# International Supply Yield Standards: Past, Present and Future Developments

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# Abstract

For the past several years, ISO/IEC JTC1 SC28 developed standards for the measurement of yield for various printing systems. Thus far, yield measurement methods are published for monochrome laser (ISO/IEC 19752), color laser (ISO/IEC 19798), color inkjet (ISO/IEC 24711) and a common set of color test pages (ISO/IEC 24712). This paper will discuss the basic methodology behind the standards. Additionally, standards under development will be discussed.

#### Introduction

Reliably determining the yield for an office printing system is important to all involved with the design and use of printers. For the manufacturer it provides design specification for monitoring processes. For marketers it enables marketing against competing products. For the consumer it facilitates comparisons and one component for an accurate cost of ownership assessment

Prior to 2004, manufactures quoted yield using several different methods, additionally, there were several disparate national standards for the measure of cartridge yield. Each of these methodologies and standards had issues, some of them being quite significant in preventing the consistent measure of cartridge yield. In the spring of 2000, ISO/IEC JTC 1/SC28 started work on the first of many standards whose goal was to provide consumers and manufactures with common tools to measure printer cartridge yield.

In the past, each manufacturer used proprietary methods to measure the number of pages that a toner or ink cartridge could produce. Most methods used a 5% coverage page for determining their stated yield. While this might seem to be standardized on the surface, it had the potential for causing poor comparisons between manufacturer's performances. With the publication of ISO/IEC 19752:2004 in the summer of 2004, customers could finally compare the yields of several manufacturers' monochrome laser printers yields in an apples-to-apples fashion. Building on the success of 19752, SC28 created additional standards for the measure of color toner and ink yields (ISO/IEC 19798 & ISO/IEC 24711) using a common set of test pages defined in ISO/IEC 24712. Recently SC28 has started work on a set of photo yield standards to meet the need of the expanding consumer photo printing market. This article will describe the underlying philosophy of the yield standards and some of the challenges and issues overcome in the development of the standards.

#### History

Before the publication of ISO/IEC 19752, manufacturers generally claimed their yields in terms of how many 5% pages they could print before the cartridge was at end of life. While on

the surface this seems to be a standard measure, there are a number of issues with this as a means to compare performance from manufacturer to manufacturer. In rough order of importance there are four major factors that can impact the yield of a printing system.

- Test page design What test page is used for measuring yield. 5% coverage defined on letter vs. A4 paper will use a different amount of toner. Some manufactures chose to use the printable area instead of the total area of the page for coverage calculations. Printing one large block of colorant vs. printing characters or vector graphics will also significantly impact the use of toner and in most cases the yield of the cartridge. Pages designed using any of the previous design criteria could be called a 5% page, but would provide a drastically different yield using the same printing system. Finally, from a consumer standpoint, most users did not know what a 5% page looked like. What they really want to know is how many of a page that they can relate too can a cartridge produce.
- 2. End of life determination How is end of life of the cartridge determined? End of life can be when the printer says the cartridge is at end of life or when there is a detectable fade. Detectable fade is highly subjective and very dependant on the test page printed and the criteria used for judging fade.
- 3. Testing conditions Printing environment has an impact on yield performance. Generally for electro-photographic (EP) systems, if the environment is cool and the Relative Humidity (RH) is low, a given cartridge will produce more pages than a cartridge tested in higher temperature and RH.
- 4. Calculation of the reported value Is a single cartridge tested and the yield reported? Manufacturing variation occurs in both the printer manufacture and manufacture of the cartridges. Proper representation of the average performance of the printing system requires some accounting of these variables. After testing multiple cartridges, should an average be reported or a measure that takes into account how much variation is present in the yield performance?

#### **Monochrome Toner**

ISO/IEC 19752 takes each of the previously described factors into account and also further defines other areas that might impact yield of a printing system.

Test Page Design: In general, customers don't care or understand what the numerical percent coverage of their printed page is. What they want to know is how many pages they can get out of a cartridge and how that compares to other printing systems when printing the same page. When developing 19752, the committee decided not to use a percent coverage and focus more on creating a well defined page that customers could relate to their everyday printing. To accomplish this, SC28 defined a test page using PostScript and converted it into a PDF page (Figure 1). This page does not have a specified coverage because, for each printing system, the actual page coverage will vary. All fonts are imbedded in the page to reduce the potential for font substation within the printer. Finally, around the periphery of the page, features are included to assess cartridge end of life. The reason these features are on diagonals is to prevent damage to the light sensitive drum due to repeated exposure in one area. The page is size and print direction independent. It will work for both A4 and letter size paper and printing in portrait and landscape directions. To make sure that the page size does not change during the printing process, cross-hatch fidicuals are in each corner of the test page. When testing, the distance between each fidicual must be within certain limits for the testing to be valid. In addition, to provide the end consumer with an idea of what the standard is measuring. the test page is freely available at www.iso.org/jtc1/sc28.



