



Page Yield / Ink Cartridge Reliability Comparison Study

HP Inkjet Print Cartridges Vs Refilled Brands

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For distribution in Asia Pacific



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Executive Summary

In June 2007, TÜV SÜD PSB Pte Ltd completed a comparative study on Hewlett Packard (HP) Original inkjet cartridges and refilled inkjet cartridges that are used in the HP Deskjet 5650 (C6490E) and HP Deskjet 930C (C6427A) printers.

The study was designed to evaluate the page yield and reliability of Original HP inkjet cartridges versus 14 brands of refilled cartridges. The 14 brands of the refilled cartridges were selected based on sales and usage in the region. All the cartridges tested in the study were procured from the Asia Pacific region.

The 14 brands of refilled cartridges were categorized in the following manner:

- 1) “Branded Remanufactured Refills**” - Remanufactured HP cartridges
- 2) “Organised Refills**” - Empty Original HP inkjet cartridges that TÜV SÜD PSB Pte Ltd had sent to be refilled at chain stores belonging to 5 locally recognised brands situated in the Asia Pacific region and
- 3) “Unorganised Refills**” - Empty Original HP inkjet cartridges that TÜV SÜD PSB Pte Ltd had refilled at stores that had no locally recognisable brand name situated in 4 major cities in 2 designated countries located in the Asia Pacific region

TÜV SÜD PSB Pte Ltd carried out the testing based on the methodology of study developed by HP as set out in Appendix 1 on page 6 of 14.

The following were observed during this study :

Page Yield – On average, Original HP inkjet print cartridges produced 106.6% (>2 times) more pages than all the refill brands tested.

Cartridge Reliability – None of the Original HP inkjet print cartridges tested were dead-on-arrival* or premature failure*, whereas on average, 25.7% of the refill cartridges tested were either dead-on-arrival or failed prematurely.

Additional Observations – The shortest and longest time taken to refill a cartridge at the various designated refill stores was between 1 minute to 3 hours. The average time taken was approximately 17 minutes. Not all cartridges could be successfully refilled. Of all the units sent for refill at stores, 14 units failed or became unusable during the refill process.

* Please refer to Appendix 2 on page 9 of 14 for the terms and definitions.



Detailed Results

1. Page Yield

From the study, on average, Original HP inkjet print cartridges produced 106.6% (>2 times) more pages than all the refill brands tested**.

When comparing the Original HP inkjet cartridges to the branded remanufactured refills only, on average Original HP inkjet print cartridges produced 59.8% more pages than the branded remanufactured refill cartridges (brands A – E) tested**.

When comparing Original HP inkjet cartridges to the refill store brands only, on average Original HP inkjet print cartridges produced 146.7% more pages than the cartridges refilled at the organised and unorganised refill stores (brands F – N) tested**.

The table and chart on page 3 show the performance of each refilled brand as compared to the performance of the Original HP inkjet cartridges. Normalized 90% lower confidence bound page yield values were used for this comparison. (Please refer to Appendix 2 on page 12 of 14 for the terms and definitions.) For each cartridge model, these values were combined to create a single index value for every brand tested. The score for the HP brand is represented by 100.0%, whilst the scores for each refill brand are represented as compared to the HP brand. For the column “HP/Brand relative page yield difference”, the percentages indicates how many percent more pages Original HP inkjet cartridges printed as compared to any given brand. For example, Brand A had a score of 56.4% when compared to the HP brand, indicating that Original HP inkjet cartridges printed 77.3% more pages than Brand A.

** This comparison was based on normalized 90% lower confidence bound page yield values. (Please refer to Appendix 2 on page 12 of 14 for the terms and definitions).

