one page is categorized as Individual Use or Unusable following this recovery process, the cartridge is DOA. 3. Cartridge is broken or missing parts. 4. Cartridge fails to operate upon installation and does not recover upon removing the cartridge and re-installation.
Recovery Process	Print Quality recovery involves the following two step process: • Recovery process 1: Print the cleaning page or perform a full calibration depending on the defect type. Reprint the 6 page print suite and evaluate those pages for categorization. If at least one page is categorized as Unusable, Recovery process 2 should be performed. • Recovery process 2: Remove the cartridge, shake it and reinstall. Print a cleaning page or perform a full calibration depending on the defect type. Reprint the 6 page print suite and evaluate those pages for categorization.
Interventions	A cartridge set may have an Intervention if a page is categorized as Individual or Unusable. The following recovery process is required: • Recovery process 1: Print the cleaning page or perform a full calibration depending on the defect type. Reprint the 6 page print suite and evaluate those pages for categorization. If at least one page is categorized as Individual or Unusable, Recovery process 2 should be performed. If all pages are better than Individual, continue testing. • Recovery process 2: Remove the cartridge, shake it and reinstall. Print a cleaning page or perform a full calibration depending on the defect type. Reprint the 6 page print suite and evaluate those pages for categorization. If any of the 5 images are still categorized as individual use, continue the testing. No more interventions shall be allowed for the test set. If any of the 5 images are Unusable the test would end and intervention documented. A maximum of two interventions shall be allowed for a Cartridge Test Set if it recovered after the first intervention recovery process.
Problem Cartridges	Toner cartridges categorized as DOA.
Limited Use	Sample pages with PQ categorized as either Internal Use, Individual Use, or Unusable.
Print Quality Levels — **External Use**	Acceptable for all uses, including distribution outside a company to customers, vendors, suppliers, etc. Examples: marketing materials to promote the company or products, official company correspondence, invoices.
Print Quality Levels — **Internal Use**	Acceptable for distribution inside a company, but not acceptable distribution outside a company. Examples: documents to distribute to colleagues, immediate superiors or subordinates as business communication.
Print Quality Levels — **Individual Use**	Usable as a copy to read, file, or mark-up in the office, but not acceptable for distribution, either within or outside a company.
Print Quality Levels — **Unusable**	Not acceptable for any business purpose.
Color Fidelity	The measure of the ability of a non-HP toner cartridge set to accurately reproduce colors printed using HP cartridge sets as benchmark.