



Reliability Comparison Study

HP Inkjet Print Cartridges vs. Refilled Brands

Cartridge Reliability Print Quality

September 2005

For distribution in the Americas and Asia Pacific

Executive Summary

During 2005, QualityLogic conducted a study for HP designed to test the quality and reliability of Hewlett-Packard (HP) inkjet print cartridges compared to thirteen brands of refilled inkjet print cartridges for the HP DeskJet 6122 (C8954A) and HP PSC 1350 (Q3501A) printers. The brands tested were from North America (8 brands), Europe (4 brands), and Asia Pacific (1 brand).

The test was designed to print close to 2,800 pages per refilled brand of cartridge. Printing was performed in a continuous mode in a controlled environment. Test pages were developed by QualityLogic and designed to replicate the type of pages customers would typically print.

Cartridge Reliability by Brand – when combining all problem categories, an average of 70.3 percent of all refilled print cartridges tested exhibited reliability problems, compared to 2.0 percent of the HP print cartridges tested (see Table 1).

Print Quality by Brand – on average, refilled print cartridges printed more than three times the number of “Low Quality” pages than HP print cartridges when looking at the percent of “Low Quality” pages printed for the each brand (see Table 2). A “Low Quality” page is defined as print quality level 1, 2, or 3 as defined in Appendix 1.

Refilled Brands Tested

North America

- Basix
- Cartridge World
- Corporate Express
- Nu-kote
- Office Depot
- OfficeMax
- Rhinotek
- Universal

Europe

- PC World
- Pelikan
- Tesco
- Wecare

Asia Pacific

- Print-Rite

Test Overview

Cartridge print quality and reliability for each brand were determined by inspecting all pages printed to determine the print quality (PQ) of the page. Each page inspected was rated on a scale of 1 to 5 (with 5 being best) to determine the PQ Level of that page. Pages classified with a PQ Level of 4 or 5 were considered "High Quality" and pages classified with a PQ Level of 1, 2, or 3 were considered "Low Quality" (refer to Appendix 1 for details).

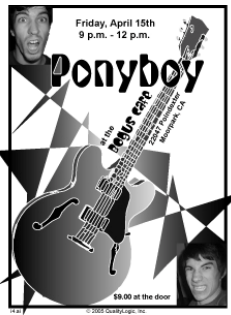
Test Pages



File: i1
Application: Adobe Illustrator 7.0
Description: The Kids' Place



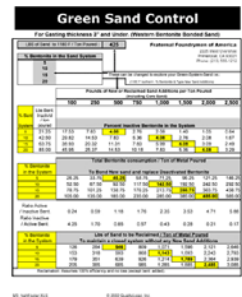
File: i3
Application: Corel Draw
Description: Real Estate flyer



File: i4
Application: Adobe Illustrator 7.0
Description: Ponyboy flyer



File: m1
Application: Microsoft Word XP
Description: Text page



File: m3
Application: Microsoft Excel XP
Description: Spreadsheet



File: p1
Application: Corel Draw
Description: Photo page on multipurpose media



File: p2
Application: Corel Draw
Description: Photo page on photo media

Since a combination of two cartridges working together as a set for each brand was required to print the test pages, the PQ Level of each of the cartridges (Tri-color and Black) was recorded for each page inspected. This allowed for quality and reliability comparisons by cartridge, as well as by total pages printed. This number of “High Quality” pages per cartridge per brand was then used for the following comparisons:

Cartridge Reliability by Brand - each problem cartridge was classified as Low Quality, a Premature Failure, or Dead on Arrival (DOA). DOAs, Premature Failures, and Low Quality cartridges were then combined to determine an overall problem percentage for each brand.

Print Quality by Brand – in this comparison an overall percentage of “High Quality” and “Low Quality” pages was calculated for each brand.

