Electro-Photographic & Ink Jet Color Cartridge Yield Test Documents: Problems, Approaches, Suggestions

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Abstract

Reliably determining the yield for color electro-photographic (EP) or inkjet (IJ, including solid ink) cartridges is important to all involved with color printing products. For manufacturers, it provides design specification for monitoring processes. For marketers, it helps positioning against competing products. For consumers, it facilitates assessment and comparison of cost-of-ownership.

Efforts toward agreement on a standardized measurement methodology have raised significant issues. Factors such as determination of end-of-life, environmental operating conditions, and sample testing size can be leveraged from the monochrome EP standard effort. However, color test document content raises new and unique problems.

Although this effort is focused on office users, consumers have similar needs. In today's office and consumer environments, most digital documents are created in an RGB color space. The conversion from this RGB space to an individual printer's CMYK toner or ink color space is unique to each printer. A discussion of the relationship of this issue to color toner or ink yield measurement follows, along with suggestions for the parameters defining a set of color test documents to standardize an appropriate solution.

Introduction

Within the ISO/IEC, JTC1/SC28[1] is responsible for the standardization of information technology office equipment via INCITS[2] W1, its U.S. representative. As of this writing, a proposed standard for the evaluation of Monochrome EP Cartridge Yield[3] that includes a monochrome Test Page is under final review; the authors were editors and key contributors to the development of that standard and its test document.

Development of a standard for the evaluation of Color Cartridge Yield has recently been proposed, with the authors as committee co-chairmen. Color printing in the office is not limited to EP technology; liquid and solid Ink Jet technologies are also significant. In consideration of the complexity of this issue, it has been decided to split this development into three parts. Two of the parts concern standardizing the methodology for determining toner yield and ink yield in EP and Ink Jet technology printers, respectively. These standards will adapt the methodology developed for monochrome yield testing as necessary and appropriate for these color technologies.

The color test document is common across printing technologies, as it is related to the office user, who may be considered technology-agnostic. This paper concerns the development of such an ISO/IEC standard color test document. It is hoped that standardization will bring the benefits of yield data integrity to marketers and manufacturers, as well as consumers.

Perhaps the most significant application of this yield data is in the estimation of the toner or ink contribution to the cost of a printed color document. The average cost to print a page, Cost-per-Print, is determined by summing the ratios of the cost of the required amount of each color toner or ink to the number of printed pages; for cartridge-based systems these are the ratios of the cartridge cost to the cartridge yield. (Since many EP cartridge systems use toner at non-uniform rates throughout cartridge life, full cartridge testing is required.) A test document used as a standard for such an important parameter should be representative of typical user experience in the target market.

Target Market

Our target market is the office, in the current and foreseeable future. There are many ways to characterize the office environment. Office uses cover a large variety of documents. They range from simple text (such as in letters and emails), to color presentation slides and handouts, all the way to photographs (such as in proposals, sales support, and personnel documents).

Office Documents

Typical applications, sometimes referred to as office suites, might include word processing, spreadsheets, presentations, e-mail, and web browsing. Graphics and imaging applications are used, but much less so than in graphic arts or even home markets; graphics and imaging outputs are usually integrated into word processing or presentation applications before printing, and page layout is usually limited to word processor capabilities. Increasingly, documents combine elements of text, graphics, and images – and increasingly these documents contain color.

Manufacturers have historically quoted monochrome printer cartridge yield assuming toner covers 5% of the page. However, the monochrome committee's work found two significant problems: each manufacturer used its own test page, many of which no longer generate a full 5% coverage; and a given test page does not necessarily generate the same toner coverage on two different printers, even those from the same manufacturer.

Perhaps the most significant of such technicalities may be characterized using the term *dot gain*, familiar in prepress graphic arts. Simply stated, the digital request to print a single dot on a specific media usually results in a printed dot that is larger; this is true in both toner- and ink-based print systems. (Therefore, test methodology should specify media used – especially with IJ print systems.) The dot gain of office printers has tended to become smaller as the technologies mature, thereby changing the printed coverage for the same test document. A test document that used to create 5% physical printed coverage may only create 4% today. Users are concerned with the yield and associated cost-per-print of the document – without loss of print quality. In consultation with the international community, considerations such as these led the committee to conclude that a standardized test document is key to reflecting the user experience.