Detailed Results – cont'd

Brand Type	Brand	No. of Cartridges tested	Normalized 90% Lower Confidence Bound Page Yield Values (Please refer to Appendix 2 on page 12 of 14 for the terms and definitions)	
			HP / Brand Relative Page Yield Difference	Brand / HP Absolute Page Yield Difference
HP	HP	68	Not Applicable	100.0%
Branded Remanufactured Refill	Brand A	68	77.3%	56.4%
Branded Remanufactured Refill	Brand B	69	78.7%	56.0%
Branded Remanufactured Refill	Brand C	68	43.3%	69.8%
Branded Remanufactured Refill	Brand D	68	127.3%	44.0%
Branded Remanufactured Refill	Brand E	68	15.3%	86.7%
Organised Refill	Brand F	70	124.8%	44.5%
Organised Refill	Brand G	71	138.0%	42.0%
Organised Refill	Brand H	68	124.7%	44.5%
Organised Refill	Brand I	68	97.8%	50.6%
Organised Refill	Brand J	68	92.0%	52.1%
Unorganised Refill	Brand K	72	382.2%	20.7%
Unorganised Refill	Brand L	68	243.2%	29.1%
Unorganised Refill	Brand M	68	129.6%	43.6%
Unorganised Refill	Brand N	68	165.3%	37.7%
Sum / Average of Branded Remanufactured Refills		341	59.8%	62.6%
Sum / Average of brands refilled at Organised and Unorganised Refill Stores		621	146.7%	40.5%
Sum / Average of Branded Remanufactured Refills and Refill Store Cartridges Tested		962	106.6%	48.4%

Table 1 : Cartridge Page Yield

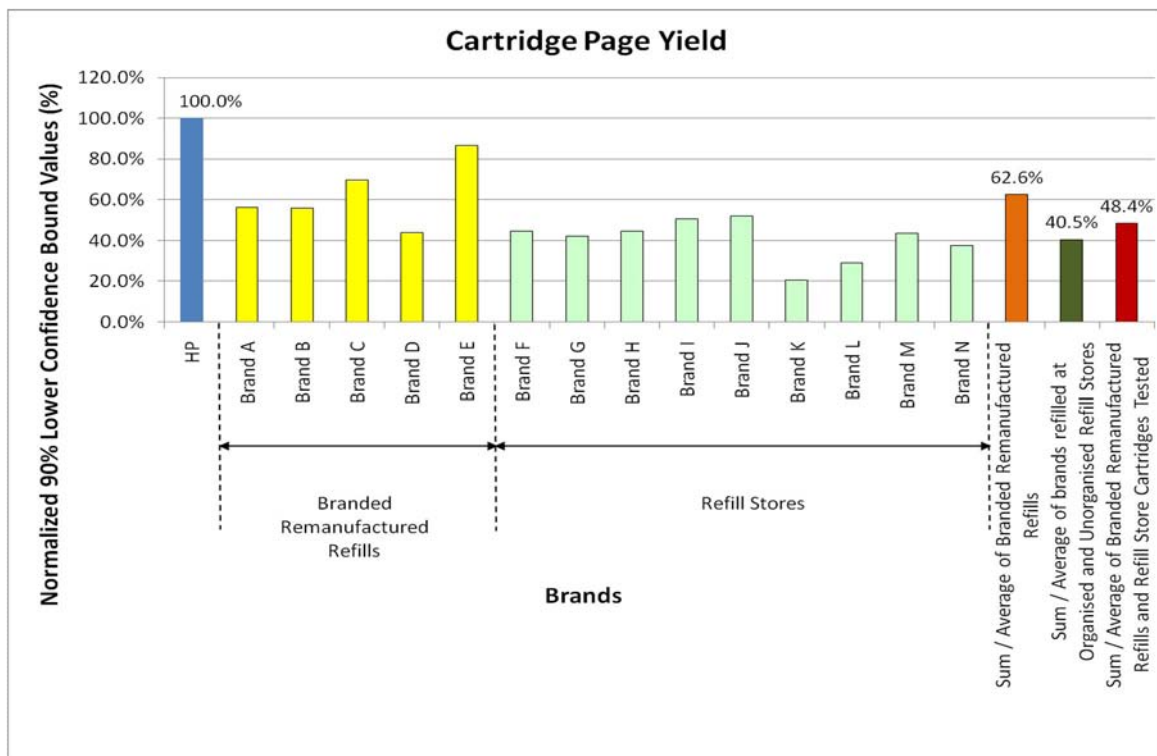


Chart 1 : Cartridge Page Yield

Detailed Results – cont’d

2. Cartridge Reliability

From the study, none of the Original HP inkjet print cartridges tested were dead-on-arrival* or premature failure*, whereas on average, 25.7% of the refill cartridges tested were either dead-on-arrival* or failed prematurely.

More specifically, 12% of the branded remanufactured refills (brands A – E) tested were either dead-on-arrival* or failed prematurely, and 33.2% of the brands refilled at organised* and unorganised* refill stores (brands F – N) tested were either dead-on-arrival* or failed prematurely.