Figure 1 – ISO/IEC 19752 Test Page

End of life: ISO/IEC 19752 uses one of two methods for determination of cartridge end of life; either when the printer itself indicates that the cartridge is at end of life or indication of a well defined print degradation. Having the printer signal end of cartridge life is simple; if the printer stops and indicates that the printer is at end of life then the cartridge is at end of life. If the printer does not provide an end of life signal, then end of life must be determined visually. For a visual evaluation of end of life, there must to be a well defined set of features on the test target and a rigorous inspection method. For ISO/IEC 19752, fade is defined as a noticeably lighter, 3 mm or greater, gap located in the text or boxes around the periphery of the test page. The determination of the change in lightness is made referenced to the 100th page printed for each cartridge in testing. This is to prevent a light printing cartridge from being judged to at end of life prematurely. Additionally, for cartridges where the manufacturer specifies a

shake procedure, two shake procedures are allowed at fades, at the third fade the cartridge is considered at end of life.

Testing Conditions: The environment affects how much toner a printer will use when printing a given page. For the EP printing process, RH will have a larger impact than temperature, but both variables impact the amount of toner used in printing. To reduce the variation caused by different and varying environments, the standard requires that the printing environment be controlled on a 15 minute rolling average to  $23^{\circ}C \pm 2^{\circ}C$  and the RH to  $50\% \pm 10\%$ .

Calculation of the reported value: In a manufacturing process there will be variation. This applies to both the manufacture of the printer and the cartridge. In an attempt to capture some of this variation in the measurement, the drafters of the standard decided to test multiple printers and cartridges. In some cases, the printer can cause as much variation in tested yield as the cartridges. A sample size of nine cartridges and three printers is the bare minimum for starting to characterize this variation. Originally the sample size was set at four printers with four cartridges each for a total of 16 cartridges, but this quantity was reduced to reduce the cost and time of the test. After the data are gathered there are multiple ways that these data could be analyzed. The most simple method would be to take the average of the set of individual cartridge yields, this would provide some information to the customer, but not represent how large the standard deviation was in the sample. This is can significantly impact the anticipated customer experience. If one manufacture has a very tight distribution of yield and another manufacture does not, they could have the same average yield, but a customer would be more likely to experience the published yield using a cartridge with a tight distribution. To account for the yield variation, ISO/IEC 19752 reports the 95% Lower Confidence Bound (LCB) on the mean.

Lower Confidence Bound = 
$$\overline{X} - (t_{\alpha,n-1})^* \frac{s}{\sqrt{n}}$$

Where:

X is the population average

s is the standard deviation of the sample population

*n* is the number of samples tested

 $t_{\alpha,n-1}$  is determined with a Students' t-Distribution Table with n -1 degrees of freedom (df or 'v') and an  $\alpha$  of 0.1. This provides a 2-tailed confidence interval with 90% confidence. The specific t-statistic for 8 degrees of freedom, and 90% confidence is  $t_{\alpha,n-1} = 1.860$ .

This effectively de-rates the calculated average yield based upon the standard deviation of the yield and the number of cartridges sampled. Reporting the LCB provides the customer with a better representation of the cartridge population average yield.

In the summer of 2004, the test page and methodology passed the final voting and was published. Immediately, several manufacturers and test houses embraced this standard. Following on the successful publication of 19752, work started on the developing standards for color cartridge yield.

# **Color Printer Yield**

The most obvious difference in testing a color versus a monochrome printer system is that now at least four cartridge yields have to be measured simultaneously. For an inkjet printing system there are potentially even more colors involved, even for plain paper printing operations. This requires modification to both the test page and the methods for measuring yield.

The same goals used in the development of the monochrome test page drove the design of the color test pages. In the case of monochrome, it was easy to include all required elements and provide adequate coverage on a single printed page. For color this was too difficult. There must be features to detect ink/toner out and colors must be as evenly distributed as possible across Cyan, Magenta, Yellow and black (C,M,Y,K) to optimize the testing of cartridges. As in the monochrome standard, the test pages should also provide content that a customer could relate too. For these reasons, a 5 page test suite was designed for color yield testing. These pages provide features to evaluate both ink and toner out, distribute approximately equal amounts of C,M,Y and K colorant and, for the most part, are documents that a consumer can visualize printing.



