TEST REPORT

spencerLAB DIGITAL COLOR LABORATORY

Color Cartridge Reliability Comparison Study – 2024

HP LaserJet Color Toner Cartridges vs. EMEA Remanufactured Brands

The *spencerLAB* DIGITAL COLOR LABORATORY has conducted a cartridge reliability comparison testing of original HP LaserJet color toner cartridges and two Remanufactured brands of color toner cartridges sold in the EMEA region. The test included CF410A (Black), CF411A/X (Cyan), CF412A (Yellow), and CF413A (Magenta) cartridges for the HP LaserJet Pro M452dn color printer.

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-Arrival (DOA), Low Quality (LQ), and Premature Failure (PF) [see definitions in Appendix 4], were evaluated to determine the total number of Problem Cartridges 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 definition in Appendix 4].

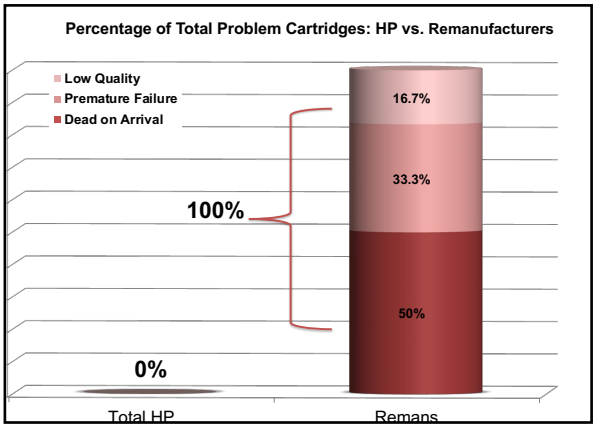
Key Findings

- Original HP color toner cartridges tested showed no Problem Cartridges, whereas 100% of the Remanufactured color cartridges tested exhibited some type of Reliability problem, such as Dead-on-Arrival, Low Quality, or Premature Failure.
- Original HP color cartridges had the largest percentage (98.8%) of External Use Print Quality samples, surpassing the quality of all tested Remanufactured brands where only 1.7% of the samples inspected were acceptable for External Use.
- Remanufactured brands tested exhibited more Print Quality Samples with defects, including hue shifts, banding, ghosting, dots, and streaks.
- Remanufactured 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 cartridges produced an average of 50% more Usable Pages than Remanufactured brand cartridges.

Test Results

Cartridge Reliability

Tested HP cartridges were more reliable than the Remanufactured brands; none of the HP cartridges were deemed Problem Cartridges - no Low Quality, no Premature Failures, and no Dead-on-Arrival 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.

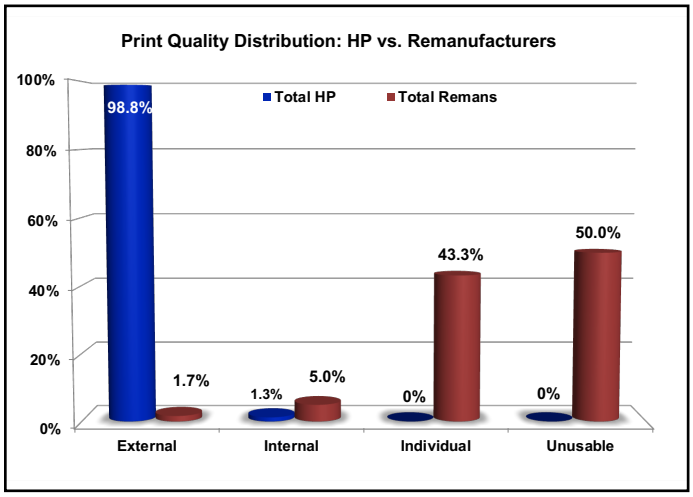


The Remanufactured cartridges exhibited Reliability issues throughout the test. Of the twenty-four Remanufactured cartridges procured (six CMYK cartridge sets) 100% were deemed as Problem cartridges, with 50% of cartridge sets deemed DOA. Premature Failure cartridges (those with page counts of less than 80% of the average page count for all HP cartridges, but not DOA) accounted for 33.3% of the Remanufactured cartridges, and Low Quality cartridges (those with 50% or more pages categorized as Limited Use, but not DOA or PF) accounted for 16.7%.