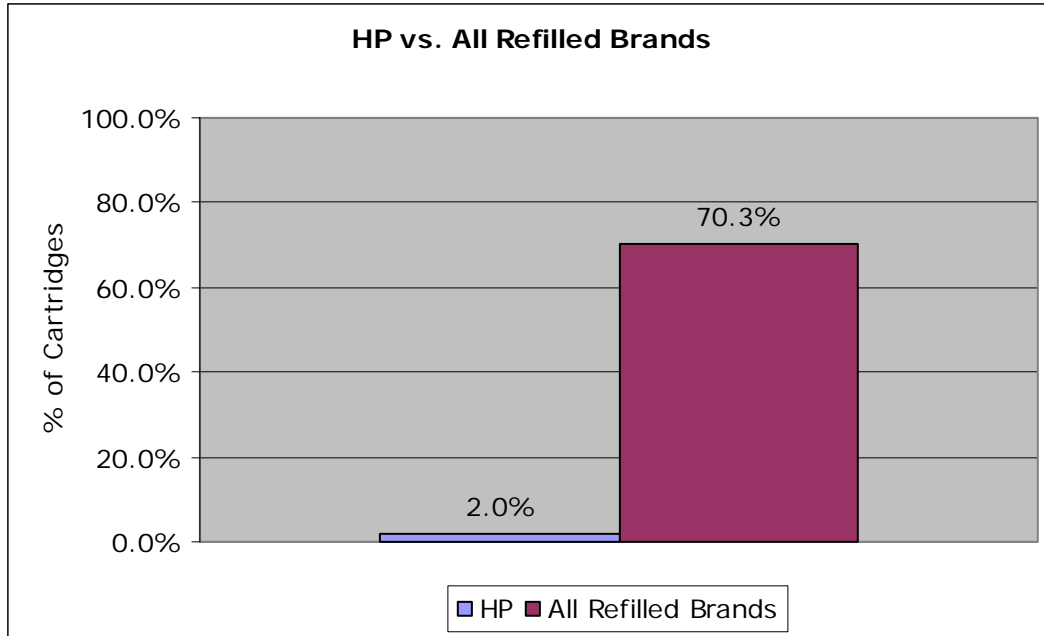
Results

Cartridge Reliability by Brand

On average, 70.3% of refilled cartridges had some form of reliability problem, compared to 2.0% of HP cartridges.

Brand	Number of Cartridges Tested	DOA	PF	LQ	Total Problem Cartridges	Percent Problem Cartridges	Refill % Problem / HP % Problem
HP	50	0	0	1	1	2.0%	
Brand A	30	5	0	12	17	56.7%	28.3
Brand B	30	8	6	8	22	73.3%	36.7
Brand C	30	0	1	17	18	60.0%	30.0
Brand D	30	2	2	18	22	73.3%	36.7
Brand E	30	0	1	22	23	76.7%	38.3
Brand F	30	8	3	11	22	73.3%	36.7
Brand G	30	3	1	17	21	70.0%	35.0
Brand H	30	1	2	22	25	83.3%	41.7
Brand J	30	2	0	15	17	56.7%	28.3
Brand K	30	3	1	21	25	83.3%	41.7
Brand L	30	4	0	19	23	76.7%	38.3
Brand M	30	4	1	10	15	50.0%	25.0
Brand N	30	5	0	19	24	80.0%	40.0
HP	50	0	0	1	1	2.0%	
All Refilled Brands	390	45	18	211	274	70.3%	35.1

Table 1:
Cartridge Reliability by Brand



Graph 1:
Cartridge Reliability - Percent Cartridge Problems

DOA Cartridges

A cartridge was classified as a DOA if it printed 10 or fewer “High Quality” pages and fewer than 2.5% of the Adjusted Average Yield for like cartridges from this manufacturer.

For example, if a cartridge failed to print at least 10 “High Quality” pages but still printed more than 2.5% of its Adjusted Average Yield, this cartridge was considered to be a Premature Failure (having a high number of “Low Quality” Pages) rather than a DOA. The following is an example of the types of problems observed:

- Severe ink leakage in the packaging during shipment (cartridge arrives in a pool of ink in the plastic bag)
- Ink leaking into the printer
- Cross-contaminated colors
- Printer unable to recognize the cartridge
- Cartridges that printed no pages
- Color cartridges that never printed one of the three colors

Premature Failure (PF) Cartridges

If the total number of pages printed by a cartridge was less than 75% of the Adjusted Average Yield for like cartridges of a brand, it was classified as a Premature Failure.

For example, if a cartridge printed a total of 200 pages, but the Adjusted Average Yield for that brand of cartridge was 325 pages, this cartridge would be classified as a Premature Failure.