Office Color Documents

In the transition to color printing in the office, it has been simple for color printer manufacturers to assume that user document coverage averages 5% per color; that is, 5% Cyan, 5% Magenta%, 5% Yellow, and 5% blacK. An office user's representative color test documents will contain some combination of text, graphics, and images. Our task is to define these combinations and percentages.

Whether or not these percentages are representative of office user color printing, creation of a color test document to generate such coverage raises interesting issues beyond to dot gain. There is a hidden problem in specifying the percentages of Cyan, Magenta, Yellow, and blacK – which will be explored below.

Office Workstation Environment

The "Wintel" environment – various flavors of the Microsoft Windows Operating System (OS) running on Intel-based computers – dominates the office workstation market. This imposes a significant limitation to our approach – the fundamental OS only supports a three-channel color space, RGB. Support for CMYK, a four-channel space, requires additional software, such as applications and drivers that support Adobe's PostScript page description language (and a printer capable of interpreting PostScript and receiving CMYK data). Office suite applications do not generally support CMYK, and rely on the workstation OS to provide connectivity to printing.

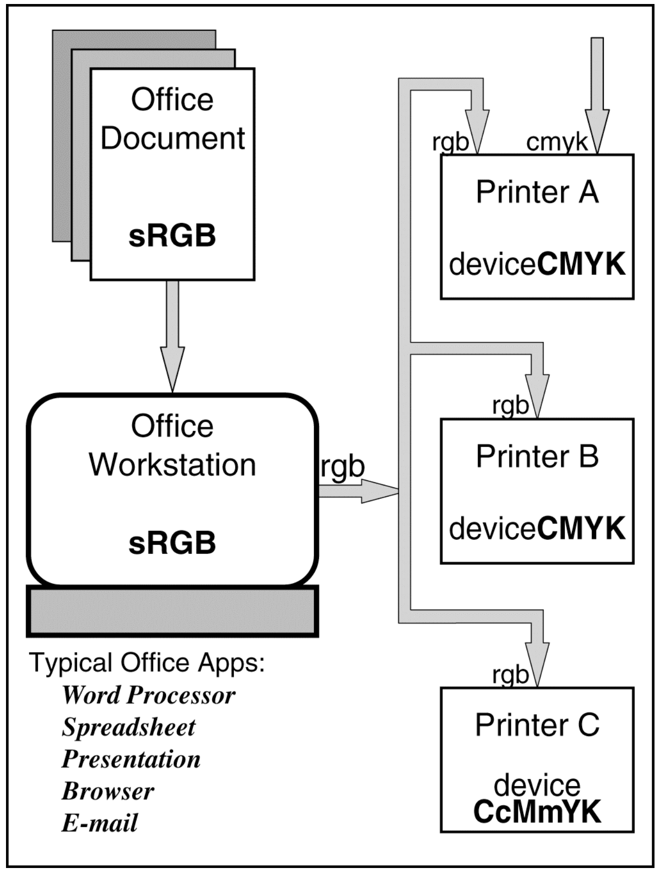

Figure 1. Office Color Document – Color Spaces

Office Printers

While PostScript-compatible printers (*e.g.* Figure 1, Printer A) all support CMYK, many office printers – especially entry-level EP as well as IJ color printers (*e.g.* Figure 1, Printer B) – only support RGB. Some entry-level printers actually use the computational power of the workstation in order to significantly reduce their cost. Such controllers in effect integrate some RIP functionality into their printer drivers. Some printers are intended for photographic printing as well as office applications, and augment their CMYK colorants with additional colors such as orange and green or light versions of cyan and magenta, for example. These printers convert RGB input data into device-specific six (or more) colors, replacing conventional color separations by diverting some of the CMYK data into additional channels (*e.g.* Figure 1, Printer C). Control of such additional colors is not available to the office user.

