TEST REPORT

spencerLAB DIGITAL COLOR LABORATORY

Monochrome Cartridge Reliability Comparison Study – 2016

HP LaserJet Toner Cartridges vs. Freecolor Brand by Clover Imaging Group

The *spencerLAB* DIGITAL COLOR LABORATORY has conducted a cartridge reliability comparison testing of original HP Inc. (HP) Monochrome LaserJet toner cartridges and one (1) non-HP brand of monochrome toner cartridges sold as substitutes in EMEA. The test included CF280A (80A) and CF283A (83A) cartridge models for the HP LaserJet Pro 400 M401n and HP LaserJet Pro M127fn, respectively. The one non-HP brand tested was Freecolor, sourced from Germany. Twenty (20) cartridges of each brand were tested to get statistically significant overall results.

The analysis compared the Reliability, Comparative Page Yield, and the overall Print Quality (PQ) throughout the life of the toner cartridge models tested for each brand. Cartridge Reliability factors, such as Dead-on-Arrivals (DOA) and Low Quality (LQ) cartridges [See definitions in Appendix 4], were evaluated to determine the total number of Problem Cartridges for each brand. Print samples from each cartridge brand were collected at equal intervals over the life of the cartridge, and sorted using a Print Quality Acceptance scale generated from a psychometric research study. The four PQ acceptance levels were – External Use (all uses including distribution outside the company), Internal Use (distribution inside company), Individual Use, and Unusable.

Key Findings

- ***Testing of the Original HP toner cartridges yielded no Problem Cartridges, whereas 90% of non-HP cartridges exhibited some kind of reliability problem.***
- ***HP cartridges also had the largest percentage of External Use Print Quality samples, clearly surpassing the quality of all tested non-HP brands.***
- ***Original HP cartridges produced an average of 21% more Usable Pages than non-HP cartridges.***

Cartridge Reliability – Problem Cartridges

HP cartridges were far more reliable than the tested non-HP brands; none of the tested HP cartridges were deemed Problem Cartridges. The non-HP cartridges exhibited several Reliability issues such as DOA and LQ, with a total of 90% Problem Cartridges.

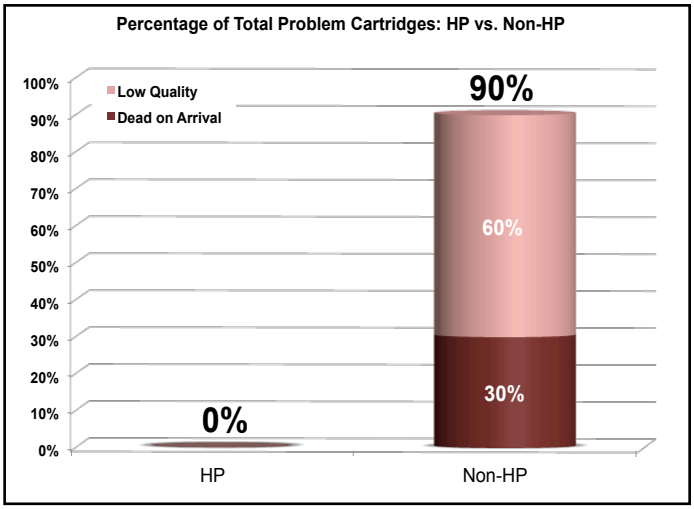
Print Quality Page Distribution

HP toner cartridges printed a total of 95% of the Print Quality samples categorized as External Use, compared to the tested non-HP cartridges that printed a total of only 27.1% External Use samples.

Test Results

Cartridge Reliability: Dead-on-Arrival & Low Quality

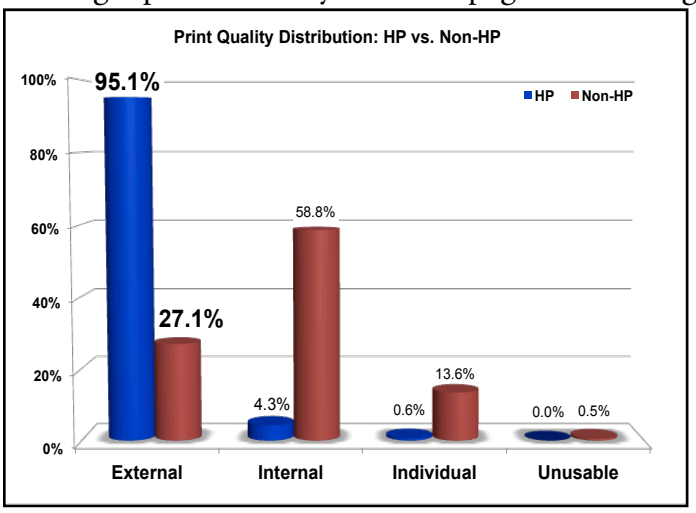
HP cartridges were significantly* more reliable than the tested non-HP brands; none of the tested HP cartridges were deemed Problem Cartridges (DOA or LQ).