The following are some observations that were made when cartridges failed prematurely:

- Ink leaking from the cartridge into the printer
- Anomalies on printed pages that became more severe over time

Low Quality (LQ) Cartridges

A cartridge was classified as Low Quality if it failed to print at least 90% “High Quality” pages, but was neither DOA nor a Premature Failure. The following details the most common print quality problems observed in these cartridges:

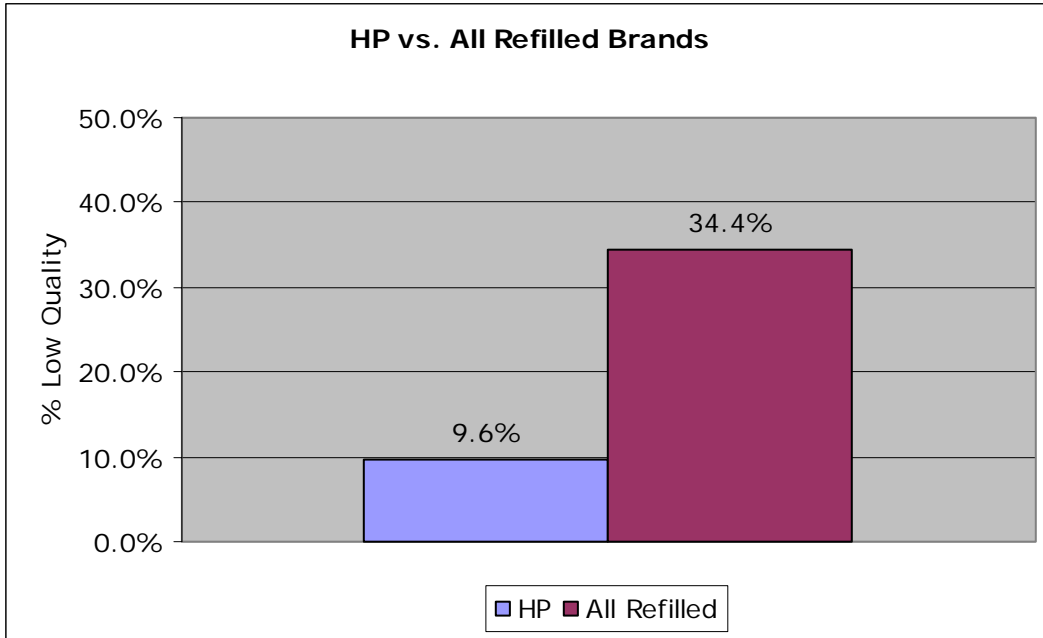
- Banding – generally seen as evenly spaced line anomalies that are normally visible all the way across the page.
- Bleed Through – seen as areas on the back of a printed page where ink has saturated the page and is clearly visible.
- Color Bleed – generally visible on a printed page where one of the colors is seen crossing intended boundaries and is moving into spaces where that specific color ink was not intended.
- Ink Void – seen as a more severe form of banding, a thicker line across the page where ink is missing from the page.
- Missing Dots – a small section on a page where expected content is missing
- Mottle – a section of filled color that is not evenly distributed, appears blotchy with darker and lighter sections.
- Random Ink Dots – random content on a page that should not be present.
- Smear – small lines to the sides of intended content that should not be present.
- Smudge – an unexpected or irregular amount of ink visible on the printed page (front or back of page). Usually small but length is measurable.
- Streak – filled areas where there is a definite lighter section, generally does not continue across the entire page.
- Uneven Line Thickness – lines that run vertically or horizontally that should be uniform, but vary in thickness.
- Wrong Color Dots – areas where color is missing or miss-applied.
- Intermittent Color Loss – color shifts that can occur intermittently across the page.

Print Quality by Brand

On average, refilled print cartridges printed more than three times the number of “Low Quality” pages than HP print cartridges when looking at the percent of “Low Quality” pages printed for the each brand.

