Page Yield / Ink Cartridge Reliability Comparison Study

HP Inkjet Print Cartridges vs. Refilled Brands

April 2007

For distribution in North America

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Executive Summary

In April 2007, QualityLogic completed a study for HP designed to test the page yield and reliability of Hewlett-Packard (HP) inkjet print cartridges compared to 13 brands of refilled inkjet print cartridges for the HP DeskJet 5650 (C6490A) and HP DeskJet 6940 (C8970A) printers. All brands tested were sold in North America. The refilled inkjet print cartridges were comprised of refilled cartridges carrying the store brand, refilled cartridges sold under a third-party brand, and empty cartridges that QualityLogic had refilled at refill stations.

The results of the study show that HP inkjet print cartridges outperformed the refilled inkjet print cartridges.

Page Yield – When looking at the total pages printed from those cartridges tested, on average Original HP inkjet print cartridges produced 57.5% more pages than the refill brands tested.

Cartridge Reliability – None of the Original HP inkjet print cartridges were dead-on-arrival or premature failure (as defined in Appendix 2 – Definitions), whereas, on average 20.9% of the refill cartridges tested were either dead-on-arrival or failed prematurely.

Additional Observations – For refill stations, cartridge refill times varied from between 15-20 minutes to more than 24 hours. Not all cartridges could be successfully refilled. Of all cartridge refill attempts at refill stations, 40 units failed or became unusable during the refill process.

Refilled Brands Tested

Store / Refill brands

- OfficeMax store brand
- Office Depot store brand
- PrintPal refilled cartridges
- Caboodle Cartridge refilled cartridges
- Rapid Refill Ink refilled cartridges
- Staples store brand
- Nu-kote refilled cartridges
- Corporate Express store brand

Refill station brands

- OfficeMax refill station
- Office Depot refill station
- Cartridge World refill station
- Island Ink-Jet refill station
- Walgreens refill station

Detailed Results

Page Yield

When looking at the total pages printed from those cartridges tested, on average Original HP inkjet print cartridges produced 57.5% more pages than the refill brands tested based on comparing the normalized 90% lower confidence bound values (as defined in Appendix 2 – Definitions).

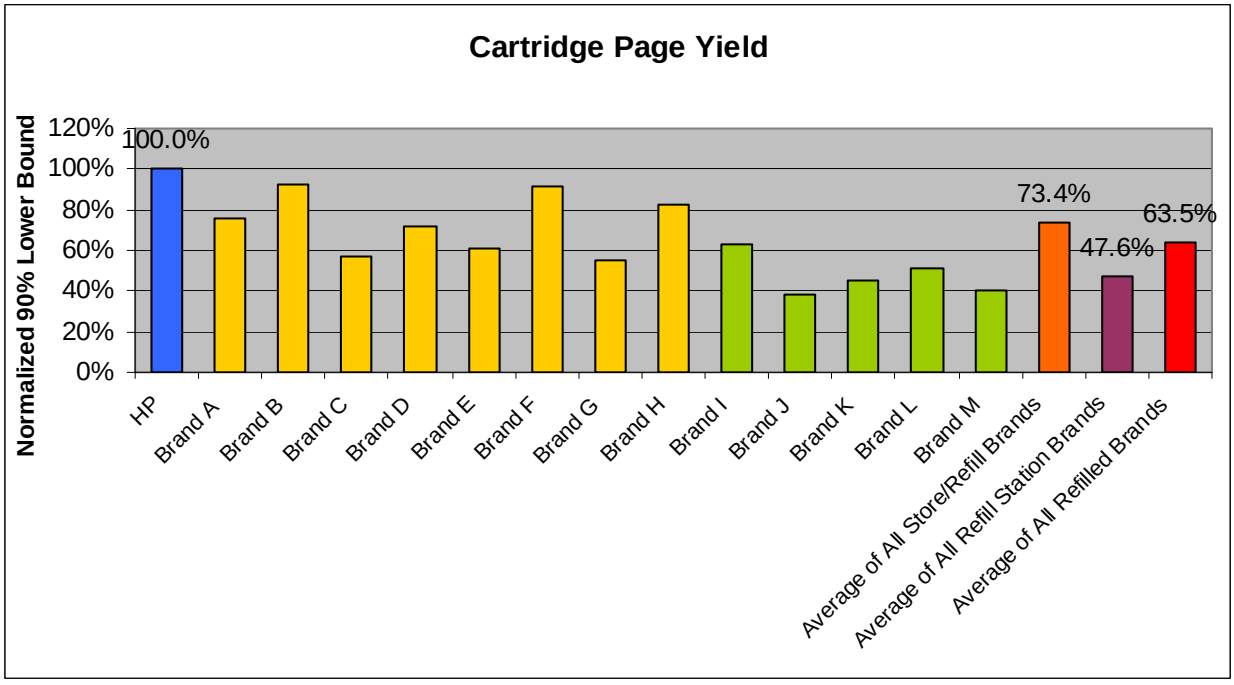
More specifically, when comparing HP to the store/refill brands tested only, based on the total pages printed for this subset of cartridges tested, on average Original HP inkjet print cartridges produced 36.2% more pages than the store/refill brands (brands A-H) tested based on comparing the normalized 90% lower confidence bound values (as defined in Appendix 2 – Definitions).

