Multi Color Pigmented Inks for Large Format Ink-Jet Printing

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Abstract

The benefits of new pigment inks and an new ink set for large format printers (LFPs) were validated. The ink hues were optimized to provide efficient coverage of special colors used primarily in the printing industry. Targets for effective hues were set, and a combination of inks with well-balanced hues were verified for the best ink set. An ink set with orange and green, along with optimized CMY process colors, was found to be effective.

1.Introduction

Large format printer (LFP) performance and image quality are steadily advancing. These advances are closely associated not only with photographs and fine art but also with conventional printing technology. LFPs have gained wide use in the proofing field, where short turnaround times and cost efficiency are essential, because LFPs that print with pigment inks exhibit high color stability immediately after printing [1]. Initially, the printing industry demanded offset-printing-level quality, meaning that LFPs had to cover the normalized color spaces of the various printing standards and be able to reproduce consistent output quality anytime and anywhere.

In recent years demand has grown for LFPs that can be used not only in offset printing but in fields where an abundance of special colors are used, such as in flexography and photogravure printing. Inkjet printers that use special colors are being launched to market to answer this demand. This paper describes the technical advantages of Epson UltraChrome HDR™ Ink, a multicolor inkjet system that enable an extended range of colors to be printed.

The sample prints evaluated for this report were produced by several different LFP models, on Premium Glossy Photo Paper (170) at a resolution of 1440 x 720 dpi (and in some cases 720 x 1440 dpi).

2. Optimum hue combination

2-1) Selection of target hues

Package printing has become the focus of considerable interest in recent years. New snack food, frozen food, cosmetics and other products are being developed throughout the year. The package printing industry for products such as these is apparently standing up well even in the midst of the current recession. Products quickly become stale and outdated unless manufacturers are able to continuously come up with goods that look ever more eye-catching on store shelves. For this reason, manufacturers are constantly scrambling to devise new concepts. Package printing generally requires a wider color reproduction range than does offset printing. Moreover, not only are CMYK used in blends, special colors are often used singly. Special colors are defined in color guides distributed by multiple companies. The various publications that serve as color guides specify in the neighborhood of 1,000 special colors, which are assigned names or numbers. At the design review stage, printing companies, manufacturers of food items and other products, advertising agencies and plate-makers and so forth specify the name of special colors for printed packages. Figure 1 is a distribution chart showing colorimetric values of patches specified in the open-source DIC Color Guide - Part 2 (Ver. 3).

On top of this is overlaid the gamut of Epson's Stylus Pro 7800 (launched in 2005). The chart shows the L*a*b* space specified by CIE sliced by L* value, with the a* and b* planes separated. As is evident from the chart, many special colors are distributed outside the region toward dark blue near L* values of 30 and 40 and outside the high L* value light regions in the green and orange directions. Given this, there is a clear need to create ink that can be effectively used for these hues so that LFPs match the needs of the package printing sector.