The dead-on-arrival* and premature failure* cartridges are listed separately for each brand as well as 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 branded remanufactured refills*, for brands refilled at organised* and unorganised* refill stores, and for branded remanufactured refills and refill store cartridges tested. For example, Brand A had a total of 68 cartridges in the test. Six cartridges (8.8%) were found to be dead-on-arrival*, and one cartridge (1.5%) was found to fail prematurely. There were a total of seven (10.3%) problem cartridges in the test for Brand A.

* Please refer to Appendix 2 on page 9 of 14 for the terms and definitions.

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%
Branded Remanufactured Refill	Brand A	68	6	8.8%	1	1.5%	7	10.3%
Branded Remanufactured Refill	Brand B	69	12	17.4%	3	4.3%	15	21.7%
Branded Remanufactured Refill	Brand C	68	2	2.9%	4	5.9%	6	8.8%
Branded Remanufactured Refill	Brand D	68	9	13.2%	4	5.9%	13	19.1%
Branded Remanufactured Refill	Brand E	68	0	0.0%	0	0.0%	0	0.0%
Organised Refill Kiosk	Brand F	70	20	28.6%	6	8.6%	26	37.1%
Organised Refill Kiosk	Brand G	71	15	21.1%	4	5.6%	19	26.8%
Organised Refill Kiosk	Brand H	68	7	10.3%	13	19.1%	20	29.4%
Organised Refill Kiosk	Brand I	68	10	14.7%	9	13.2%	19	27.9%
Organised Refill Kiosk	Brand J	68	10	14.7%	7	10.3%	17	25.0%
Unorganised Refill Kiosk	Brand K	72	26	36.1%	6	8.3%	32	44.4%
Unorganised Refill Kiosk	Brand L	68	17	25.0%	10	14.7%	27	39.7%
Unorganised Refill Kiosk	Brand M	68	10	14.7%	10	14.7%	20	29.4%
Unorganised Refill Kiosk	Brand N	68	12	17.6%	14	20.6%	26	38.2%
Sum / Average of Branded Remanufactured Refills		341	29	8.5%	12	3.5%	41	12.0%
Sum / Average of brands refilled at Organised and Unorganised Refill Stores		621	127	20.5%	79	12.7%	206	33.2%
Sum / Average of Branded Remanufactured Refills and Refill Store Cartridges Tested		962	156	16.2%	91	9.5%	247	25.7%