When comparing HP to the refill station brands tested only, based on the total pages printed for this subset of cartridges tested, on average Original HP inkjet print cartridges produced 110.1% more pages than the refill station brands (brands I-M) tested based on comparing the normalized 90% lower confidence bound values (as defined in Appendix 2 – Definitions).

In the chart below, each brand is referenced in comparison to the performance of the HP brand. The normalized 90% lower confidence bound page yield values (as defined in Appendix 2 – Definitions) were used for this comparison. These values from each cartridge model tested were combined to create a single index value for each brand tested. The score for the HP brand is represented as 100.0%, with the scores for each refilled brand represented as compared to the HP brand (higher or lower based on performance.) For the HP/Brand Relative Page Yield comparison, the percentages shown indicate that HP cartridges printed that percentage more pages than the given brand. For example, Brand A had a score of 76.0% compared to the HP brand, indicating that HP printed 31.6% more pages than Brand A.

Brand Type	Brand	Number of Cartridges Tested	Normalized 90% Lower Confidence Bound Page Yield	HP/Brand Relative Page Yield Difference
HP	HP	68	100.0%	n/a
Store/Refill Brand	Brand A	68	76.0%	31.6%
Store/Refill Brand	Brand B	68	92.8%	7.8%
Store/Refill Brand	Brand C	68	57.2%	74.8%
Store/Refill Brand	Brand D	68	71.9%	39.1%
Store/Refill Brand	Brand E	68	61.0%	63.9%
Store/Refill Brand	Brand F	34	91.2%	9.6%
Store/Refill Brand	Brand G	35	54.7%	82.8%
Store/Refill Brand	Brand H	34	82.2%	21.7%
Refill Station	Brand I	68	63.0%	58.7%
Refill Station	Brand J	72	38.3%	161.1%
Refill Station	Brand K	68	45.1%	121.7%
Refill Station	Brand L	68	51.5%	94.2%
Refill Station	Brand M	45	40.1%	149.4%
Sum/Average of All Store/Refill Brands		**443**	**73.4%**	**36.2%**
Sum/Average of All Refill Station Brands		**321**	**47.6%**	**110.1%**
Sum/Average of All Refilled Brands		**764**	**63.5%**	**57.5%**