All non-HP brand toner cartridges suffered from Reliability issues such as DOA and LQ, yielding a total of 90% Problem Cartridges of the 20 tested with DOA cartridges making up 30%. Problem cartridges are disruptive causing inconvenience to the user and substantially impacting productivity and increasing the overall cost of the cartridge.

Print Quality Distribution

HP cartridges produced significantly* greater number of pages with higher Print Quality (PQ) than the non-HP brands tested. Tested HP cartridges produced a total of 95.1% of print samples categorized as good for External Use. Comparatively, the non-HP brand cartridges produced only 27.1% of pages that were good for External Use.



HP cartridges produced only 4.9% Limited Use pages (with PQ categorized as either Internal Use, Individual Use, or Unusable); whereas, Limited Use pages accounted for 72.9% of non-HP brand output. Of the non-HP brand Limited Use pages, 56% exhibited print quality defects such as vertical and horizontal Streaks and Ghosting.

Comparative Page Yield†

Original HP cartridges produced an average of 21% more Usable Pages than non-HP cartridges. The average page count of each SKU tested – 80A and 83A – was taken to calculate the overall average page count.

* Statistically significant at 95% confidence level

† Comparative Page Yield was not determined using ISO/IEC Standard 19752 and is NOT ISO yield. Comparative Page Yield was determined by printing a 4-page Print Quality Test Suite until End-of-Life (EOL) [defined in Appendix 4]. Comparative Page Yield calculation incorporates reliability factors such as Dead on Arrival (DOA) that affect the total page yield.

The *spencerLAB* Digital Color Laboratory

Through more than two decades of industry service, Spencer & Associates Publishing, Ltd. has earned a premier reputation for its expertise in evaluating digital color imaging and printing. Its independent test division, the *spencerLAB* digital color laboratory, is internationally recognized as a leader in unbiased, third-party research and comparative analysis of digital imaging and printing system performance; the laboratory strictly adheres to the integrity of its methodology, even in commissioned studies. *SpencerLAB* provides leadership in quantitative and qualitative comparisons, benchmarking key performance metrics of digital printing systems in all technology classes, from desktop printers to digital color presses – providing research and evaluation services, compliance certifications, benchmark test software/hardware, and focus group management.

Leading vendors and firms for whom printing is mission-critical rely upon *spencerLAB* to provide strategic support and benchmarking of Print Quality, Ink/Toner Yield and Cost-per-Print, Throughput, Availability, Reliability and Usability for ink- and toner-based as well as other printing technologies. Corporate users rely upon *spencerLAB* for guidance in print system acquisition and usage optimization. For more information, please visit www.spencerlab.com.

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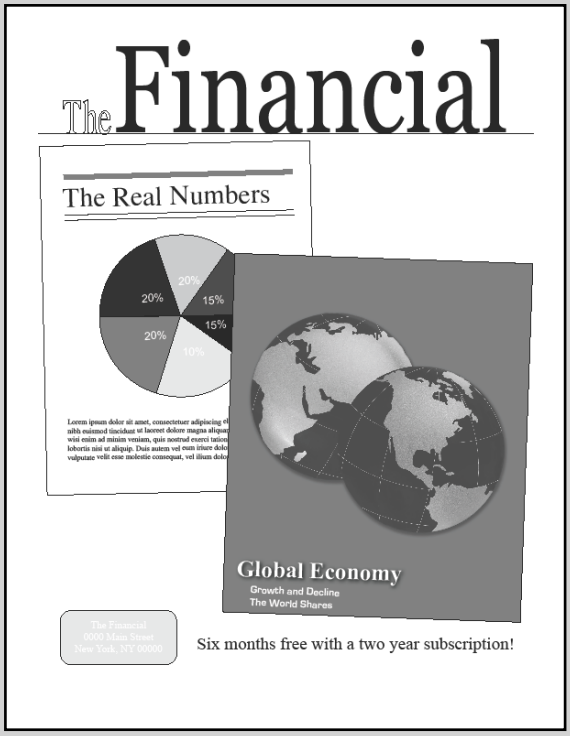
spencerLAB RELIABILITY TESTED

