

Colour Cartridge Reliability Comparison Study – 2014

HP LaserJet Colour Toner Cartridges vs. EMEA Non-HP Brands

The **spencerLAB** DIGITAL COLOR LABORATORY has conducted a cartridge reliability comparison testing of Hewlett-Packard [HP] LaserJet colour toner cartridges and six (6) non-HP brands of colour 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 six (6) non-HP brands tested were ActiveJet, Armor, Cactus, Freecolor (Clover), Pelikan, and Xerox.

The analysis compared the Reliability, Print Quality (PQ), and Colour Fidelity and Consistency throughout the life of the toner cartridges tested for each brand. Cartridge Reliability factors, such as Dead-on-Arrivals (DOA) and Early End-of-Life (EEOL) were evaluated to determine the total number of Problem Cartridges for each brand. User Interventions due to poor Print Quality were also tracked for each brand. Print samples and colour 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 colour charts were measured to evaluate Colour Fidelity and Consistency. [See definitions in Appendix 4]

KEY FINDINGS

- *Original HP colour toner cartridges tested showed no Problem Cartridges, whereas 14% of non-HP colour cartridges tested exhibited Dead-on-Arrivals or had an Early End-of-Life.*
- *Original HP colour toner cartridges experienced no user Interventions due to print quality problems, whereas 78% of the non-HP colour cartridge sets required at least one or more user Interventions due to poor print quality.*
- *Non-HP colour cartridges exhibited poor Colour Fidelity with inaccurate colour rendition over the life of the cartridge sets compared to colours produced by Original HP colour cartridge sets.*
- *Original HP colour toner cartridges provided more consistent colour over the life of the cartridges compared to non-HP colour cartridges.*
- *Original HP colour cartridges had the largest percentage (99%) of External Use Print Quality samples, clearly surpassing the quality of all tested non-HP brands where only 49% of the samples inspected were acceptable for External Use.*

The **spencerLAB** DIGITAL COLOR LABORATORY, a division of Spencer & Associates Publishing, Ltd., is an independent test laboratory with a broad base of industry clients. Although this independent comparative study was commissioned by Hewlett-Packard Company, **spencerLAB** believes these results maintain its reputation for the integrity of its procedures and analyses. Results stated herein are based upon direct testing by **spencerLAB** of actual products believed to be representative.

TEST RESULTS

CARTRIDGE RELIABILITY

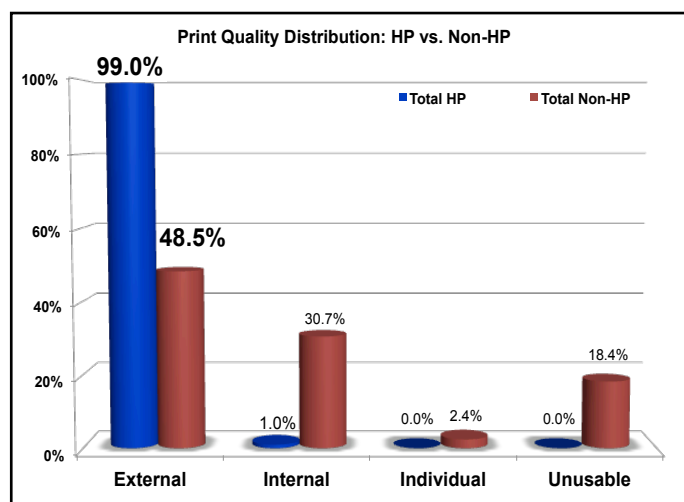
HP cartridges were more reliable than the non-HP brands; none of the HP cartridges were deemed Problem Cartridges. None of the HP cartridge sets required any user Interventions due to poor print quality.

The non-HP cartridges exhibited Reliability issues before, during, and after installation. Out of the 130 procured non-HP cartridges, 14% were deemed as Problem Cartridges. 14 of the 18 (78%) tested non-HP cartridge sets required at least one or more user Interventions to attempt a recovery due to poor print quality.

Problem Cartridges and Print Quality Problems				
Cartridge Brand	Problems Cartridges			PQ Problems
	Dead on Arrival	Early End-of-Life	Total	Interventions
HP	0%	0%	0%	0%
Non-HP	10%	4%	14%	78%

PRINT QUALITY DISTRIBUTION

HP cartridges produced significantly* greater number of pages with higher Print Quality than the non-HP brands. HP cartridges produced a total of 99.0% of print samples categorized as good for External Use. Comparatively, the non-HP brand cartridges produced only 48.5% of pages that were good for External Use.



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 51.5% of non-HP brand output. Non-HP brand Limited Use pages exhibited print quality defects such as vertical and horizontal Streaks (47.3%) and Colour Shift (27.8%).