Table 1:
Cartridge Page Yield



Graph 1:
Cartridge Page Yield

Cartridge Reliability

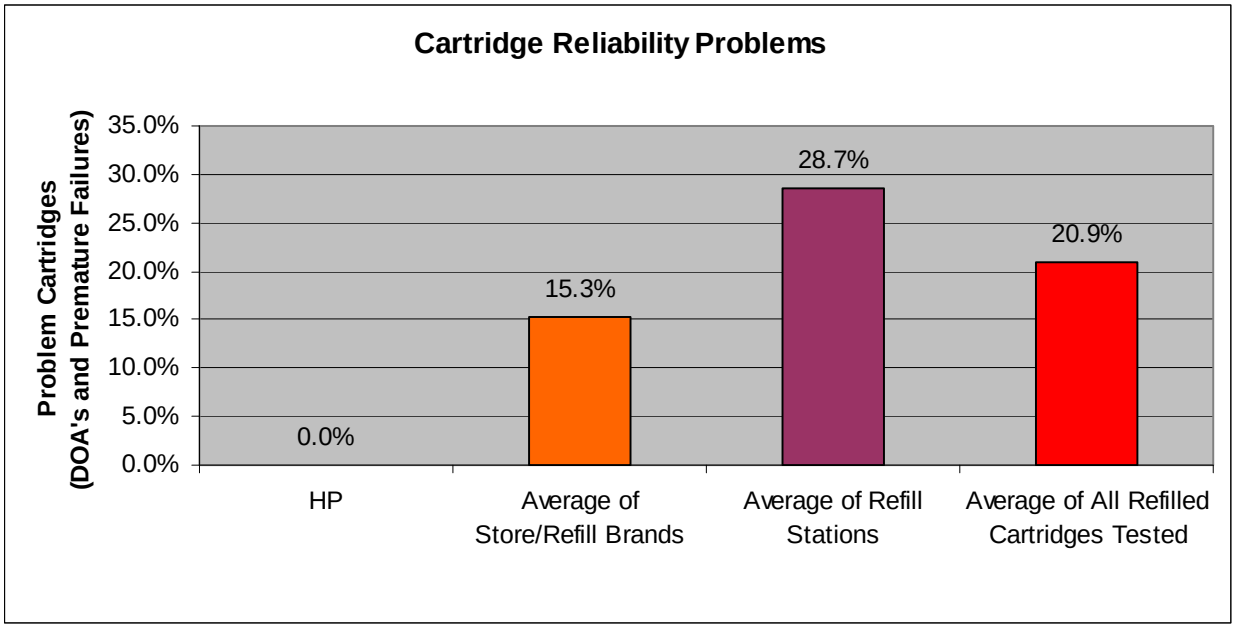
None of the Original HP inkjet print cartridges tested were dead-on-arrival or premature failure (as defined in Appendix 2 – Definitions), whereas, on average 20.9% of the refill cartridges tested were either dead-on-arrival or failed prematurely.

More specifically, none of the Original HP inkjet print cartridges tested were dead-on-arrival or premature failure (as defined in Appendix 2 – Definitions), whereas 15.3% of the store/refill brand cartridges (brands A-H) tested were either dead-on-arrival or failed prematurely, and 28.7% of cartridges refilled at refill stations (brands I-M) were either dead-on-arrival or failed prematurely.

Brand Type	Brand	Number of Cartridges Tested	Dead-On-Arrival		Premature Failures		Problem Cartridges	
			No.	%	No.	%	No.	%
HP	HP	68	0	0.0%	0	0.0%	0	0.0%
Store/Refill Brand	Brand A	68	4	5.9%	2	2.9%	6	8.8%
Store/Refill Brand	Brand B	68	1	1.5%	3	4.4%	4	5.9%
Store/Refill Brand	Brand C	68	4	5.9%	11	16.2%	15	22.1%
Store/Refill Brand	Brand D	68	2	2.9%	4	5.9%	6	8.8%
Store/Refill Brand	Brand E	68	3	4.4%	16	23.5%	19	27.9%
Store/Refill Brand	Brand F	34	1	2.9%	2	5.9%	3	8.8%
Store/Refill Brand	Brand G	35	6	17.1%	6	17.1%	12	34.3%
Store/Refill Brand	Brand H	34	0	0.0%	3	8.8%	3	8.8%
Refill Station	Brand I	68	8	11.8%	6	8.8%	14	20.6%
Refill Station	Brand J	72	12	16.7%	12	16.7%	24	33.3%
Refill Station	Brand K	68	9	13.2%	9	13.2%	18	26.5%
Refill Station	Brand L	68	13	19.1%	2	2.9%	15	22.1%
Refill Station	Brand M	45	13	28.9%	8	17.8%	21	46.7%
Sum/Average of Store/Refill Brands		**443**	**21**	**4.7%**	**47**	**10.6%**	**68**	**15.3%**
Sum/Average of Refill Stations		**321**	**55**	**17.1%**	**37**	**11.5%**	**92**	**28.7%**
Sum/Average of All Refilled Cartridges Tested		**764**	**76**	**9.9%**	**84**	**11.0%**	**160**	**20.9%**

Table 2:
Cartridge Reliability

The dead-on-arrival and premature failure cartridges are listed separately for each brand and also combined to create a total problem cartridge value for each brand. The percentages shown are referenced to the number of cartridges tested per brand. These values were then combined to create a sum/average value for the store/refill brands, refill stations, and all refilled cartridges tested. For example, Brand A had a total of 68 cartridges in the test. Four cartridges (5.9%) were found to be dead-on-arrival, and two cartridges (2.9%) were found to fail prematurely for a total of six (8.8%) problem cartridges in the test for Brand A.