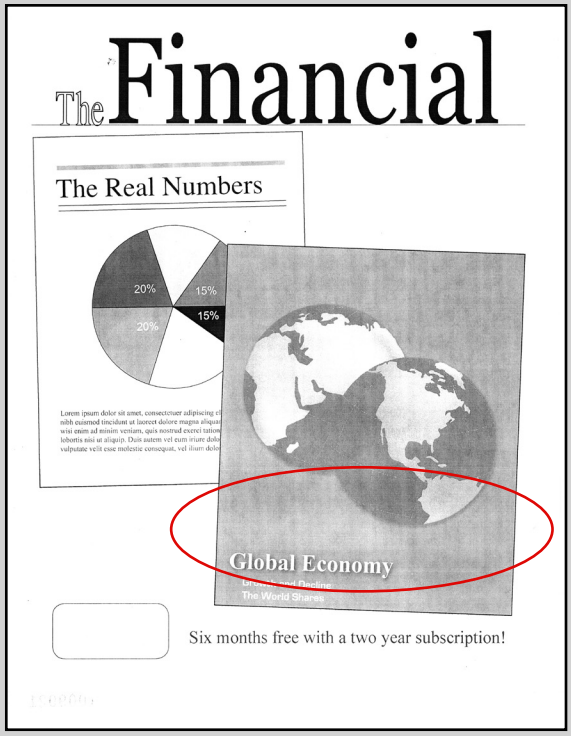
Appendix 1: Additional Brand Results

Print Quality Problems

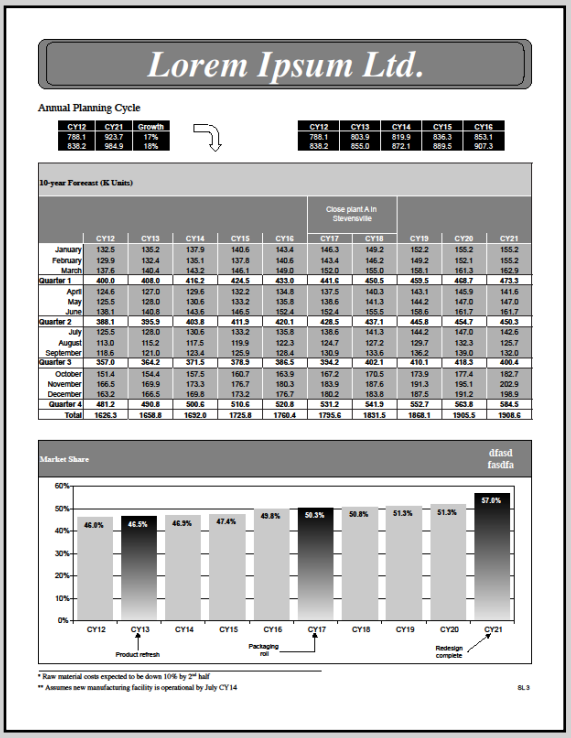
Original



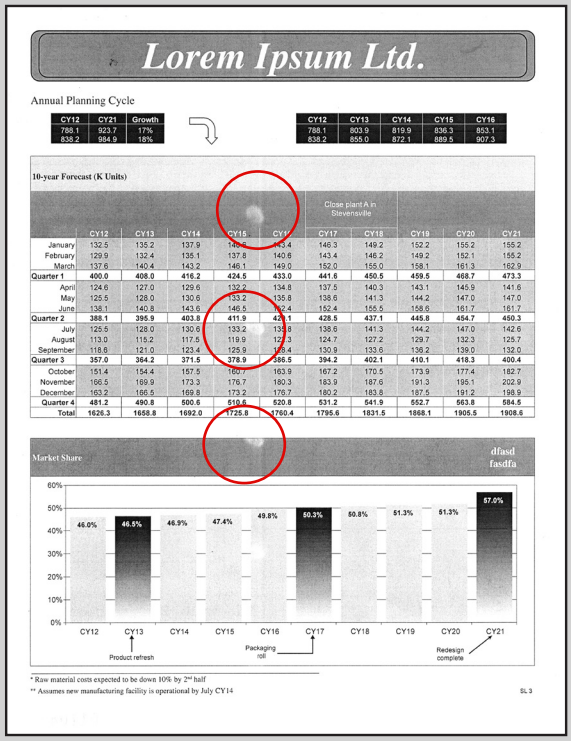
Non-HP 83A



Original



Non-HP 80A



Appendix 2: Methodology

Test Parameters

The test included 80A and 83A cartridge models for the HP LaserJet Pro 400 M401n and HP LaserJet Pro M127fn, respectively. The one non-HP brand tested was Freecolor, sourced from Germany. The non-HP brand was selected by HP and procured by *spencerLAB* for testing. Twenty (20) cartridges of each brand were tested to get statistically significant overall results.

