*spencer*LAB
DIGITAL COLOR LABORATORY

Color Cartridge Reliability Comparison Study – 2019

HP LaserJet Color Toner Cartridges vs. Non-HP Brands in Europe

The *spencerLAB* DIGITAL COLOR LABORATORY has conducted a cartridge reliability comparison testing of HP LaserJet color toner cartridges and six Non-HP brands of color toner cartridges. The test included CE410A/X (Black), CE411A (Cyan), CE412A (Yellow), and CE413A (Magenta) cartridges for the HP LASERJET Pro 400 color Printer M451dn. The six Non-HP brands tested were Xerox, Armor OWA, Freecolor, Prime Printing, Black Point, and Cactus, all sourced from within the Europe.

The analysis compared the Reliability, Print Quality (PQ), and Color Fidelity 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 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 46% of Non-HP color cartridges tested exhibited Dead-on-Arrivals or had an Early End-of-Life.

- Original HP color toner cartridge sets experienced no user Interventions due to print quality problems, whereas 61% of the Non-HP color cartridge sets required at least one or more user Interventions due to poor print quality.

- Non-HP color cartridge sets 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 (98%) of External Use Print Quality samples, clearly surpassing the quality of all tested Non-HP brands where only 33% of the samples inspected were acceptable for External Use.

- Original HP cartridges produced an average of 22% more Usable Pages than Non-HP cartridges.

TEST RESULTS

CARTRIDGE RELIABILITY

HP cartridges were more reliable than the Non-HP brands; 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.
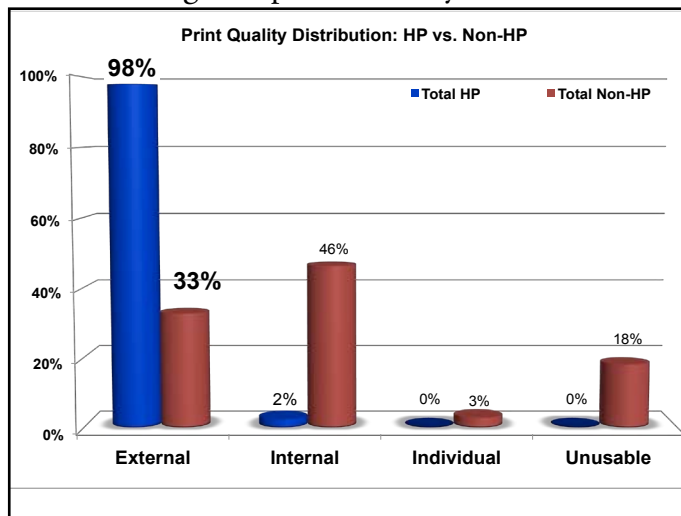
The Non-HP cartridges exhibited Reliability issues before, during, and after installation. Out of the 78 procured Non-HP cartridges, 46% were deemed as Problem Cartridges. Eleven of the eighteen (61%) tested Non-HP cartridge sets required at least one or more user Interventions to attempt a recovery due to poor print quality.

Problem Cartridges and Print Quality Problems				
Cartridge Brand	**Problem Cartridges**			**PQ Problems**
	Dead-on-Arrival	Early End-of-Life	Total	Interventions
HP	0%	0%	0%	0%
Non-HP	8%	38%	46%	61%

PRINT QUALITY DISTRIBUTION

HP cartridge sets produced a significantly greater number of pages with higher Print Quality than the Non-HP brands. HP cartridge sets produced a total of 98% of print samples categorized as good for External Use. Comparatively, the Non-HP brand cartridge sets produced only 33% of pages that were good for External Use.