Graph 2:
Cartridge Reliability Problems

Appendix 1: Test Methodology

The following is a summary of the methodology used for this study:

The printers and print cartridges selected for this study were as follows:

Printer	Black Cartridge	Color Cartridge
HP DeskJet 5650 (C6490A)	HP 56 (C6656AN)	HP 57 (C6657AN)
HP DeskJet 6940 (C8970A)	HP 96 (C8767W)	HP 97 (C9363W)

A total of 762 refilled print cartridges and 68 HP print cartridges were tested using a total of 42 HP DeskJet 5650 printers and 30 HP DeskJet 6940 printers.

Printing was performed in a continuous mode in a controlled environment using the five-page test suite from ISO/IEC 24712, and the environmental conditions specified in ISO/IEC 24711. To account for reliability-driven cartridge issues, defective cartridges were included in the page yield calculation. Consequently, the reported page yield numbers are not based on the ISO/IEC 24711 standard since ISO/IEC 24711 requires that defective cartridges are excluded from the page yield calculation.

Test pages were as follows:

				
Page 1 – Business Letter	**Page 2 - Spreadsheet**	**Page 3 - Newsletter**	**Page 4 - Slide**	**Page 5 - Diagnostic**

QualityLogic procured all printers, paper, and HP print cartridges through standard retail channels. Refilled print cartridges were obtained through multiple retail channels in multiple cities, where possible, or directly from the manufacturer. For the refill station brands tested, approximately 50% of the test data is based on cartridges that were refilled once, approximately 30% is based on cartridges that were refilled twice and approximately 20% is based on cartridges that were refilled three times.

QualityLogic selected Xerox Commercial 4200 plain paper (8½ x 11, 20 lb., 92 Brightness) for all printing for this study.

Cartridge transportation policies were designed to replicate customer behavior. Cartridges were shipped via ground shipment or air shipment utilizing air-tight, pressurized containers to protect against transportation-induced reliability problems.

Printer settings were left at the factory default. Driver quality settings were set to Normal and plain media.

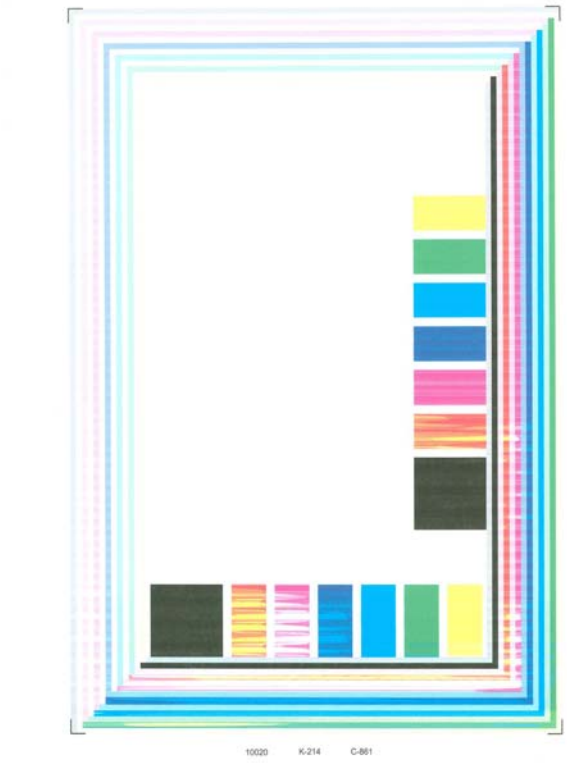
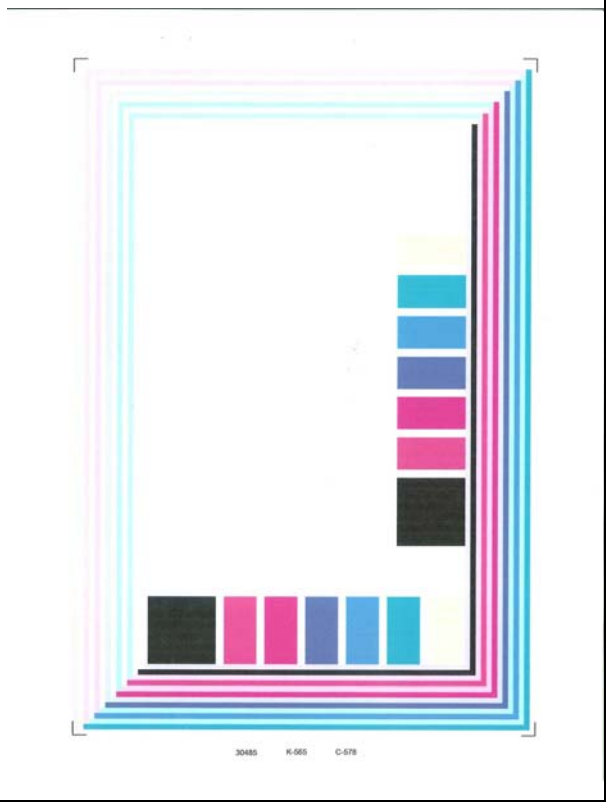
Each cartridge was inspected for leaks or other damage upon entering the test. A cartridge with substantial visible ink spilled in the bag or on the cartridge was declared DOA due to the leak. All other cartridges were printed to End-of-Life (EOL) as defined in Appendix 2: Definitions.