Superior cartridge reliability can decrease downtime, increase user productivity, and decrease the overall cost of printing due to lack of having to replace supplies or reprint output.

Print Quality Distribution

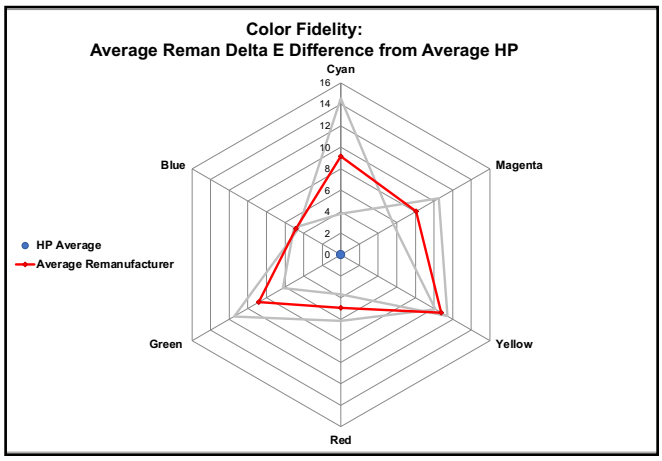
HP cartridges produced a significantly greater number of pages with higher Print Quality (PQ) than the Remanufactured cartridges tested. Tested HP cartridges produced a total of 98.8% of print samples categorized as good for External Use. Comparatively, the Remanufactured cartridges produced 1.7% of pages that were good for External Use.



HP cartridges produced just 1.3% Internal Use pages, with no pages deemed as Unusable or Individual. Conversely, Remanufactured brands produced 98.3% Limited Use pages, including 5.0% Internal, 43.3% Individual, and 50% Unusable. The Remanufactured brands Limited Use pages exhibited print quality defects such as hue shifts (42%), banding (22%), ghosting (20%), dots (14%), and streaks (11%).

Color Fidelity

The Remanufactured brands exhibited overall poor Color Fidelity. With one (1) delta E (1976) considered as a 'Just Noticeable Difference', the Remanufactured cartridges rendered significantly inaccurate colors when compared to the colors produced by the Original HP cartridge sets which were used as the benchmark.



The average and individual color difference (dE) between color values printed by Remanufactured and HP cartridge sets for each of the six color patches is shown in the spider chart above.

Remanufactured cartridge sets showed an high delta E average of 7.49 on the six color patches (Red, Green, Blue, Cyan, Magenta, and Yellow). The largest difference of average delta E from the HP average was noted on the Remanufactured brands Yellow (10.79), Cyan (9.17), Green (8.85), and Magenta (8.06). Again, it should be noted that a dE of less than 1.0 is imperceptible to the human eye; those with higher dE would be significantly obvious.

The *spencerLAB* Digital Color Laboratory

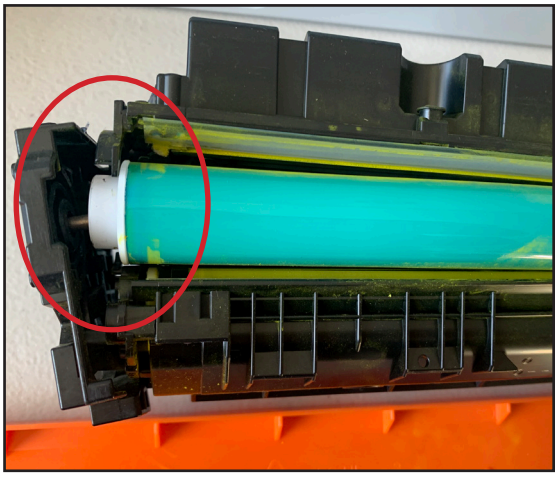
With over thirty-five years of industry service, Spencer & Associates Publishing, Ltd. has earned a premier reputation for its expertise in evaluating digital color imaging and printing. Its independent test division, the *spencerLAB* DIGITAL COLOR LABORATORY, is internationally recognized as a leader 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.