Table 2 : Cartridge Reliability

Detailed Results – cont'd

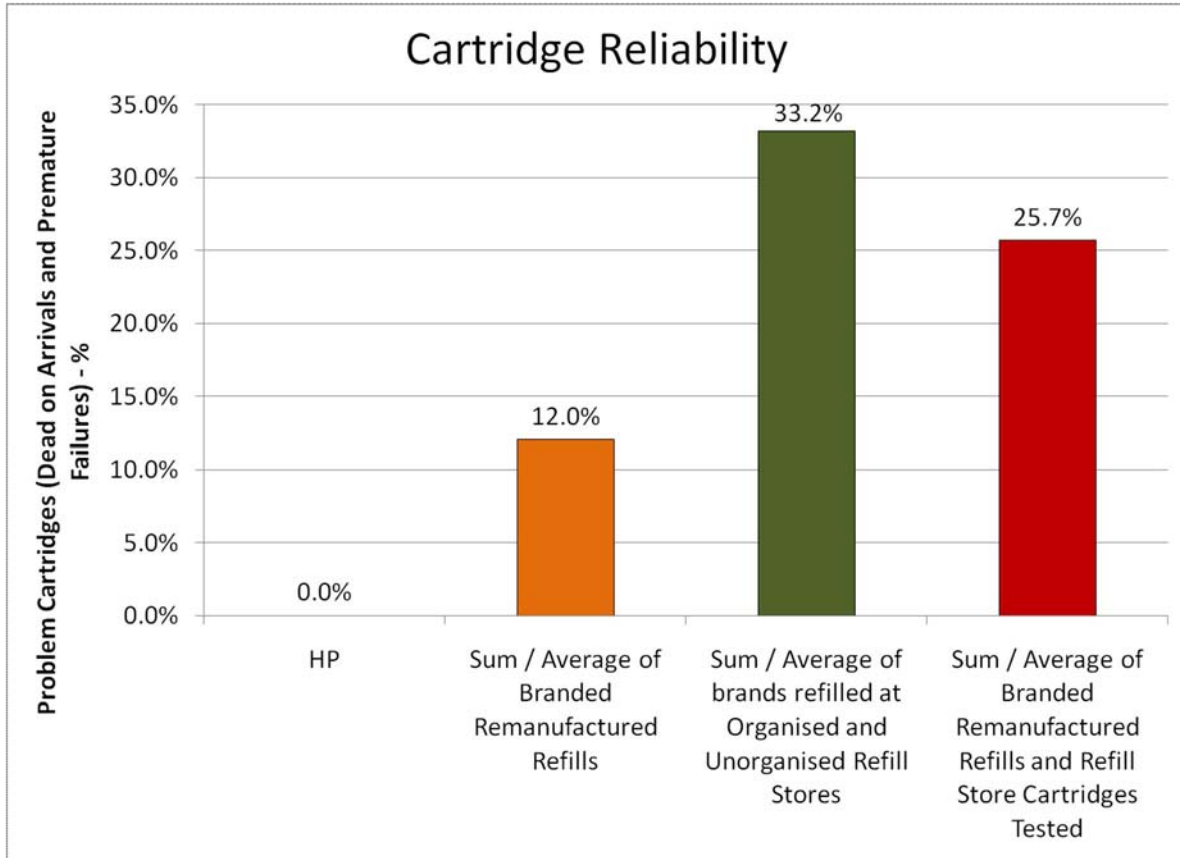


Chart 2 : Cartridge Reliability Failures

Appendix 1 : Methodology of Study

Below is a summary of the methodology used for this study.

A1.1 Test items

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

Printer	Black Print Cartridge	Color Print Cartridge
HP Deskjet 5650 (C6490E)	HP 56 (C6656A)	HP 57 (C6657A)
HP Deskjet 930C (C6427A)	HP 45 (51645A)	HP78A (C6578A)

17 HP Deskjet 5650 printers and 24 HP Deskjet 930C printers were used to test 68 Original HP inkjet print cartridges and 962 refilled print cartridges. HP Everyday Paper (210 x 297mm, 80g/m2, Hi White) was used for all printing in this study.






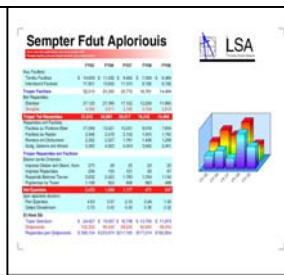

Appendix 1 : Methodology of Study – cont’d

A1.2 Procurement of test items

TÜV SÜD PSB Pte Ltd procured all printers, paper and Original HP inkjet cartridges through standard retail channels. Branded remanufactured refill print cartridges were purchased via our agents in the respective cities, directly from the manufacturer. The 14 brands of the refilled cartridges were selected based on sales and usage in the region. All the cartridges tested in the study were procured from the Asia Pacific region. For the refill store brands tested, approximately 50% of the test data is based on cartridges that were once refilled, approximately 30% of the test data is based on cartridges that were twice refilled and approximately 20% of the test data is based on cartridges that were refilled three times.

A1.3 Test duration, test environment and print suite

Printing was performed continuously 7 days a week, 24 hours a day in a controlled environment of 20-23°C and 60%±10%RH. The 5 – page test suite from ISO/IEC 24712 was used for this study. The test pages were as follows :

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

A1.4 Transportation of test cartridges to and from test facility

Cartridges were placed in air tight plastic bags and shipped via air shipment in glass containers to the respective countries for the refills. This is to protect against transportation induced failures. The glass containers have been pressure tested to 40000ft prior to test commencement to simulate similar conditions during air shipment.

A1.5 PC and Printer settings

PCs were installed with operating system Windows 98 and Adobe Reader version 6.0 along with the respective printer drivers for the HP 930C Deskjet printers and HP 5650 Deskjet Printers.

“Plain Paper” media type setting was selected and the print mode that comes out by default was used. Image and print quality modifiers were set to “Normal”. Auto media detection, user selectable ink conservation modes, page modifiers “Fit to Page” and “Font Substitution” was disabled.



Appendix 1 : Methodology of Study – cont'd

A1.6 Testing process


Each cartridge was visually inspected for leaks and other damage prior to test commencement. Printing was performed until at least 17 black and 17 cartridges per brand reached end of life. Black and color cartridges were tested in parallel. After either the black or color cartridges were completed for a particular brand, Original HP inkjet cartridges were used to complete the printing for the remainder cartridge. All results and effects of these Original HP inkjet cartridges were ignored in the test.