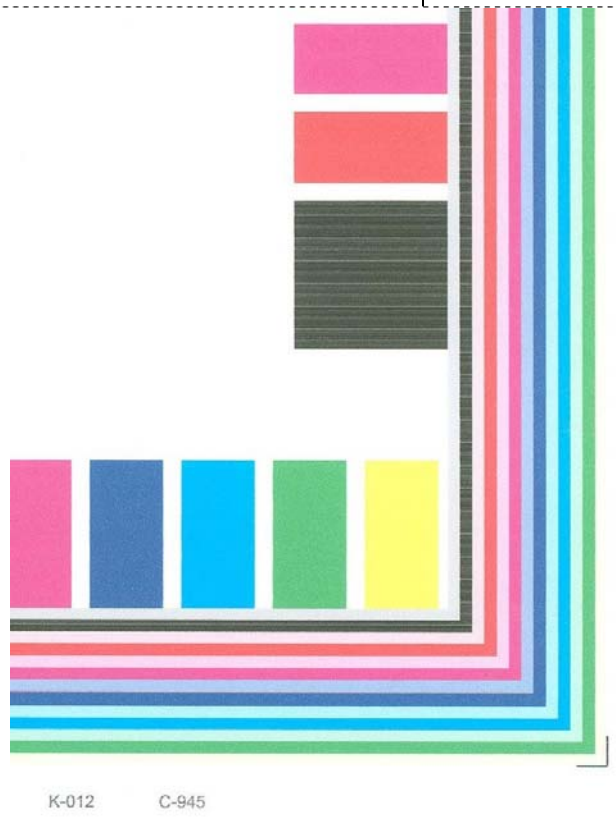
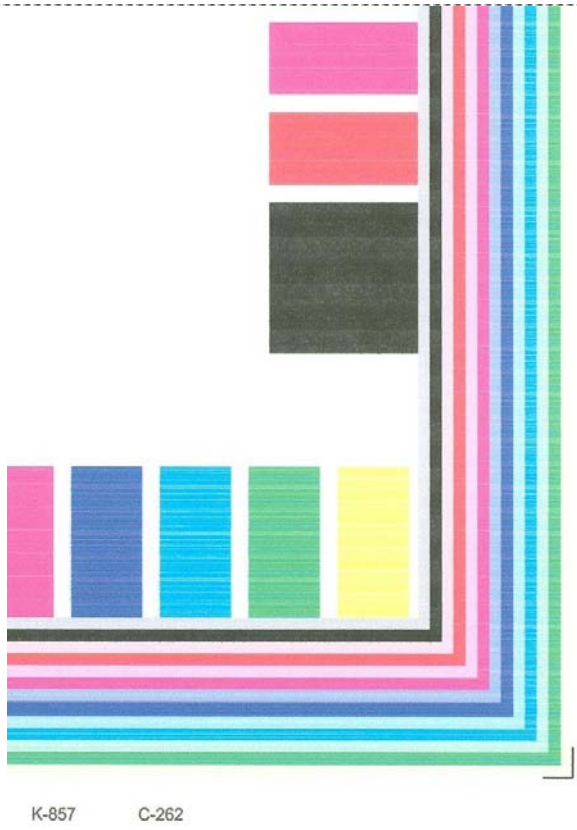
Printing continued until at least 17 black and 17 color cartridges successfully reached EOL for each printer model tested. Color and black cartridges were tested in parallel. As 17 color or black cartridges were completed for a brand, HP original cartridges were used to complete the rest of the brand. All results and effects of these HP original cartridges were ignored in the test.