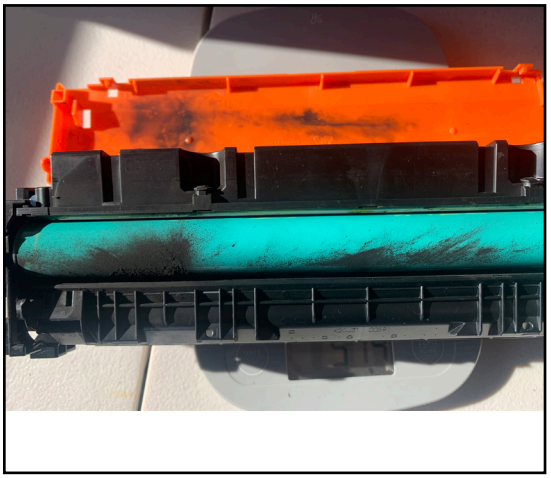
For more information, please visit www.spencerlab.com.

March 2024

Appendix 1: Problem Cartridge Photos - Remanufactured Brands

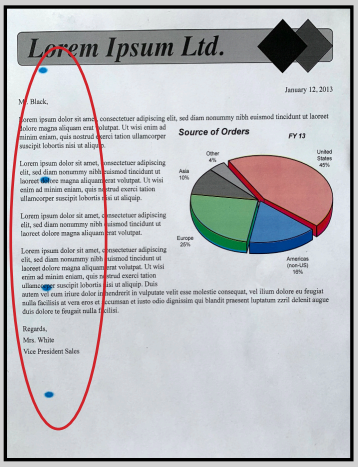


Cartridge Broken & Leaking at Unpacking

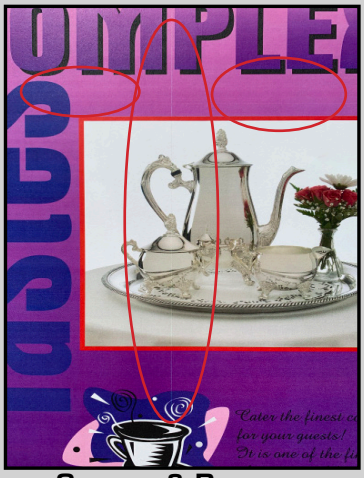


Cartridge Leaking at Unpacking

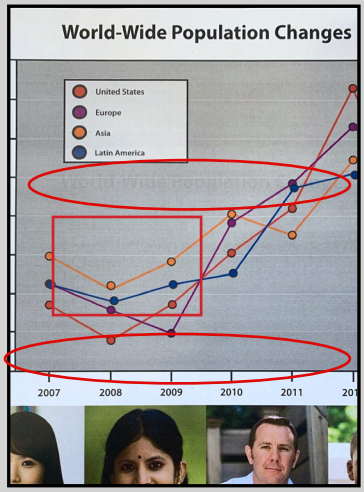
Remanufactured Brands - Low Print Quality



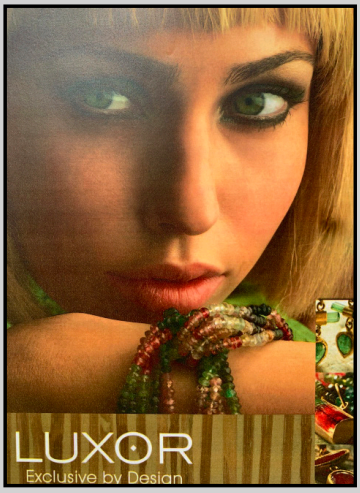
Dots



Streaks & Banding



Ghosting & Banding



Hue Shift

[Some images zoomed in to show defect]

