



## **Page Yield/Reliability Comparison Study**

### **HP Inkjet Print Cartridges vs. Refilled Cartridges**

**January 2009**

**For distribution in North America**

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## Executive Summary

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In January 2009, QualityLogic completed a study for HP designed to test the page yield and reliability of Hewlett-Packard (HP) 92A, 93A, 98A, 95A, 21A and 22A inkjet print cartridges compared to a sample of cartridges from leading branded refilled cartridges and refill service providers. All cartridges tested were sold in North America.

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

**Page Yield** – When looking at the total pages printed from those cartridges tested, on average, Original HP inkjet print cartridges produced 65.8% more pages than the refilled cartridges tested.

**Cartridge Reliability** – None of the Original HP inkjet print cartridges tested failed in the study, compared to an average failure rate of 33.2% for the refilled cartridges tested.

The refilled cartridge test sample included cartridges from the following:

**Branded Refilled Cartridges**

- Elite Image
- Innovera
- Nukote
- Office Depot
- OfficeMax
- Rhinotek

**Refill Service Providers**

- Cartridge World
- OfficeMax
- Walgreens

## Detailed Results

### Page Yield

When looking at the total pages printed from those cartridges tested, on average, Original HP inkjet print cartridges produced 65.8% more pages than the refilled cartridges tested, based on comparing the 90% lower confidence bound page yield values. (See Appendix 2 for study definitions.)

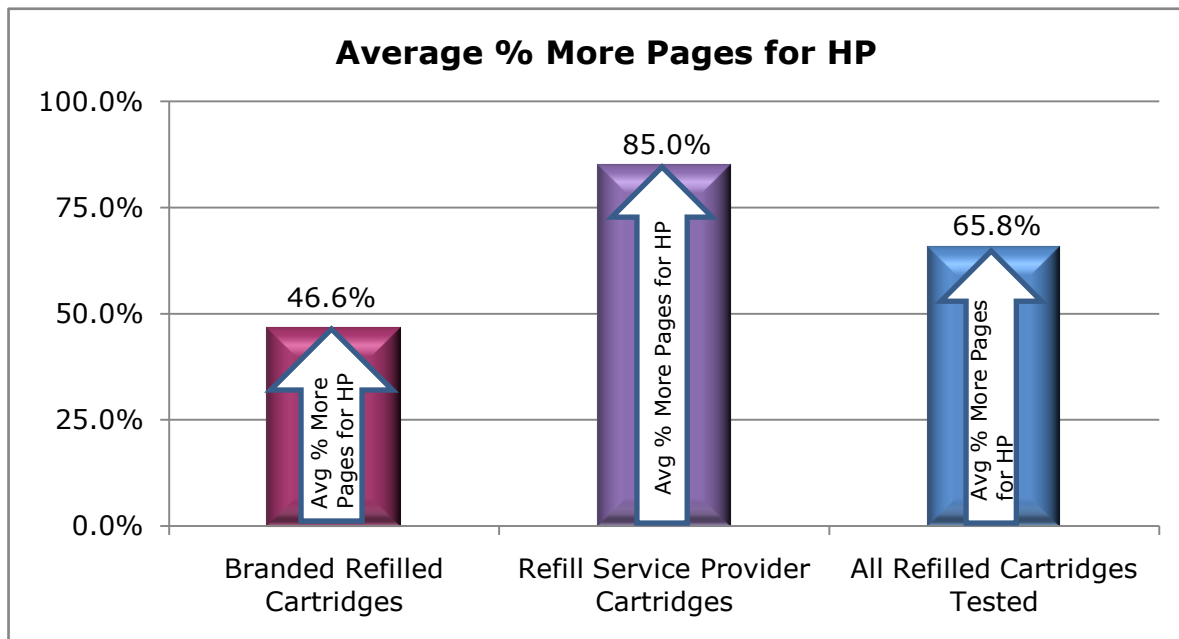
Original HP inkjet print cartridges produced 46.6% more pages, on average, than the branded refilled cartridges tested.