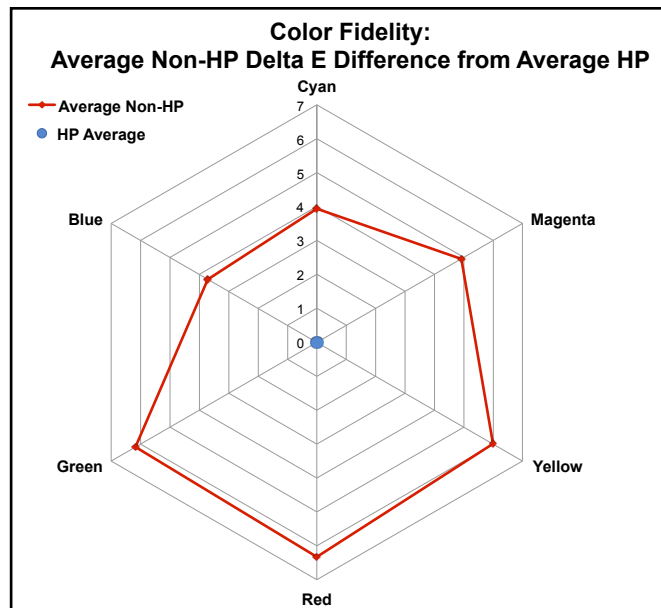HP cartridge sets produced only 2% Limited Use (with PQ categorized as either Internal Use, Individual Use, or Unusable) pages, all of which were Internal Use pages with 0% Individual and 0% Unusable pages (see chart at left). Whereas, Limited Use pages accounted for 67% of Non-HP brand output. Non-HP brand Limited Use pages exhibited print quality defects such as Hue Shift (17%), Fade (12%), Banding (horizontal in portrait mode; 12%), Streaks (7%), and Ghosting (7%).

Print Quality Distribution: HP vs. Non-HP

COLOR FIDELITY

The Non-HP brands exhibited overall poor Color Fidelity. The Non-HP cartridges rendered noticeably* inaccurate colors when compared to the colors produced by the Original HP cartridge sets which were used as the benchmark.

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

Color Fidelity:
Average Non-HP Delta E Difference from Average HP

— Average Non-HP
● HP Average

Non-HP cartridge sets showed an average of 5.18 delta E on six color patches (Red, Green, Blue, Cyan, Magenta, and Yellow). The largest difference from the HP average was noted on the Non-HP Red color patch with an average of 6.33 delta E.

PAGE COUNT

Original HP cartridges produced an average of 22% more Usable Pages than Non-HP cartridges. The average Usable page count of each tested brand was taken to calculate the overall average page count.

THE *spencerLAB* DIGITAL COLOR LABORATORY

Celebrating 30 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. The *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.

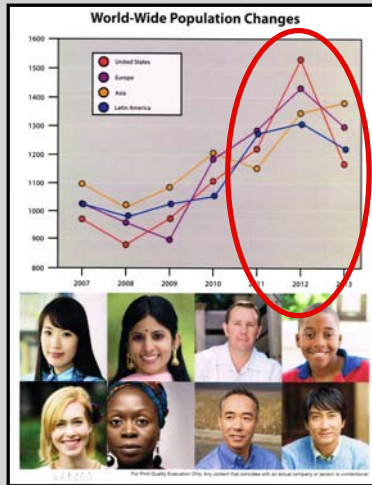* One (1) delta E (1976) is considered as a Just Noticeable Difference

APPENDIX 1: PROBLEM CARTRIDGE PHOTOS - NON-HP BRANDS
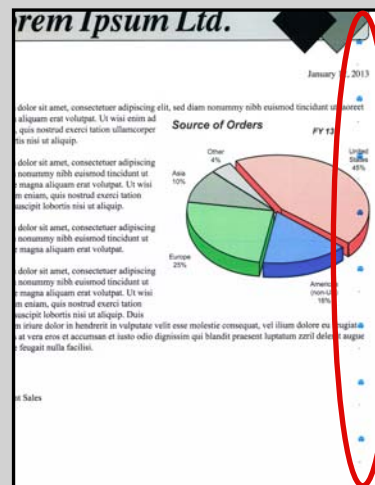

Images magnified to show leaks.

LEAKING CYAN CARTRIDGE, BRAND E

NON-HP - LOW PRINT QUALITY

HUE SHIFT, BRAND C

[Some images zoomed in to show defect]

SMUDGE, BRAND E

BANDING - BRAND B

FADE, BRAND C

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

APPENDIX 2: METHODOLOGY

TEST PARAMETERS

The test included CE410A/X (Black), CE411A (Cyan), CE412A (Yellow), and CE413A (Magenta) cartridges for the HP LaserJet Pro 400 color Printer M451dn. The six Non-HP brands tested were Xerox, Armor OWA, Freecolor, Prime Printing, BlackPoint, and Cactus, all sourced from within Europe. When standard yield Black (CE410A) cartridges were not available, high yield Black (CE410X) cartridges were purchased and tested for that brand. A total of twelve (or more, if replaced for DOA or Early End-of-Life) cartridges were tested for each brand.