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Appendix 2: Methodology

Test Parameters

The test included CE410A (Black), CE411A/X (Cyan), CE412A (Yellow), and CE413A (Magenta) color cartridge models for the HP LaserJet Pro color Printer M452dn. Two (2) Remanufactured brands were tested with both sourced from within Europe. Where standard-yield A model cartridges were not available, high-yield X model cartridges were purchased and tested for that brand.

Original HP Black, Cyan, Magenta, and Yellow cartridges were acquired from multiple retail vendors in the United States either through retail, online, or direct channels, depending on availability. A total of twelve cartridges (three cartridge sets consisting of four color cartridges - CMYK) were tested for each brand.

Multiple HP Color LaserJet printers were used in testing to minimize printer-to-printer performance variation. Printers were tested and cleaned prior to each brand being tested.

Four (4) individual Test cartridges of a brand were installed in a test printer, and that set of four cartridges (CMYK) was considered a Cartridge Set.

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 10 operating system and Acrobat Reader version 2023.003.20284. Test files were printed in printer default mode for plain paper, on Hammermill Fore Multi-Purpose 20lb., 96 Brightness, office paper, 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 [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. 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.

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. Cartridges determined as DOA had the full count categorized as Unusable Pages.

Using the psychometric Print Quality acceptance scale, *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. 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 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.

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. The CIELAB ($L^* a^* b^*$) measurements of each color patch at equivalent intervals were averaged over the life of the cartridge, from beginning to Unusable, for each brand.

Remanufactured 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

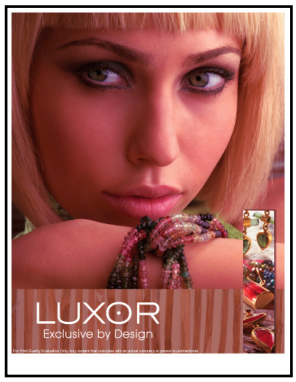
SpencerLAB used proprietary sorting and analysis algorithms to calculate the average Print Quality rating of each sample for each test set. The resulting score was used to determine the rank order of samples in each test set.

Color Shift Test Set Sample

External Reference

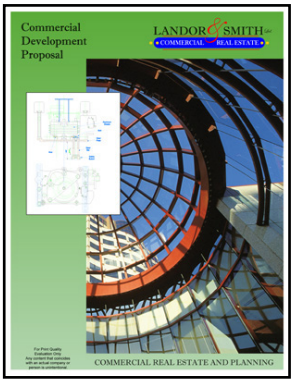
External/Internal Boundary
Lower PQ - Internal