Testing was conducted to align with the sample size requirements in ISO/IEC 24711, which requires a minimum of three physical cartridges to be tested in each of three printers. To ensure a statistically significant result, testing continued until a minimum of nine of each cartridge arrived at EOL due to Fade.

The test methodology for this reliability comparison study was developed by Hewlett-Packard and implemented by QualityLogic.

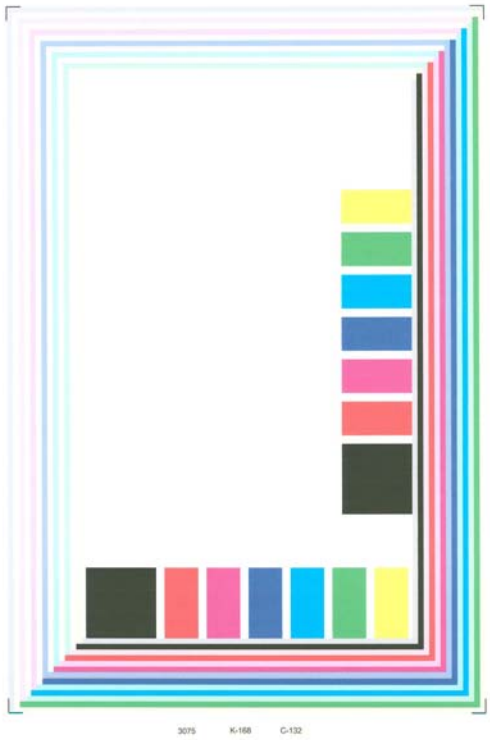
Appendix 2: Definitions

Test Project Terminology	Definition
Substantial ink leakage	- Ink visibly spilled in the plastic bag containing the cartridge. - Ink visibly spilled in the interior of the cartridge packaging. - Ink visibly spilled over the print head nozzles.
  	
End-of-Life (EOL)	A condition determined by one of three mechanisms: 1. Fade has occurred on the diagnostic page. 2. Streak removal procedure steps have been exhausted. 3. Cartridge is Dead-on-Arrival (DOA).
Fade	A significant decrease in density on the bands or blocks of the last page in the test page suite, which is a diagnostic page. This decrease in density does not have to occur completely across the page to be considered fade. For a comparison to determine if fade is occurring, reference the 10th page printed by that printer.
 	