The cartridges which had reached end of life were sent to organised refill stores* and unorganised refill stores* for the refilling. The cartridges which were once refilled and have passed the Page Yield test were used as the empty for the second refill. Correspondingly, the twice refilled cartridges which have completed Page Yield test were used as the empty for the three times refilled. For each of the refilling stages, care was taken to ensure that cartridges were not switched between store brands, that a cartridge which was refilled more than once remains within a given refill store, and that cartridges handed in for the refill were the same ones returned for the testing. In the event of empty cartridges that cannot be successfully refilled and were substituted with another pre-refilled or alternative cartridge by the refill store vendor, that substitute or replacement was not used for the test.



In order for the results obtained to be statistically significant and valid, a minimum of 9 black and 9 color cartridges were successfully printed to end of life due to fade.

*Please refer to Appendix 2 on page 9 of 14 for the terms and definitions.

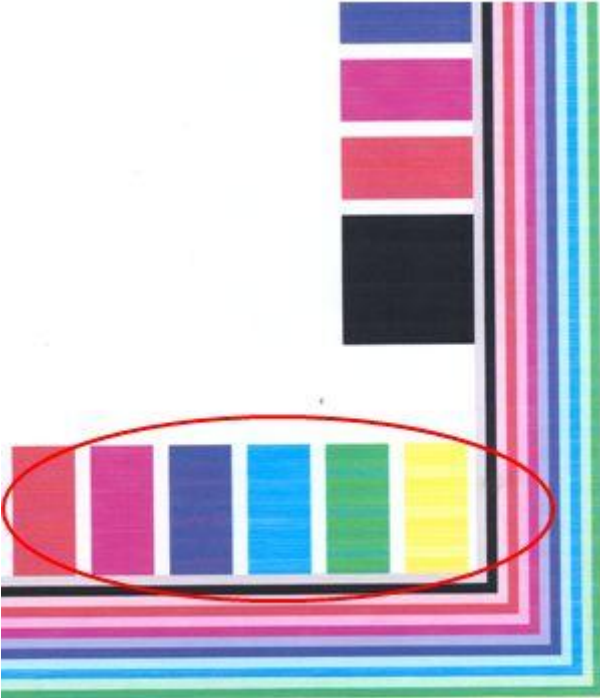
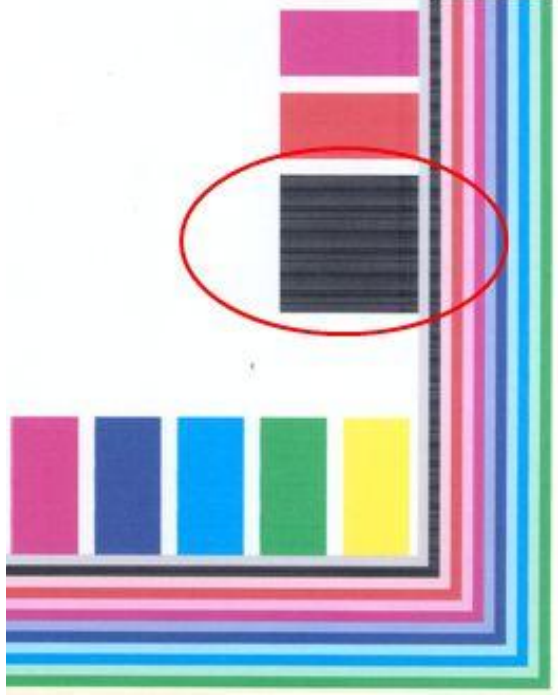
Appendix 2 : Terms and Definitions

Terminology used in Study	Definition
1. Dead On Arrival (DOA)	A condition determined by one of three mechanisms: <ul style="list-style-type: none"> • Cartridge found to have substantial leakage (as defined below) at start or during testing. • 50 or less pages printed by a cartridge. • Color mix (as defined below) has occurred and incorrect colors printed on 10 consecutive pages – color cartridge failure mechanism only.
2. Premature Failure	A cartridge that has a page yield of less than 75% of the average page yield (as defined below) for that cartridge brand.
3. Branded Remanufactured Refill	These are remanufactured HP cartridges
4. Organised Refill Stores	Where a refill store has a locally recognized brand name, this is referred to as an organised refill outlet. These shops typically have a string of chain outlets located at different parts of the city/region. The refill outlets for the refill were randomly selected in 5 geographically different locations within the city/region. A cartridge refilled more than once is allowed to be refilled in another store within the same chain. E.g. Cartridge refilled at Brand Name X Store A for first refill, can be refilled at Brand Name X Store T for second refill.
5. Unorganised Refill Stores	Where a refill store has no locally recognized brand name, the refill store is referred to as an unorganised refill outlet. The refill outlets for the refill were randomly selected in 5 geographically different locations within 4 major cities in 2 countries. (E.g. North, South, East, West and Central). A cartridge refilled more than once must be returned to the same store it was first refilled.
6. Substantial ink leakage	<ul style="list-style-type: none"> - 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.
	