Another, perhaps lesser-known, characteristic of some office color printers is their internal limitations on total toner or ink coverage for various technology issues. Unlike graphic-arts printers, even those office printers that can accept CMYK input data frequently convert that data, perhaps through an intermediate CIE-based color space, into device-specific CMYK – this conversion accommodates gray component replacement and/or under color removal, the possible addition of rich blacks, optionally different processing of text and images, etc. Additionally, 100% ink coverage may not dry fast enough, toner or ink dot gain may yield full coverage at less than a 100% request, total toner/ink coverage may be limited at, say, 230% for design reasons, etc.

Color Space Issues

Test Document Color Space

As discussed above, the large majority of office computers run OS's, such as various flavors of Windows, that operate in an sRGB color space. In fact, unless sophisticated print drivers such as PostScript are added, most office computers cannot handle the four color channels needed for CMYK. Furthermore, most office printers will not accept all CMYK inputs without alteration: some limit the total toner or ink coverage to typically less than 300%; some internally convert any CMYK input to RGB and back again in order to establish control of the blacK channel; and some only accept RGB color space input. A potential International Standard should accommodate these realities.

This analysis inexorably leads to the recommendation that color toner/ink yield test document files be created in the sRGB color space.

While most readers clearly understand the concept, with apologies a brief review will allow us to highlight certain key issues.

Color Space Review

Color is a perception – the result of electromagnetic radiation within the visible spectrum being received by the eye and processed. This radiation is usually composed of multiple wavelengths (or frequencies), and the perceived color is related to the sum of the different wavelengths. For example, simultaneous red and green light energy will not be perceived as a combination of red and green colors, but as the single color yellow.

Sources of visible light energy operate in what is known as *additive* color spaces. The additive *primaries*, those basic colors that when mixed together create stimuli that essentially cover the visible spectrum, are Red, Green, and Blue – independent variables (orthogonal vectors) specifying colors within the 3-dimensional additive *RGB color space* they define. Computer monitors are energy sources, and operate in an additive color space, generating color from RGB primaries. Recent efforts toward defining RGB color spaces have lead to an interim consensus on a specific RGB space known as *sRGB*, and this color space is now widely available, generally as the default without user intervention.

When light energy is reflected off a surface before reaching the eyes, some energy is absorbed. If, for example, a ripe banana absorbs light energy in the blue part of the spectrum, the reflected red through green energy will appear yellow. Objects that absorb visible light energy are known as operating in *subtractive* color spaces. When red is absorbed, the reflected color is Cyan; absorbing green leaves Magenta; and absorbing blue (like the banana) leaves Yellow. Cyan, Magenta, and Yellow, the subtractive primaries, form the basis of the *CMY color space* and similarly specify colors within their defined 3-dimensional space.

Since Cyan, Magenta, and Yellow are not pure energy sources, the even absorption of all visible colors using these primaries requires the addition of a fourth, redundant blacK primary – the CMYK color space (still 3-dimensional – since the blacK primary is used to replace a combination of Cyan, Magenta, and Yellow, it does not add a fourth independent variable).

Color Space Conversion

Printed office documents are not sources of energy, but rather objects that absorb visible light; therefore, they exist in a subtractive color space and must be created with Cyan, Magenta, Yellow, and blacK colorants. The RGB test document files will be printed in the printer's device-unique CMYK color space; therefore, a color space conversion will be required.

This leads us to a key problem in creating a standard test document for toner or ink yield. The color test document design must anticipate a conversion from sRGB to the printer's CMYK; however, while sRGB is a defined standard, the printer's CMYK is unique to that device – and may not be publicly available. Even if it is known, the blacK contribution is determined by the device and may even change along with gamut intentions through driver settings and/or with element types within a document.

The potential impact of varying K-channel generation philosophies can be extremely significant. As an extreme example, while a *rich black* may be generated by 100% C + 100% M + 100% Y, a simple black may be generated by just 100% K. In the first instance the toner or ink coverage is 300%, while it is only 100% in the alternative. Both instances might correspond to a 0% R + 0% G + 0% B request. While a printer might use the CMY combination for images, it might use just K for text.

Some printers also print with five, six, or more colors, adding light versions of CMYK. (Some graphic arts printers add Orange and Green colorants in order to expand their gamut.) Control of the conversion from sRGB to the printer's colorants is device-dependent – it is in the hands of the individual printer design.