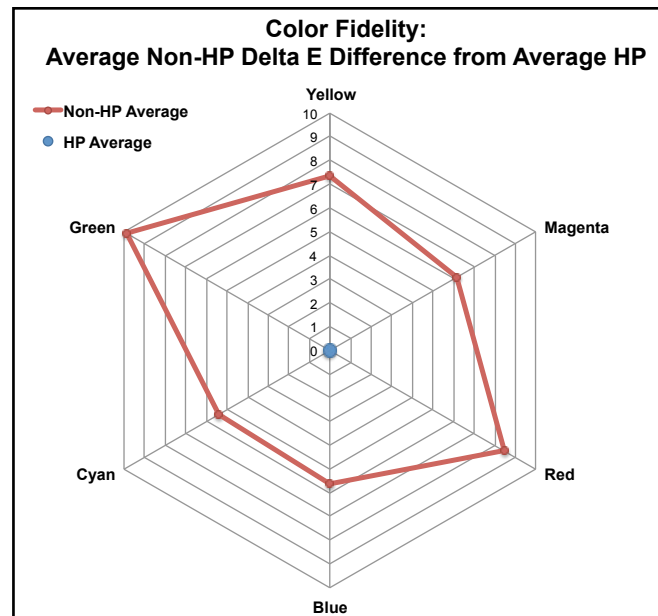
* Statistically significant at 95% confidence level

COLOUR FIDELITY AND CONSISTENCY

The non-HP brands exhibited overall poor Colour Fidelity. The non-HP cartridges rendered noticeably[†] inaccurate colours when compared to the colours produced by the Original HP cartridges which was used as benchmark. Non-HP cartridges showed an average of 7.1 delta E on six colour patches (Red, Green, Blue, Cyan, Magenta, and Yellow). The largest difference from the HP average was noted on the non-HP Green colour patch with an average of 9.85 delta E.

The average colour difference (delta E) between colour values printed by non-HP and HP cartridge sets for each of the six colour patches is shown in the spider chart.

Over the life of the cartridge sets, HP colour cartridges rendered a more consistent colour gamut than the average non-HP cartridges.



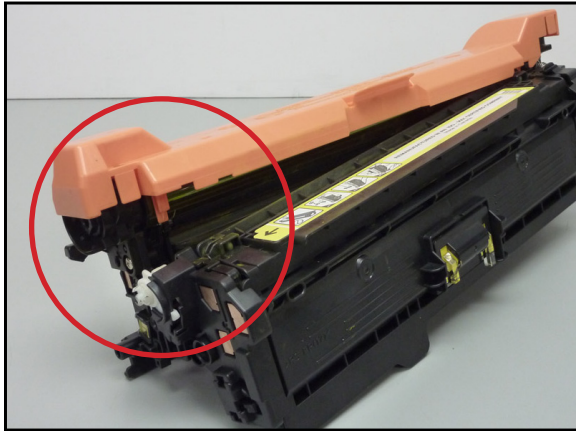
THE **spencerLAB** DIGITAL COLOR LABORATORY

Celebrating more than 25 years of industry service, SPENCER & ASSOCIATES PUBLISHING, LTD. has earned an international reputation for expertise in Colour 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.

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

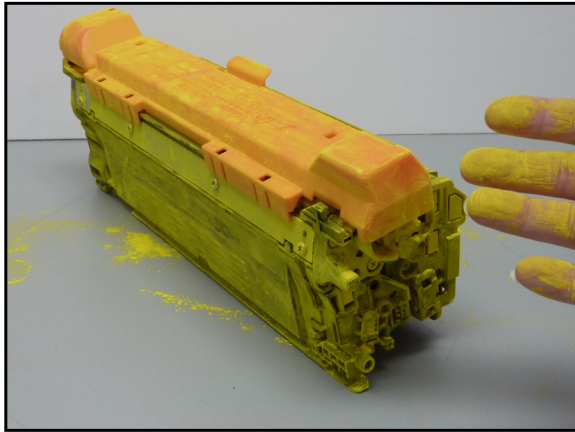
APPENDIX 1: PROBLEM CARTRIDGE PHOTOS - NON-HP BRANDS



BROKEN CARTRIDGE, YELLOW



PULL TAB STUCK, MAGENTA



TONER LEAKAGE, YELLOW



TONER LEAKAGE, BLACK

NON-HP - PRINT QUALITY PROBLEMS

COLOUR PROBLEM, BRAND F, MAGENTA

STREAKS, BRAND F, MAGENTA

COLOUR PROBLEM, BRAND B, BLACK

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APPENDIX 2: METHODOLOGY

TEST PARAMETERS

The test included CE400A/X (Black), CE401A (Cyan), CE402A (Yellow), and CE403A (Magenta) colour cartridge models for the HP LASERJET Enterprise 500 color Printer M551n. The six (6) non-HP brands tested, in early 2014, were ActiveJet, Armor, Cactus, Freecolor (Clover), Pelikan, and Xerox. Xerox cartridges were sourced from Canada and USA; all other brands were sourced from countries in EMEA.

Original HP Black, Cyan, Magenta, and Yellow cartridges were acquired from multiple retail vendors in the USA. Each brand of non-HP cartridges were acquired from multiple vendors, when available, either through retail, online, or direct channels.