Original HP inkjet print cartridges produced 85.0% more pages, on average, than the cartridges refilled by refill service providers.

In the chart below, each refilled cartridge type is referenced in comparison to the performance of the HP brand. The average 90% lower confidence bound page yield values were used for this comparison.

Cartridge Type	Number of Cartridges Tested	Average Percentage More Pages for HP Cartridges
HP	60	n/a
Branded Refilled Cartridges	118	46.6%
Cartridges refilled by Refill Service Providers	90	85.0%
<b>All Refilled Cartridges Tested</b>	<b>208</b>	<b>65.8%</b>

**Table 1:**  
**Cartridge Page Yield Comparison – 90% Lower Confidence Bound**



**Graph 1:**  
**Cartridge Page Yield Comparison - 90% Lower Confidence Bound**

### Cartridge Reliability

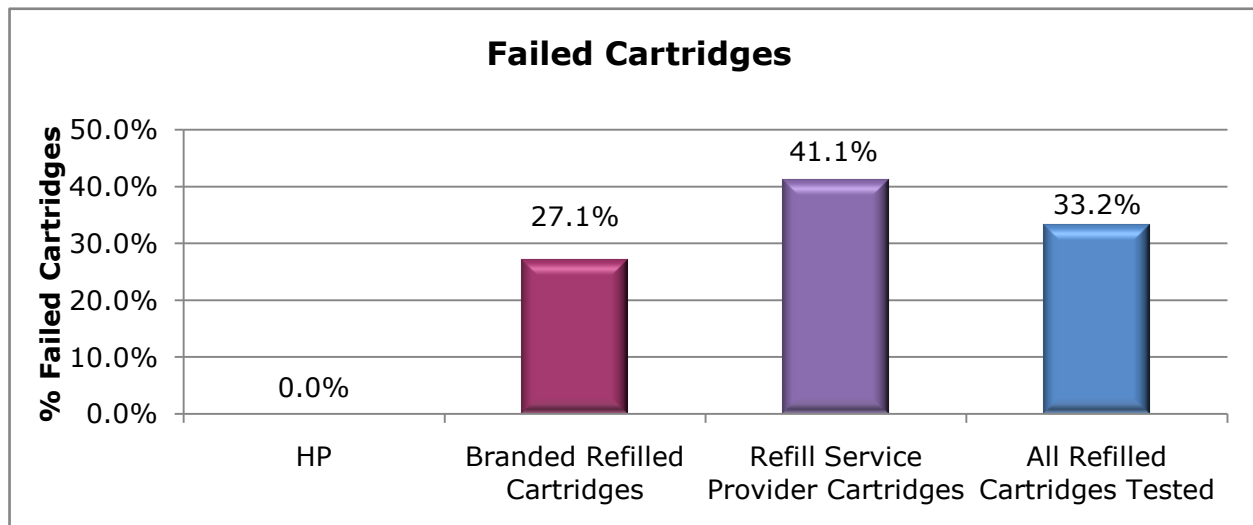
None of the Original HP inkjet print cartridges tested failed in the study, compared to an average of 33.2% of refilled cartridges tested which were either dead-on-arrival or reached end of life early.

As shown in the table below, in the study 13.9% of the refilled cartridges tested were DOA and 19.2% reached end of life early.

Cartridge Type	Number of Cartridges Tested	Dead-On-Arrival		Early End of Life		Total Failed Cartridges	
		No.	%	No.	%	No.	%
HP	60	0	0.0%	0	0.0%	0	<b>0.0%</b>
Branded Refilled Cartridges	118	13	11.0%	19	16.1%	32	<b>27.1%</b>
Cartridges refilled by Refill Service Providers	90	16	17.8%	21	23.3%	37	<b>41.1%</b>
<b>All Refilled Cartridges Tested</b>	<b>208</b>	<b>29</b>	<b>13.9%</b>	<b>40</b>	<b>19.2%</b>	<b>69</b>	<b>33.2%</b>

**Table 2:  
Cartridge Reliability**

The cartridges which were dead-on-arrival or reached end of life early are listed separately for each cartridge type. Dead-on-arrival and early end of life cartridges were combined to create a total failed cartridge percentage for each cartridge type.