While highlighting the difficulties of converting from sRGB to the device CMYK color space, this argument simultaneously reconfirms the need to create the test document in sRGB. Restating our objective, the test document should reflect the user experience, and allow comparison of the cost to print among various printers, incorporating diverse technologies.

Test Document Content

As noted above, office users print a large variety of color documents. While difficult, we may attempt to group them into four general categories:

- Text, such as letters and emails
- Photographic Images, part of a document as well as stand-alone
- Presentation slides and handouts
- Compound Documents, combining text, graphics, and images; these may range from display text with simple graphics, to web pages with advertisements, to business reports with graphics and charts, to sales collaterals with tints, complex graphics and images.

Each of these categories has different average color usage, and may involve different gamut intentions in their conversion from RGB.

This raises the question of whether the color test document should be a single page – in essence a compound document with elements representative of each category, or a multi-page document with pages exemplifying the different categories. These different categories should be represented within the test document in approximate proportion to their use in the office. This data may be difficult to acquire, and may change with time as the office color printing market matures within the life of the proposed standard. Perhaps some researchers have addressed this issue. One pragmatic approach is to establish a compromise consensus – it could be argued that such a standard would be a significant improvement over the current state.

Some current office color printers indeed track the number of CMYK dots that are digitally requested (without dot gain). Anecdotal reports indicate that typical office users rarely exceed 6% coverage per primary, and often run well below 5% per colorant. Of course, if a significant number of monochrome documents are printed on a color printer, these results will shift to reflect that.

Therefore, it might be suggested that the color test document should contain an overall coverage that does not exceed the RGB equivalent of 5% each CMYK. Achieving this objective in the face of the aforementioned color space conversion issues is one of the open issues before the committee.

End-of-Life Determination

The addition of specific content to facilitate End-of-Life determination may be important. This could be in the form of test targets, or an additional page in a multi-page document. Of course, such an addition should not significantly change the color coverage distribution.

Conclusion

The committee's analysis of the requirements for a standardized test document for the measurement of toner and ink yield has lead to the conclusion that a common document for testing various office technologies is appropriate. However, the document must be created in an RGB color space (such as sRGB). This leads to questions concerning how to achieve desired printing-primary coverage targets.

Other open issues include: what should these printing primary coverage targets be; media choice; what should be the mix of text, graphics, presentations, images, and compound documents; how many pages should the document contain (and the implications of more than a single page); and what targets should be included to facilitate end-of-life determination.

References

1. *International Standards Organization / International Electrotechnical Commission (ISO/IEC),* Joint Technical Committee 1 / SubCommittee 28 (JTC1/SC28) is responsible for international standardization of information technology office equipment.
2. *InterNational Committee for Information Technology Standards* (INCITS), the primary U.S. focus of standardization in the field of Information and Communications Technologies (ICT), also serves as American National Standards Institute (ANSI)'s Technical Advisory Group for ISO/IEC JTC1.
3. *Method for the Determination of Toner Cartridge Yield for Monochromatic Electrophotographic Printers and Multifunction Devices that May Contain Printer Components.*

Biographies

David Spencer founded Spencer & Associates Publishing & the SpencerLab Digital Color Laboratory in 1989; previously he was chairman of Data Recording Systems, group executive of Muirhead NA, president of Litton Datalog, and headed Graphics Engineering at EG&G. Mr. Spencer's work has primarily focused on integrating the technical and business aspects of print systems, including color image quality and cost-per-print. He is an active member in ISO/IEC JTC1 SC28 standards committee, a member of IS&T, a senior member of IEEE, and holds patents in data compression and reprographics. He received his SBEE and SMEE degrees from the Massachusetts Institute of Technology.

Paul Jeran joined Hewlett-Packard in 1992. During that time he has been involved in the development of new printing technologies, print quality measurement and printer reliability. Currently he is a member of the Advanced Technology Section working to establish print quality metrics for LaserJet printers. He is an active member in ISO/IEC JTC1 SC28 standards committee. Mr. Jeran received his BS and MS degrees in Mechanical Engineering from the Rochester Institute of Technology.