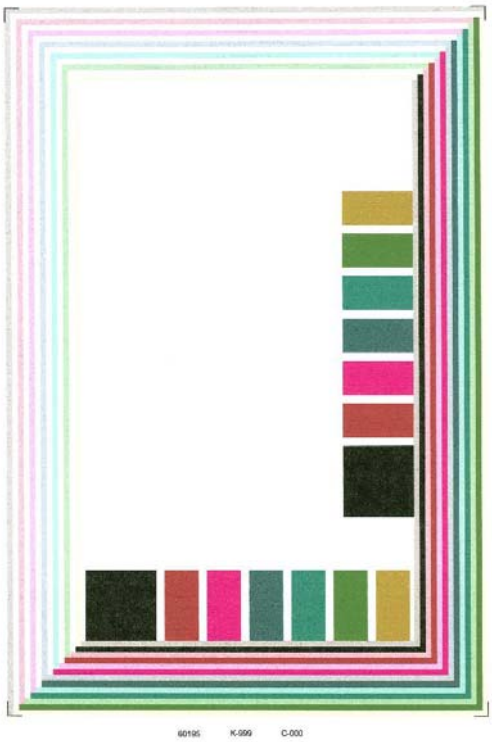
Streaks	Very thin lines of color or the lack of color where it should be, in the blocks surrounding the edge of the diagnostic page. Streaks differ from fade in the width and severity of the reduction in density. Streaks can appear due to a number of reasons, including thermal issues and clogged nozzles.
 Black Streaks	 Color Streaks
Streak Removal Procedures	This is the cartridge cleaning procedure (servicing) used to restore print performance. If streaks are observed on three consecutive diagnostic pages, a streak removal procedure should be implemented. Streak removal operations should be conducted according to the HP printer manual documentation. If there were additional cleaning steps advised for the non-HP cartridges, they were included within the cleaning process. Use of a "light" and "strong" cleaning procedure counts as one cartridge cleaning operation. Cleaning is verified by reprinting the diagnostic page. If streaks are still present, the clean procedure is repeated. Any pages printed during the cleaning operation are not counted in the yield calculation. Due to the significant amount of ink that is used for cleaning, the maximum permissible number of times that the streak removal operation can be used on a given cartridge is three times. Cartridges which require a fourth service are considered to be at EOL.
Individual Cartridge Yield	Individual cartridge yield is calculated by counting the number of diagnostic pages printed between cartridge installation and EOL, then multiplying by five. The diagnostic page is the last plot printed in the test suite.

Average Cartridge Page Yield	Average cartridge yield for a given cartridge type $\overline{X} = \sum_{i=1}^{n} \frac{x_i}{n}$ Where • x_i is the individual cartridge yield. • n is the sample size i.e.(17 for example), excluding cartridges identified as "Dead-on-Arrival" as per definition above. This average cartridge page yield number is solely used for the purposes of calculating premature failures.
90% Lower Confidence Bound Page Yield	Calculated as: $\overline{X} - \left(t_{\alpha,n-1}\right) * \frac{s}{\sqrt{n}}$ Where $t_{\alpha,n-1}$ Can be found on a Students' t-Distribution Table with n -1 degrees of freedom (df or 'ν') and an α of 0.1. This provides a 2-tailed confidence interval with 90% confidence. A different sample size and/or different confidence interval will yield a different $t_{\alpha,n-1}$. The 90% lower confidence bound value means that one can be 90% confident that the true mean page yield is equal to or greater than the value of the lower bound of the confidence interval. The page yield values used for this calculation include cartridges identified as dead-on-arrival and premature failure.
Normalized 90% Lower Confidence Bound Page Yield	Converted 90% Lower Confidence Bound Page Yield into index values by setting the 90% Lower Confidence Bound page yield value for the HP brand to 100% and the 90% Lower Confidence Bound page yield value for the refill brands tested as a percentage value relative to HP. Example: 90% Lower Confidence Bound page yield HP = 800 90% Lower Confidence Bound page yield refill brand A = 600 Normalized 90% Lower Confidence Bound Page Yield HP = 100.0% Normalized 90% Lower Confidence Bound Page Yield refill brand A = 75.0%
Dead On Arrival	A condition determined by one of three mechanisms: 1. Cartridge found to have substantial leakage (as defined above) at start or during testing. 2. 50 or less pages printed by a cartridge. 3. Color mix (as defined below) has occurred and incorrect colors printed on 10 consecutive pages – color cartridge failure mechanism only.

Color Mix	Defined as a color cartridge that cannot print the correct Cyan, Magenta and Yellow colors as shown on the diagnostic page 5 of the page yield test suite. Ink has mixed in an unintended manner inside the cartridge and has caused a discoloring of the ink. An example of Color Mix is provided below. Compare the colored blocks in the correct example to those of the color mix page.



Correct Diagnostic Page



Color Mix page

Test Page Suite	A series of five pages that are printed consecutively in order as a single job, ending with a diagnostic page. ISO/IEC 24712.

Premature Failure	A cartridge that has a page yield of less than 75% of the average page yield (as defined above) for that cartridge brand.
Problem Cartridge	Cartridges identified as dead-on-arrival and cartridges identified as premature failures (as defined above).