Three (3) new HP Color LaserJet printers were assigned to each non-HP brand 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 colour cartridge is depleted. Once all cartridges were 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. When Black-A cartridges were not available Black-X cartridges were purchased and tested for that brand. A total of 24 cartridges were tested for brands that had Black-X and a total of 26 cartridges were tested for brands that had Black-A. 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) Colour 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. (75 gsm), 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 colour temperature of 5000°K +/- 500 and luminance of 550 lux +/- 50 was used in both psychometric and print sample evaluation study.

COLOUR FIDELITY AND CONSISTENCY ANALYSIS

The Colour TC9.18 RGB file was printed along with the five (5) page Print Quality files. The printed Colour 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 colour patch were averaged over the life of the cartridge, from beginning to End-of-Test, for each brand.

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

Colour Gamut variation over the life of the cartridge sets was also evaluated by measuring the Gamut Volumes approximately every 2,000 test pages throughout the test. Average gamut volume standard deviation of HP cartridge sets was compared with that of the average non-HP cartridge sets to evaluate consistency.

APPENDIX 3: PSYCHOMETRIC STUDY – PRINT QUALITY SCALE

A psychometric study of colour 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 colour 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, colour 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.

COLOUR SHIFT TEST SET SAMPLE



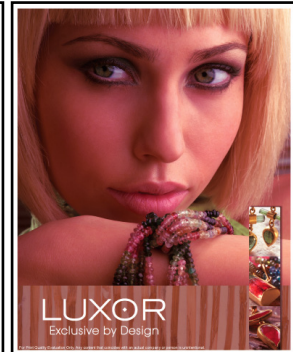
EXTERNAL REFERENCE



**EXTERNAL/INTERNAL
BOUNDARY**
LOWER PQ - INTERNAL

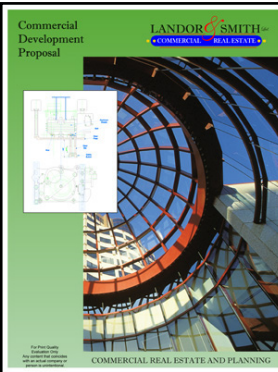


**INTERNAL/INDIVIDUAL
BOUNDARY**
LOWER PQ - INDIVIDUAL



**INDIVIDUAL/UNUSABLE
BOUNDARY**
LOWER PQ - UNUSABLE

COLOUR SHIFT TEST SET SAMPLE



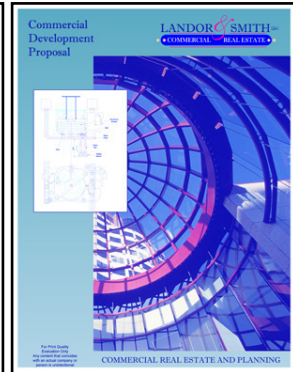
EXTERNAL REFERENCE



**EXTERNAL/INTERNAL
BOUNDARY**
LOWER PQ - INTERNAL

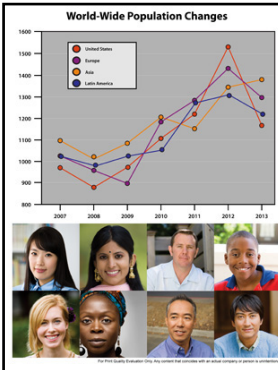


**INTERNAL/INDIVIDUAL
BOUNDARY**
LOWER PQ - INDIVIDUAL



**INDIVIDUAL/UNUSABLE
BOUNDARY**
LOWER PQ - UNUSABLE

DARK DENSITY TEST SET SAMPLE



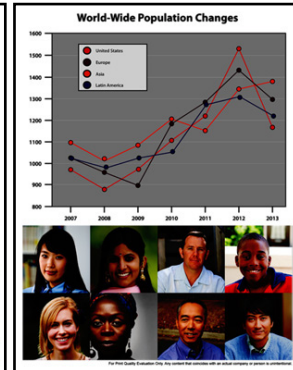
EXTERNAL REFERENCE



**EXTERNAL/INTERNAL
BOUNDARY**
LOWER PQ - INTERNAL



**INTERNAL/INDIVIDUAL
BOUNDARY**
LOWER PQ - INDIVIDUAL



**INDIVIDUAL/UNUSABLE
BOUNDARY**
LOWER PQ - UNUSABLE

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

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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: <ul style="list-style-type: none"> 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.
Early End-of-Life, (EEOL)		A cartridge failure that occurs prior to 80% of HP average page count and determined by one of four mechanisms: 1. A cartridge that has at least 50% of the handling surface covered in leaked toner, or a cartridge that leaks toner inside the printer that would accumulate to ~1cm ² . 2. A cartridge that after installation has at least one page categorized as Unusable, and does not improve during the recovery process. If any of the 5 images is Unusable the cartridge would be considered EEOL. 3. A cartridge that sustains broken components. 4. A cartridge stops printing for reasons other than PQ and does not recover.
Interventions		A cartridge set may have an Intervention if a page is categorized as Individual or Unusable. The following recovery process is required: <ul style="list-style-type: none"> 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 either DOA or EEOL.
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.
	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.
	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.
Colour Fidelity		The measure of the ability of a non-HP toner cartridge set to accurately reproduce colours printed using HP cartridge sets as benchmark.
Colour Gamut		The range of colours that can be printed using a cartridge set.