Internal/Individual Boundary
Lower PQ - Individual

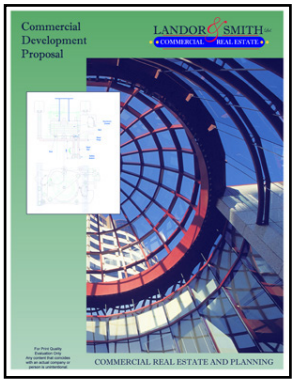


Individual/Unusable Boundary
Lower PQ - Unusable

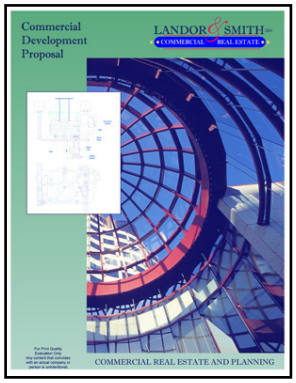
Color Shift Test Set Sample



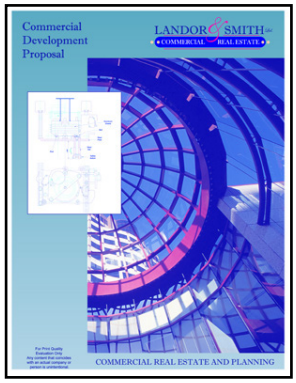
External Reference



External/Internal Boundary
Lower PQ - Internal

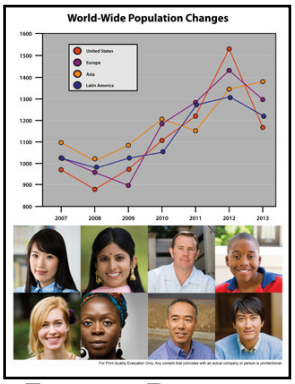


Internal/Individual Boundary
Lower PQ - Individual

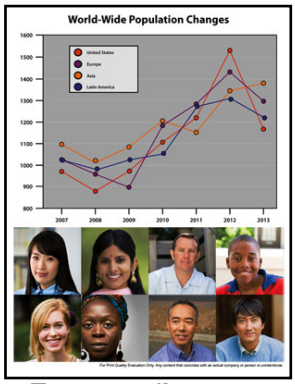


Individual/Unusable Boundary
Lower PQ - Unusable

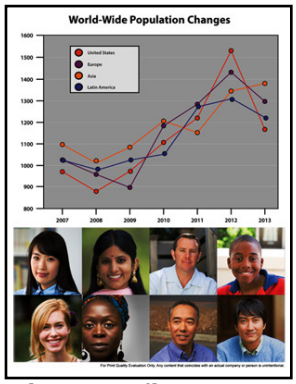
Dark Density Test Set Sample



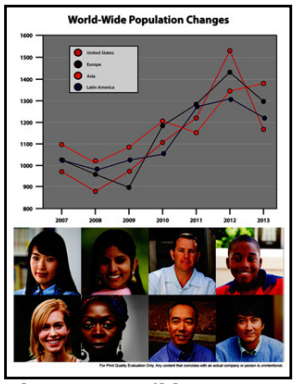
External Reference



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
Cartridge Set		A Cartridge Set is defined as the collective of four individual color cartridges (C,M,Y,K).
End-of-Test		Determined by one of four mechanisms: 1. Any Cartridge of the Cartridge Set is Dead-on-Arrival. 2. Any Cartridge of the Cartridge Set stops printing and efforts to recover are unsuccessful. 3. Degradation of Print Quality to unacceptable (Unusable) for any one of the Test Suite pages. 4. Upon 'Toner Very Low' printer notification for any Cartridge within the Cartridge Set indicating that a cartridge is at the estimated end of its useful life.
Dead-on-Arrival, (DOA)		A condition 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 set that within the first Test Suite has at least one PQ page categorized as 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, another Test Suite shall be printed and evaluated. If at least one PQ page is categorized as Unusable, a second recovery attempt of printing a cleaning page, if available, shall be performed. Following the second recovery procedure, another Test Suite shall be printed and pages evaluated for categorization. If at least one PQ page is categorized as Unusable following this recovery process, the cartridge set 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.
Premature Failure, (PF)		A cartridge set with a page count of less than 80% of the average page count for all Original HP toner cartridges of that model that were not DOA, unless other cartridge SKU stated yield differs from Original HP stated yield.
Low Quality, (LQ)		A cartridge set with 50% or more pages categorized as Limited Use, but was not DOA or PF.
Problem Cartridges		Cartridge sets categorized as either DOA, PF, or LQ.
Limited Use		Sample pages with PQ categorized as either Internal Use, Individual Use, or Unusable. If cartridge is DOA, it is deemed 100% 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.
Remanufactured Toner Cartridge		A reused HP cartridge shell that has been disassembled and had one or more components replaced. The cartridge is then refilled with toner and reassembled.


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RELIABILITY TESTED