Original HP 80A and 83A toner cartridges were acquired from multiple retail vendors in the USA. The non-HP brand cartridges were acquired either through retail, online, or direct channels, from Germany.

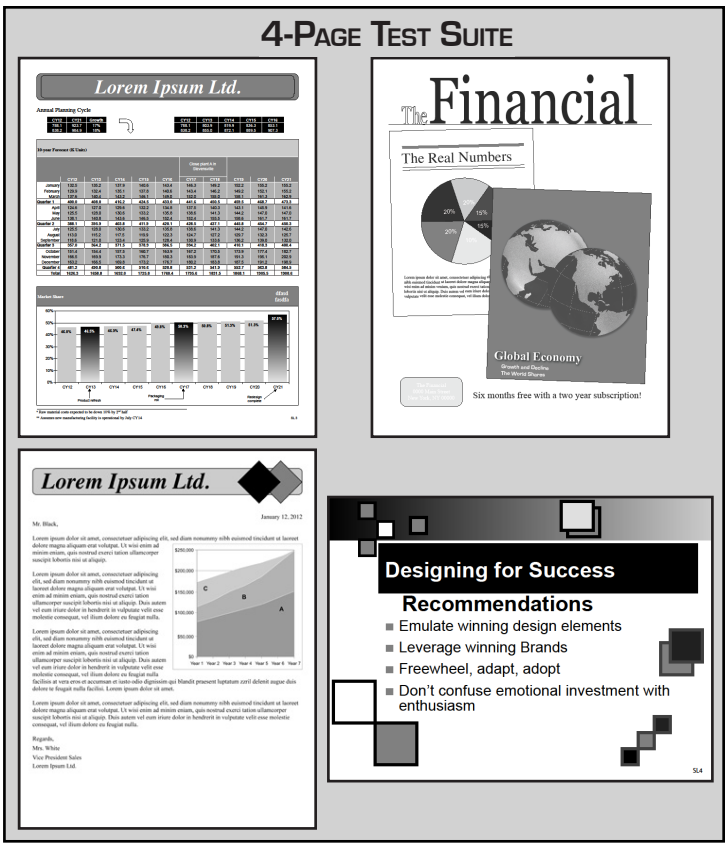
A four-page PDF test suite was printed under Windows 8.1 operating system, using Acrobat Reader 11.0.09. Test files were printed in default mode for plain paper, using the latest printer drivers available from HP's web site, on Hammermill Fore Multi-Purpose 20lb., 96 Brightness, office paper. All test printing was performed by *spencerLAB*.

Two (2) new HP test printers were assigned to each toner cartridge brand and model in order to avoid cross-contamination of brands and to minimize printer-to-printer performance variation. HP OEM starter cartridges in all test printers were depleted prior to the target cartridges being installed for testing. 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. Printing was performed in a semi-continuous manner, with stops for paper replenishment, overnight, etc., until toner cartridges reached End-of-Life (EOL). EOL is defined as degradation of Print Quality of any one page of the four-page suite to Unusable (grading scale with Unusable Print Quality benchmark established by psychometric study [see Appendix 3]). Two "shake procedures" were performed before a cartridge was deemed at EOL.

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 definitions in Appendix 4]

Print Quality Assessment



Overall Print Quality was evaluated on a total of sixty-four print samples from each toner cartridge. The sixty-four print samples comprised of sixteen four-page suites collected at equally dispersed intervals over the life of the cartridge. For cartridges that were deemed DOA due to low Print Quality, the first and last test suites printed during the cartridge recovery process were also collected and graded.

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 also 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 with luminance of 550 lux +/- 50 was used in both psychometric and print sample evaluation study.

Comparative Page Yield Calculation

Comparative Page Yield was determined by averaging the total Usable pages printed prior to EOL for all cartridges, for each SKU tested – 80A and 83A. DOA cartridges (except for Early Failure cartridges) were included as cartridges with a zero page count since no usable pages were produced.

Appendix 3: Psychometric Study – Print Quality Scale

A psychometric study of monochrome office printing users was conducted by *spencerLAB* in the greater New York City area (Hicksville, New York) in March of 2012, to establish a Print Quality acceptance scale. Participants who printed monochrome 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-eight 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, ghosting, etc. A total of fifteen test sets were created and each test set had a range of up to twelve variations (based on severity of defect) for a single defect type.