Brand	High Quality Pages		Low Quality Pages			% Low Quality
	PQ5	PQ4	PQ3	PQ2	PQ1	
HP	40.4%	50.1%	7.8%	1.4%	0.4%	9.6%
Brand A	22.6%	48.5%	26.5%	1.6%	0.8%	28.9%
Brand B	21.7%	42.5%	30.6%	4.0%	1.2%	35.8%
Brand C	27.4%	41.6%	28.5%	1.2%	1.3%	31.1%
Brand D	10.4%	49.2%	37.9%	1.8%	0.7%	40.5%
Brand E	11.4%	47.5%	39.4%	1.2%	0.5%	41.1%
Brand F	26.8%	48.8%	19.5%	1.7%	3.2%	24.5%
Brand G	17.1%	47.9%	33.0%	1.2%	0.7%	35.0%
Brand H	4.8%	45.1%	47.2%	2.0%	0.9%	50.1%
Brand J	21.1%	52.7%	23.1%	2.7%	0.4%	26.2%
Brand K	16.5%	47.3%	32.9%	2.1%	1.3%	36.3%
Brand L	14.5%	50.4%	32.5%	1.6%	1.0%	35.1%
Brand M	20.0%	46.4%	28.5%	4.0%	1.1%	33.6%
Brand N	16.4%	54.3%	25.9%	2.1%	1.3%	29.4%
HP	40.4%	50.1%	7.8%	1.4%	0.4%	9.6%
All Refilled Brands	17.7%	47.9%	31.2%	2.1%	1.1%	34.4%

**Table 2:
Print Quality by Brand**



Graph 2:
Page Quality - Percent "Low Quality" Pages

Cartridge Reliability Problem Examples

The following photos document some of the issues observed with refilled brands' print cartridges:

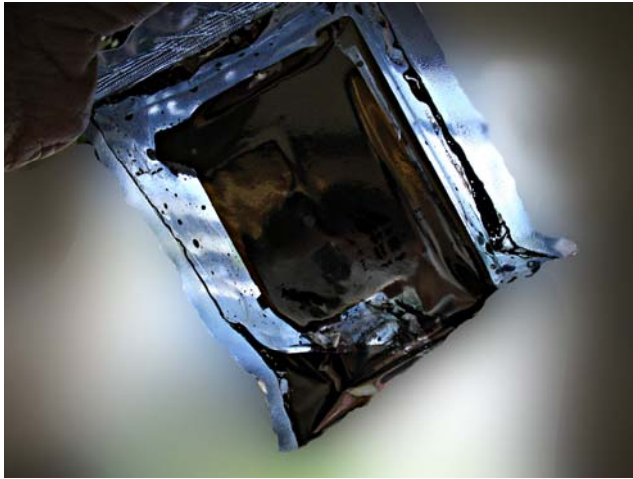


Photo 1: Brand F - black print cartridge arrived in a pool of ink (classified as DOA)

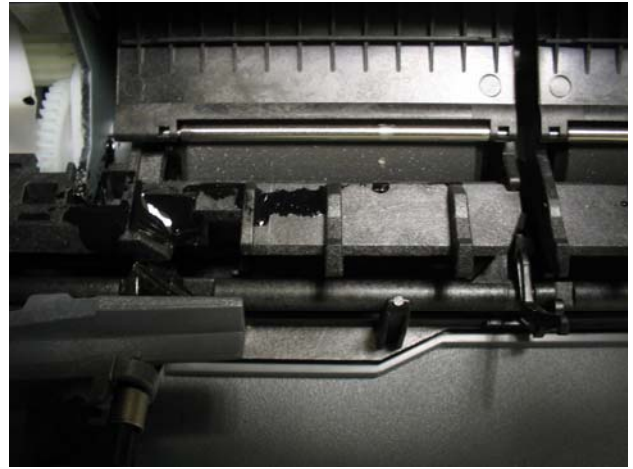


Photo 2: Brand H - print cartridge leaked black ink into the printer (classified as a Premature Failure)



Photo 3: Brand A - print cartridge leaking ink (classified as DOA)



Photo 4: Brand G - print cartridge leaking ink (classified as DOA)

Page Quality Samples

The following are examples of pages that were ranked as Print Quality (PQ) 1 and 2 pages:



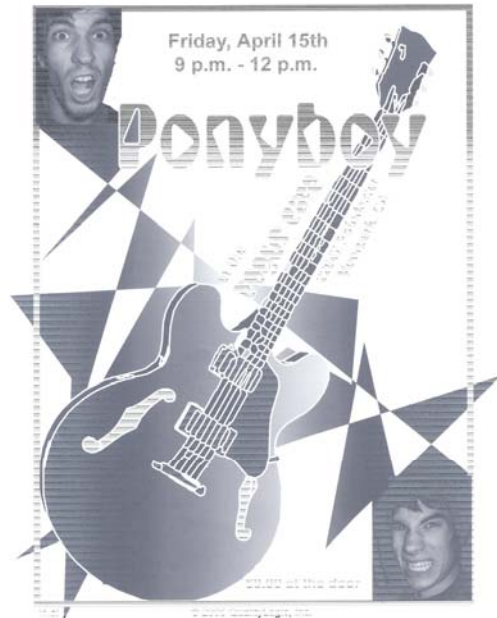
Excerpt from page sample to the right



Low Quality Page (PQ Level 1)
Black cartridge ink void



Excerpt from page sample to the right



Low Quality Page (PQ Level 2)
Black cartridge ink void

The following is a sample of a PQ 3 page – note banding throughout the page, uneven color density (known as “mottle”) in the black areas as well as color bleed, in particular between the black and yellow ink:

Homes for Sale in Moorpark!

If you live in Eastern Moorpark and are considering selling your home or know someone who is be sure to give Charles Swan a call. You will receive a gift worth \$50 if the home is listed with us.

Swan REALTORS

The most trusted name in Moorpark whether you are buying, selling or just keeping track of your neighbors.

We knew that this one would not last. Situated on a corner lot in Moorpark style, with Queen Anne touches throughout, four fireplaces, round turret and beautifully landscaped this classic shouts pride of ownership. Charles Swan sold this home for more than the owners initially planned asking. Ask for Swan when you want to sell.

First time on the market, this beauty won't last. Stunning views and a spectacular water feature accentuate this completely refurbished five bedroom home. You can walk from your new home to the theater district on High Street and the kids can walk to school.

OPEN HOUSE ON SUNDAY APRIL 7th

Who hasn't thought of living in that lovely yellow house across the street from the meeting hall. Well now you can and at a price that you can afford.

OPEN HOUSE ON SUNDAY APRIL 7th

1805 Spring

2002 Moorpark Avenue

Mottle (points to the text area)

Banding (points to the top header area)

Inter-color bleeding (points to the street map area)

i3.cdr © 2005 QualityLogic, Inc.

Appendix 1: Table of Definitions

Test Project Terminology	Definition
Adjusted Average Yield	The average of the total number of pages for each color cartridge by brand from data collected during this test. Pages printed by DOA and Premature Failure cartridges are not included in this average.
End-of-Life (EOL)	Determined as the point in time when the printer would cease to print "High Quality" pages with this cartridge installed (or ceased to print "High Quality" pages due to an ongoing malfunction).
High Quality Page	Print Quality Level 4 or 5 as defined below.
Low Quality Page	Print Quality Level 1, 2, or 3 as defined below.
Dead on Arrival (DOA) Cartridge	A cartridge that printed 10 or fewer "High Quality" pages and fewer than 2.5% of the adjusted average yield for like cartridges from this manufacturer.
Premature Failure (PF) Cartridge	If the total number of pages printed by a cartridge was less than 75% of the Adjusted Average Yield for like color cartridges of a brand, it was classified as a Premature Failure. DOA cartridges are classified separately and are not included in this category.
Low Quality (LQ) Cartridge	A cartridge that failed to print at least 90% "High Quality" pages. DOA and Premature Failures are classified separately and are not included in this category.
Page Sample Size	All printed pages were inspected for this comparison.
Problem cartridge	Cartridge exhibiting one of the problems listed above: DOA, PF or LQ.
Sample Size	The number of cartridges tested for this test
Print Quality (PQ) Level 5 Page	No apparent artifacts and a user would put this page in his or her resume, or in the case of a photo, provide this photo as a gift to someone. Combined with Level 4 (below), these pages are defined as "High Quality" pages.
PQ Level 4 Page	May have a minor flaw such as one speck or uneven graphic rendering, but the average user would still use it in a typical business document. In the case of a photo, the photo might be given to a family member, but would not be suitable for framing. Combined with Level 5 (above), these pages are defined as "High Quality" pages.
PQ Level 3 Page	Sufficiently flawed that it would not be circulated to others as a business document and would only be acceptable as a draft page. In the case of a photo, it would be reprinted. These pages are defined as "Low Quality" pages.
PQ Level 2 Page	Have lost some legibility and would need to be re-printed. These pages are defined as "Low Quality" pages.
PQ Level 1 Page	Have lost content and would need to be re-printed. These pages are defined as "Low Quality" pages.