7. End of Life (EOL)	A condition determined by one of three mechanisms: <ol style="list-style-type: none"> 1. Fade has occurred on the diagnostic page. 2. Streak removal procedure steps have been exhausted. 3. Cartridge is Dead-on-Arrival (DOA).

Appendix 2 : Terms and Definitions – cont'd

<p>8. 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 10th page printed by that printer.</p>
 <p style="text-align: center;">Example of Color Fade</p>	 <p style="text-align: center;">Example of Black Fade</p>


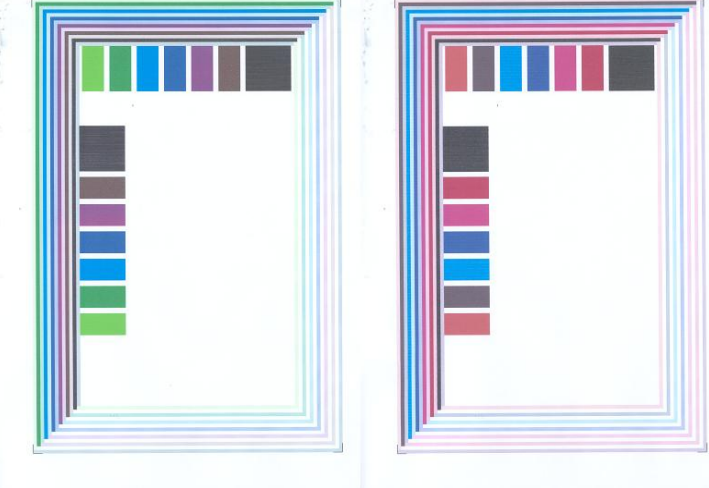


Appendix 2 : Terms and Definitions – cont’d

<p>9. 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>Example of Color Streaks</p>	 <p>Example of Black Streaks</p>
<p>10. Streak Removal Procedures</p>	<p>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. If the cleaning operation had the option of multiple cleaning strengths, the procedure indicated in the printer manual for resolving streaking should be followed. 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 End of Life.</p>

Appendix 2 : Terms and Definitions – cont’d

<p>11. Individual Cartridge Yield</p>	<p>Individual cartridge yield is calculated by counting the number of diagnostic plots printed between cartridge installation and end of life, then multiplying by five. The diagnostic page is the last plot printed in the test suite.</p>
<p>12. Average Cartridge Page Yield</p>	<p>Average cartridge yield for a given cartridge type</p> $\bar{X} = \sum_{i=1}^n \frac{x_i}{n}$ <p>Where</p> <ul style="list-style-type: none"> • 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. <p>This average cartridge page yield number is solely used for the purposes of calculating premature failures.</p>
<p>13. 90% Lower Confidence Bound Page Yield</p>	<p>Calculated as:</p> $\bar{X} - (t_{\alpha,n-1}) * \frac{s}{\sqrt{n}}$ <p>Where</p> <p>$t_{\alpha,n-1}$ 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 $t_{\alpha,n-1}$.</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 premature failure.</p>
<p>14. Normalized 90% Lower Confidence Bound Page Yield</p>	<p>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.</p> <p>Example:</p> <p>90% Lower Confidence Bound page yield HP = 800 90% Lower Confidence Bound page yield refill brand A = 600</p> <p>Normalized 90% Lower Confidence Bound Page Yield HP = 100.0% Normalized 90% Lower Confidence Bound Page Yield refill brand A = 75.0%</p>

Appendix 2 : Terms and Definitions – cont'd

<p>15. 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, 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>Good Diagnostic Page</p>	<p>View of printouts with color mixes</p>
<p>16. Test Page Suite</p>	<p>A series of five pages that are printed consecutively in order as a single job, ending with a diagnostic page (ISO/IEC 24712).</p>
	
<p>17. Problem Cartridge</p>	<p>Cartridges identified as dead-on-arrival and cartridges identified as premature failures (as defined above).</p>



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