**Graph 2:  
Cartridge Reliability**

## Appendix 1: Test Methodology

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


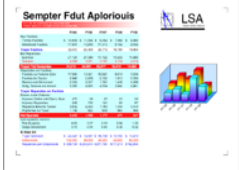



The printers and print cartridges selected for this study were as follows:

Printer	Black Cartridge	Color Cartridge
HP Deskjet 6988 (CB055A)	HP 92 (C9362W)	HP 93 (C9361W)
HP Deskjet 6988 (CB055A)	HP 98 (C9364W)	HP 95 (C8766W)
HP Officejet J3680 (CB071A)	HP 21 (C9351A)	HP 22 (C9352A)

A total of 208 refilled ink cartridges and 60 Original HP inkjet print cartridges were tested using a total of 9 HP Officejet J3680 printers and 11 HP DeskJet 6988 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 as ISO/IEC 24711 requires that defective cartridges are excluded from the page yield calculation.

The ISO/IEC 24712 test suite is shown below:

				
<b>Page 1 – Business Letter</b>	<b>Page 2 - Spreadsheet</b>	<b>Page 3 - Newsletter</b>	<b>Page 4 - Slide</b>	<b>Page 5 - Diagnostic</b>

QualityLogic procured all printers, paper, and Original HP inkjet print cartridges through standard retail channels in North America. Branded refilled ink cartridges were obtained through multiple retail channels or directly from the manufacturer in North America. Refill service provider cartridges were purchased at multiple locations for each provider in two US cities. Refill service provider cartridges were tested in the same city where the cartridge was purchased. For the refill service providers tested, approximately 60% of the test data is based on cartridges that had been refilled once, approximately 20% is based on cartridges that had been refilled twice, and approximately 20% is based on cartridges that had been refilled three times. Test data from



the Cartridge World brand is included in the refill service provider data, however all cartridges purchased at Cartridge World were swapped by Cartridge World for pre-refilled cartridges, which is the typical practice Cartridge World customers would encounter in the cities visited for the study.

To test cartridges refilled by refill service providers, new HP cartridges were prepared for refilling by printing the ISO test suite to approximately 90% of the published HP ISO yield or the first sign of fade, whichever came first. This is consistent with refiller recommendations that cartridges to be refilled not be completely emptied. A cartridge to be tested after one refill was prepared for refilling, refilled and then tested, printing to EOL per the definition in Appendix 2. A cartridge to be tested after two refills was prepared for refilling, refilled, prepared for refilling again, refilled again and then tested, printing to EOL. A cartridge to be tested after three refills was prepared for refilling and refilled three times and then tested, printing to EOL.



Pages printed while preparing cartridges for refilling were not part of the test.

QualityLogic selected HammerMill Fore MP plain paper (8½ x 11, 24 lb., 96 Brightness) for all printing in this study.

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 all test cartridges reached end of life. Color and black cartridges were tested in parallel. As the final color or black cartridges reached end of life, HP original cartridges were used to complete the testing. All results and effects of these HP original cartridges were ignored in the study.

This study tested average performance of the market, not individual brand performance. The brands and providers that were sampled were included because, together, they make up a significant portion of the overall market for refilled cartridges.