Appendix 2: Test Methodology

The test methodology for this reliability comparison study was developed by QualityLogic for HP. The following is a summary of the methodology used for this study:

A total of 390 refilled print cartridges and 50 HP print cartridges were tested. 30 refilled print cartridges from each brand (average of 11 black and 19 tri-color) were tested and 50 HP print cartridges (22 black and 28 tri-color) were tested. Three HP DeskJet 6122 printers (C8954A) and three HP PSC 1350 printers (Q3501A) were used for each brand. The #45 and #78 cartridges were tested for the HP DeskJet 6122 and the #56 and #57 cartridges were tested for the HP PSC 1350. These sample sizes were selected using statistical methods to achieve statistically significant results.

QualityLogic procured all printers, paper, and HP print cartridges through standard retail channels. Refilled print cartridges were obtained through multiple retail channels where possible or directly from the manufacturer. A set of six new printers was used for the testing of each brand to assure uniformity and accuracy of the test data independent of a particular printer. When cartridges were only available through one vendor, cartridge markings were examined to ensure lot variation.

The impact of the print cartridge on the printer's functionality was also recorded in the areas of consistent operation, leakage of ink inside the printer, and failure of printer components (rollers, carriage, etc). The cartridge bays were inspected and wiped clean of any residual ink and/or paper dust before any new cartridge was installed. Once a cartridge was installed, the printer would perform a full calibration to ensure the quality of the print jobs.

Printer settings were left at the factory default. Driver quality settings were set to Normal for all plain media print jobs and Best for the photo on plain media print jobs. The driver quality settings for photo print jobs were set to Best or Normal, based on the photo media manufacturer recommended settings. All printer/cartridge warnings were noted and cartridges were printed to End-of-Life.

Normal office conditions of temperature (23°C ±2°) and relative humidity (50% ±10%) were maintained for the duration of the test. All ink and paper consumables were stabilized in these conditions for a minimum of 8 hours prior to use, tested in the same environment, and were subject to the same fluctuations.

The following multipurpose papers and photo media were used for this comparison:

- Hewlett-Packard Multipurpose
- Hammermill Multipurpose
- Staples Multiuse
- Hewlett-Packard Premium Plus, Glossy
- Kodak Ultima Picture Paper, High Gloss
- Office Depot Professional Photo Paper, Brilliant Gloss

Each test page was serialized and identified as to the printer used to print the page, the print cartridges installed in the printer, and a sequential page number. Duplicate page numbers from each brand were avoided by assigning each printer a different page range.

Seven test pages (files i1, i3, i4, m1, m3, p1, and p2) were designed using popular application packages (Word XP, Excel XP, Adobe Illustrator 7.0 and Corel Draw) to achieve a balanced representation of printing samples.

The test pages were sent to each printer in a predetermined print sequential. Print quality assessments of the pages printed by each print cartridge and printer combination were compared at regular intervals throughout the life of the cartridges in the test.

End-of-Life was determined as follows: Each of the printer models used for this test allowed for a 3-level cleaning cycle (Basic, Intermediate and Prime). Cleaning cycles were initiated when observed page quality dropped to a PQ 2. Cleaning levels were applied incrementally with a single i1 page printed between cleaning cycles. Printing continued as long as the cartridge could be restored to the ability to print "High Quality" (PQ 4 or 5) pages. A maximum of 2 cleaning cycles was applied to any single cartridge. (Both cartridges were cleaned each time a cleaning cycle is initiated. Cleaning cycles were initiated based on a page quality drop that was assigned to a single cartridge and therefore not counted against the other cartridge residing in the printer.) When 2 cleaning cycles were exhausted and the print quality dropped to a PQ 2, End-of-Life was determined.

A cartridge could also arrive at End-of-Life with only a single cleaning cycle if the Printer Technician determined that the cartridge had printed to within 10% of the expected average yield, as determined by similar cartridges from a particular brand.

All printed pages were inspected for print quality.