Figure 2 – Color yield test suite (ISO/IEC 24712)

Again as in 19752, the pages are defined in PostScript and then converted to a single five page PDF (**Figure** 2). This file is available at www.iso.org/jtc1/sc28.

For laser printing, there is not a huge change in testing methodology between a monochrome and color device. Replacement of cartridges occurs as needed while printing pages continuously till the three cartridge sets are used. Inkjet printing is a little bit more complex due to the variable number of cartridges used in printing. In some cases, a cartridge installed in the printer might not be used while printing on plain paper and will take an extremely long time to run out of ink. For this reason, the concept of primary and supplemental cartridges was introduced into to the inkjet testing methodology.

For inkjet cartridge yield testing, there are two types of cartridges tested, primary and supplemental. Primary cartridges are defined as full density C, M, Y and K cartridges. These cartridges should contribute the bulk of the ink used in printing the test pages. Supplemental cartridges are any other cartridge installed in the printer. Some of these cartridges will be used in a

significant amount; some may not be used at all. The test methodology provides methods to account for all levels of ink usage during test.

As with the monochrome test, a minimum of three sets of primary cartridges must be tested on a minimum of three printers for a total of at least nine sets of primary cartridges. For each color of cartridge, a lower 90% confidence bound is calculated. Traditionally, For color printing systems, the performance of CM&Y are generally reported as the same number. Due to how different printing systems will render the test pages, C, M and Y page yields will seldom be the same. The differences in yield are not due to differences in fill of the cartridges, but more likely are due to how a certain manufacture chooses to render the colours in the test pages. To make the final reported results simpler for the consumer and properly represent performance to the customer, the concept of a composite yield is introduced into the color yield standards. The composite yield is defined as:

$$CY = \frac{n}{\left(\frac{1}{Y_1} + \frac{1}{Y_2} + \dots + \frac{1}{Y_n}\right)}$$

Where:

CY= composite yield for each cartridge in the system Yi = 90% lower confidence bound (LCB) of the page yield of colour i

Using this calculation, a manufacture could advertise equal C, M and Y yield performance for ease of customer understanding while still properly representing the ink/toner use of the printing system.

One final difference between the monochrome EP and the color yield standards is how the yield is stated. In the monochrome standard, the yield is specific to the cartridge. For the color standards, the cartridge yields are dependant on the printer the test is conducted on. This is because there are several situations where a single cartridge can be used in several printers with each printer system test resulting in a different yield.

In December of 2006, the two methodologies (ink and laser) and the related test suite passed final voting and were published. Again as with the publication of the monochrome laser standard, there was immediate acceptance by a wide audience.

# **Future Work**

Now SC28 is working on standards for photographic print yield. As in past standards, the philosophy originally used in the creation of 19752 will act as the basis for these new standards. In this case the goal is to have a measure of the number of 4x6 prints that a given set of cartridges can produce. The new challenges to be addressed are:

- How to cover a photo design space with a limited number of prints
- How to add features to assess color out when the number of colors in a photo printing system can sometimes exceed 10 different colors.

- How many cartridges should be tested to end of life? In some cases some of the colors might not be used for printing photos, such as a non-photo black.
- How to determine the media used for testing. Different types of photo media can significantly impact the yield of a printing system

SC28 is actively addressing these issues and hope to have a first draft by the middle of 2008.

#### References

- ISO/IEC 19752:2004 Method for the determination of toner cartridge yield for monochromatic electrophotographic printers and multifunction devices that may contain printer components
- [2] ISO/IEC 19798:2006 Method for the determination of toner cartridge yield for colour printers and multi-function devices that contain printer components
- [3] ISO/IEC 24711:2006 Method for the determination of ink cartridge yield for colour inkjet printers and multi-function devices that contain printer components
- [4] ISO/IEC 24712:2006 Colour test pages for the measurement of office equipment consumable yield.

# **Author Biography**

Paul L Jeran joined Hewlett-Packard in 1992 and has been involved in the development of new printing technologies, print quality measurement and printer reliability. He is the primary inventor of a number of patents in the field of printing and document technology and has presented several papers on image quality and print technology. Paul is currently a the technical expert for supplies standards in the LaserJet Supplies R&D laboratory. He is a member of ISO/IEC JTC1 SC28, an international office equipment standards committee, chair of the US Technical Advisory Group to SC28 and convener of WG 2 – Supplies, within SC28. He is editor or coeditor of several standards for ink and laser cartridge yield.