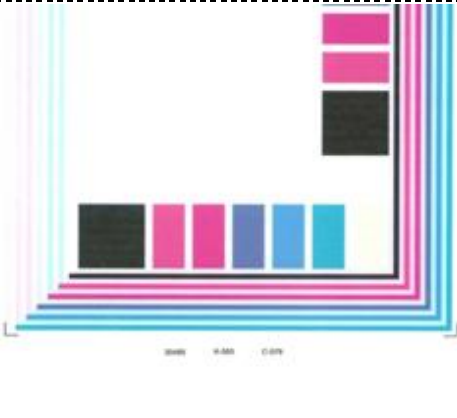
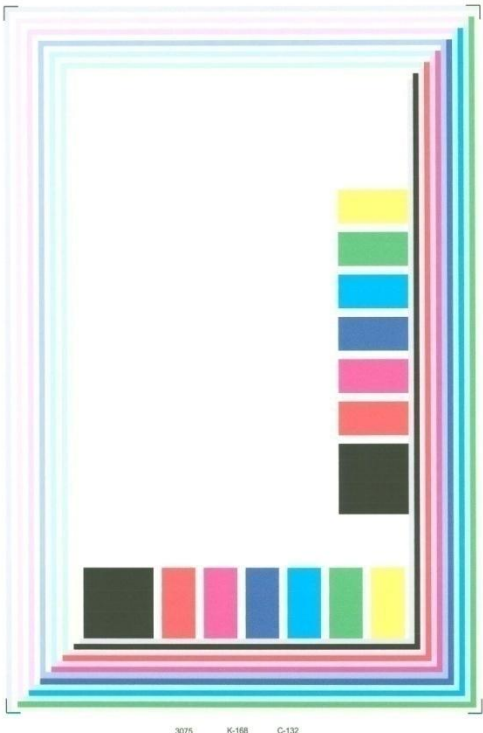

Ten cartridges of each model were tested for HP. A total of fifteen to twenty of each model were tested for each refilled cartridge type. Within this total, 4-5 cartridges from each brand or provider from which the model was available were included. Not all cartridge models were available from all brands.

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

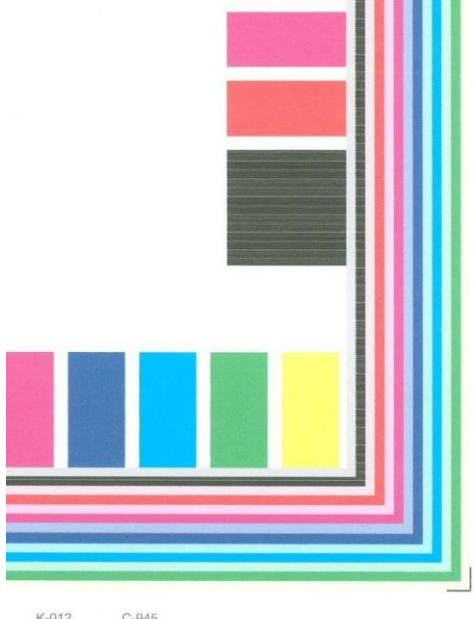
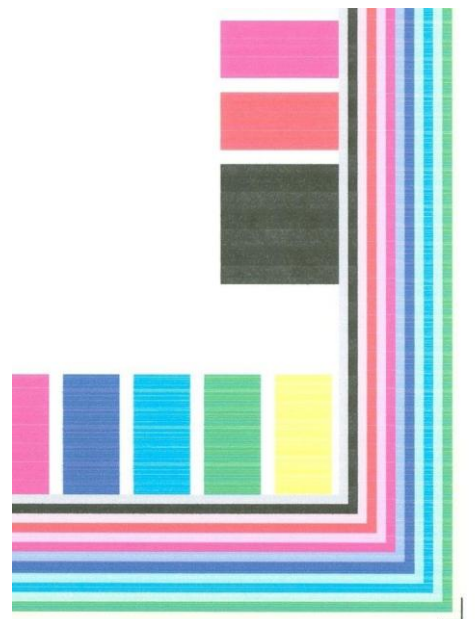
The test methodology for this reliability comparison study was developed by Hewlett-Packard and implemented by QualityLogic.