Three 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 printers to test one cartridge set on each printer. Two of these printers were used to test cartridge sets containing standard yield Black cartridges and the other two printers were used to test cartridge sets containing high yield Black cartridges. Original HP starter cartridges were used in all test printers to burn in the system.

TEST SUITE: PRINT QUALITY & COLOR TEST FILES

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 four individual Test cartridges were installed in a test printer, 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. No test cartridges were replaced after the last staggered cartridge was installed.

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 prior to testing.

Five Print Quality files and the TC9.18 RGB patch target file [see Page 5] comprised the Test Suite and were 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 approximately two hundred copies of a low coverage file in a semi-continuous manner, with two-page jobs and a pause, stopping only for paper replenishment, overnight, etc., until toner cartridges reached Unusable [see definition in Appendix 4]. All test printing was performed by *spencerLAB.*

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 eighty print samples from each toner cartridge set. All cartridge sets were expected to produce at least eighty print quality samples. If a cartridge set reached the Unusable mark prior to eighty print quality samples for grading, the remainder of the count was categorized as Unusable pages. The eighty print samples were comprised of sixteen 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 illuminance of 550 lux +/- 50 was used in both psychometric and print sample evaluation studies.

Page Count Calculation

Page Count was determined by averaging the total Usable pages printed prior to EOT for all cartridges [see definition in Appendix 4].

Color Fidelity Analysis

The TC9.18 RGB patch target file was printed along with the five page Print Quality files. The printed patch file samples were measured using an X-Rite i1iSis spectrophotometer with i1Profiler software version 1.7.2, XRD version 3.0.11, 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 Unusable, for each brand.

Non-HP cartridge patch 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:
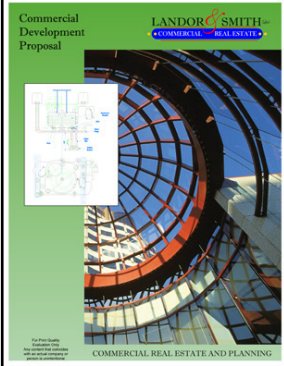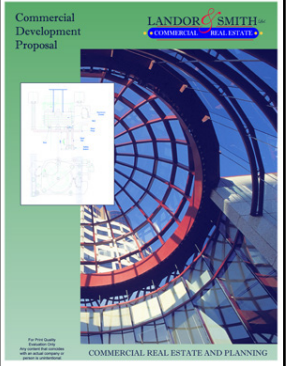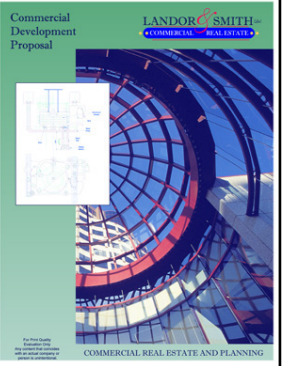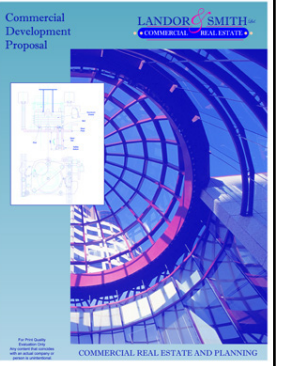
- External Use – acceptable for all uses, including distribution outside a company to customers, vendors, etc.

- 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.
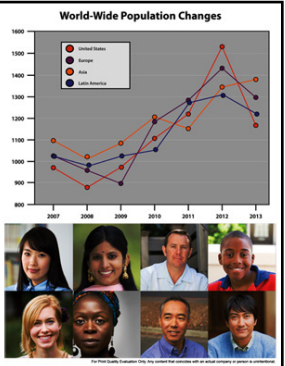
Color Shift Test Set Sample

| External Reference | External/Internal Boundary Lower PQ - Internal | Internal/Individual Boundary Lower PQ - Individual | Individual/Unusable Boundary Lower PQ - Unusable |

Color 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	End-of-Test 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 Test Suite has at least one PQ 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 the 5 PQ 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 is not a DOA but 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 are 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 performed: • 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 the 5 PQ 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 the 5 PQ 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 a DOA or EEOL.
Limited Use	Sample pages with PQ categorized as either Internal Use, Individual Use, or Unusable.

Terms		Definitions
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.
Usable Pages		Pages that were acceptable for any use, and not deemed Unusable.
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.

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