Test sets were printed on a HP LaserJet P3015 using Windows 7 and Acrobat Reader 10.1.2. Test samples were printed in default mode for plain paper, using the latest print driver available from HP's web site at the time of printing on Hammermill Fore MP 20lb., 96 Brightness, plain office paper. All printing was performed by *spencerLAB* and test sets were reviewed to ensure that the test samples were rendered as intended.

Business User Focus Groups

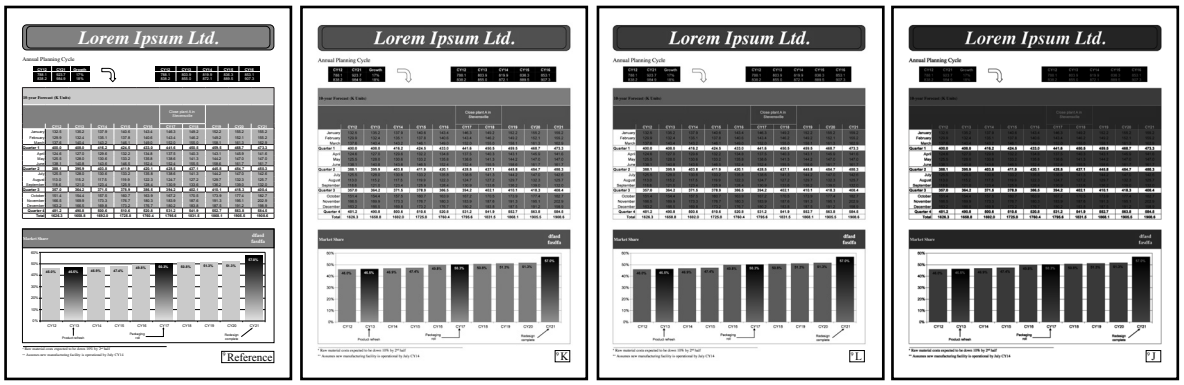
The focus group participants judged fifteen sets of print samples and sorted the samples into four Print Quality levels based on their acceptance level of Print Quality. The test samples were rated in a neutral environment, with no external lights, and uniform lighting.

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.

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

Light 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 two 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-Life, (EOL)		A condition determined by one of three mechanisms: 1. Cartridge is Dead on Arrival. 2. Cartridge stops printing and efforts to recover are unsuccessful. 3. Degradation of Print Quality to unacceptable (Unusable) for any one of the Test Suite pages. Any printer documentation recommendations are performed no more than two times to recover PQ. After the second recovery, if PQ does not recover or degrades to Unusable, EOL is reached and marked before pages of unacceptable quality.
Dead on Arrival, (DOA)		A condition determined by one of five 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 ten (10) pages has at least one page categorized as Individual Use or Unusable, and does not improve during the recovery process. • Recovery process requires following the printer manual instructions for correction of the noted defect, or if the defect is not addressed in the manual, the first attempt to recover shall be to remove the cartridge and perform a shake procedure. Following this recovery process, ten (10) more pages shall be printed and evaluated. If at least one page is categorized as Individual Use or Unusable, a second recovery attempt of printing a cleaning page, if available, shall be performed. Following the second recovery procedure, ten (10) more pages shall be printed and pages evaluated for categorization. If at least one page is categorized as Individual Use or Unusable following this recovery process, the cartridge is DOA. 3. Early Failure – a cartridge that reaches EOL with a page count of less than 20% of the average page count for all Original HP LaserJet cartridges of that model; unless non-HP cartridge stated yield differs from HP stated yield and reaches EOL with a page count of less than 20% of the average page count for all the other tested toner cartridges from that manufacturer for that model. 4. Cartridge is broken or missing parts. 5. Cartridge fails to operate upon installation and does not recover upon removing the cartridge and re-installation.
Shake Procedure		Remove toner cartridge from printer, rock or shake cartridge (as per manufacturers instructions) front to back for a minimum of 3 times. Reinstall cartridge into printer.
Low Quality, (LQ)		A cartridge with 50% or more pages categorized as Limited Use, but was not DOA.
Problem Cartridges		Cartridges categorized as either DOA or LQ.
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.
Usable Pages		Pages that were acceptable for any use, and not deemed Unusable.
Comparative Page Yield		Average number of Usable Pages produced from all cartridges of each model tested.
Non-HP Toner Cartridge		A cartridge that is sold as a substitute for an Original HP cartridge, but was not manufactured or authorized by HP.