## Appendix 2: Definitions

Test Project Terminology	Definition
End-of-Life (EOL)	<p>A condition determined by one of six mechanisms:</p> <ol style="list-style-type: none"> <li>1. Fade has occurred on the diagnostic page per ISO definition.</li> <li>2. Significant reduction in density in the bands or blocks per ISO definition.</li> <li>3. Streak removal procedure steps have been exhausted per ISO definition.</li> <li>4. Significant leakage before or during installation or any time during printing.</li> <li>5. 10 consecutive pages with color mix.</li> <li>6. Cartridge fails to print or stops printing and efforts to recover are unsuccessful.</li> </ol>
90% Lower Confidence Bound Page Yield	<p>Calculated as:</p> $\bar{X} - (t_{\alpha, n-1}) * \frac{s}{\sqrt{n}} \qquad \bar{X} = \sum_{i=1}^n \frac{x_i}{n}$ <p>Where  <math>t_{\alpha, n-1}</math> Can be found on a Students' t-Distribution Table with n - 1 degrees of freedom (df or 'v') and an <math>\alpha</math> 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 <math>t_{\alpha, n-1}</math>.</p> <p>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.</p> <p>The page yield values used for this calculation include cartridges identified as dead-on-arrival and early end of life.</p>
Individual Cartridge Yield	<p>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.</p>
Average % more pages	<p>Average percent more pages is calculated for each cartridge type by model: ((HP 90% LCB - Refilled 90% LCB)/refilled 90%LCB). Average percent more pages for each of the models are averaged together to create the average % more pages for HP vs. each cartridge type. Average % more pages for HP vs. each of the cartridge types are averaged together to create the average percent more pages for HP vs. all refilled cartridges.</p>
Dead On Arrival	<p>A condition determined by one of three mechanisms:</p> <ol style="list-style-type: none"> <li>1. Cartridge found to have substantial leakage (as defined above) at start or during testing.</li> <li>2. 10 or fewer pages printed by a cartridge before end of life.</li> <li>3. Cartridge fails to operate upon installation.</li> </ol>
Early End of Life	<p>A cartridge that has a page yield of less than 75% of the HP average page yield for that cartridge model in the test.</p>

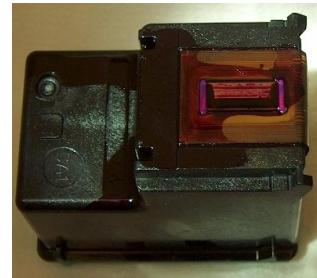
<p>Fade</p>	<p>A significant decrease in density on the bands or blocks of the last page in the test page suite, which is a diagnostic page. This decrease in density does not have to occur completely across the page to be considered fade. For a comparison to determine if fade is occurring, reference the 10<sup>th</sup> page printed by that printer.</p> <p>Two examples of fade pages are provided below.</p>
	
<p>Color Mix</p>	<p>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.</p> <p>An example of Color Mix is provided below. Compare the colored blocks in the correct example to those of the color mix page.</p>
 <p>Correct Diagnostic Page</p>	 <p>Color Mix page</p>



<p>Streaks</p>	<p>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.</p>
 <p>K-012 C-945</p> <p style="text-align: center;">Black Streaks</p>	 <p>K-857 C-262</p> <p style="text-align: center;">Color Streaks</p>
<p>Streak Removal Procedures</p>	<p>This is the cartridge cleaning procedure (servicing) used to restoring print performance. If streaks are observed on three consecutive diagnostic pages a streak removal procedure was implemented. Streak removal operation was 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.</p> <ol style="list-style-type: none"> <li>1. If the cleaning operation has the option of multiple cleaning strengths, the procedure indicated in the printer manual for resolving streaking should be followed.</li> <li>2. Use of a "light" and a "strong" cleaning procedure counts as one cartridge cleaning operation.</li> <li>3. Cleaning is verified by the reprinting of the diagnostic plot. If streaks are still present then the clean procedure is repeated again.</li> <li>4. Any pages printed during the nozzle cleaning operation are not counted in the yield calculation.</li> </ol> <p>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 3 times. Cartridges which require a fourth service are considered to be at End of Life                  All clean steps were recorded and reported by cartridge i.e. page number streak occurred on, number and types services required and did the cartridge recover.                  A cartridge not demonstrating streaking or other problems but which has experienced 3 cleanings because the cartridge in the sku pair has experienced streaking was NOT removed.</p>

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.



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.