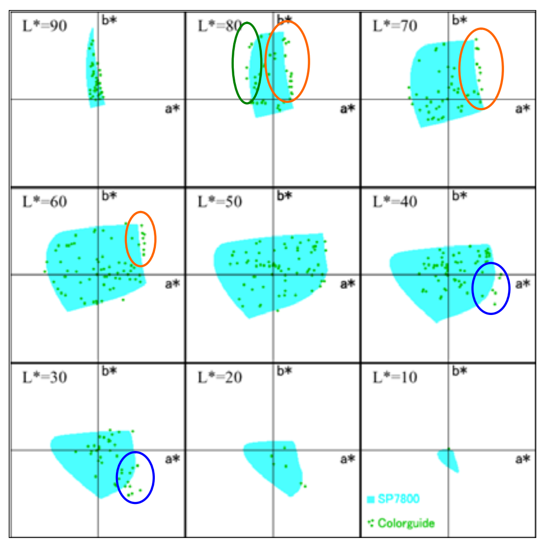

Figure 1. *SP7800 gamut chart and special color distribution chart (extract)*

2-2) Optimum magenta hue

The SP7800's reproduction is poor in the relatively dark blue region near L* values of 30 and 40. Color reproduction in the blue region could conceivably be gained by adding an effective color to that area. First, however, the magenta ink used on the SP7900 (2007) was verified. In proofing, it is said that the process colors of the inkjet printer, i.e. the proofer, ought to be matched to some degree to the printing system. However, since there is no one single type of process color ink for offset printing (”printing ink”), it is not possible to perfectly match the proofer’s hue to magenta printing ink. In other words, the hues will always be a little different. The use of a color management system (CMS) to match colors is a fundamental of inkjet proofing. Naturally, the color of solid magenta printing ink is also matched on the inkjet printer by the CMS. That is, to match the magenta printing ink, the inkjet magenta is combined with other inks and the density of the solid magenta printing ink is simulated. If the magenta printing ink is in the positive b* direction, yellow ink is added. If it is in the negative b* direction, cyan (or light cyan) is added. Disliked in the latter case is the presence of cyan ink dots, since the presence of dark cyan ink dots adversely affects the graininess. Yellow dots, conversely, are not very obvious. Hence, magenta inkjet ink should be set slightly towards the negative b* direction in comparison to the magenta printing ink. Given the above, the requirements for magenta ink hues for future print proofs are as follows:

1. The inkjet ink must have greater saturation than the printing ink and the hue at maximum saturation must be close to that of the printing ink.
2. Since inkjet magenta cannot possibly be matched with all magenta printing inks, the inkjet ink preferably should be shifted toward the negative b* direction overall when compared to magenta printing inks on the market.

Magenta ink used with the SP7800 and SP7880 and The ICC profiles of ”Japan Color 2001C” used for offset printing are charted on the a*b* plane in Figure 2.

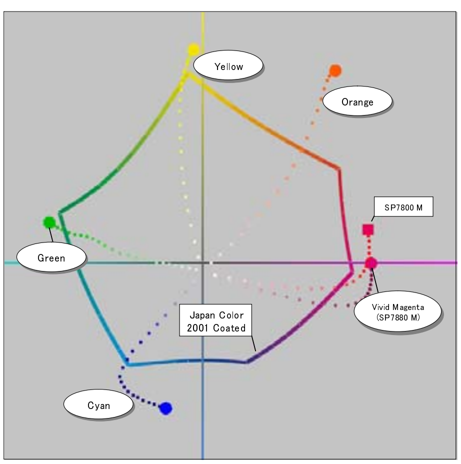

Figure 2. *Magenta ink hues (SP7800 vs. SP7880) and ICC profile of Japan Color 2001*

The maximum saturation of SP7800 magenta leans quite far into positive b* territory compared to conventional magenta printing ink. If this is corrected, the magenta ink can be expected to match the printing ink while improving reproduction in the blue region. Therefore, the quinacridone pigment used by the SP7880 was modified so that the hue matched the printer’s process colors fairly closely.

This magenta ink is provided on the SP7880/9880 and SP7900/9900 as Vivid Magenta. The effect of using Vivid Magenta ink is shown in Figure 5 along with the effect of Orange and Green inks, which is explained later. As can be seen from the figure, the color area of the blue region in the targeted dark portion is wider, covering a large portion of the special colors in this region.

2-3) Orange and Green hues

As we saw in Figure 1, a large number of colors are specified in the high L* value orange and green regions. Obviously, ink of hues that cover these regions is desirable. Suitable hues of green and orange were thus investigated.

First, green. Figure 1 indicates that ink sets have thus far lacked hues particularly in the bright green region in the vicinity of L* 80. As mentioned above, combining dark colors with bright colors is undesirable because doing so impairs graininess. Thus, to efficiently cover this bright green area, the color has to be reproduced, to the extent possible, by using a single color of ink rather than by using a combination of two or more inks. Using chlorinated copper phthalocyanine is the preferred way to meet this requirement. Figure 3 shows the characteristics of optimized green ink with the L* values plotted on the vertical axis. The hues are as shown in Figure 2. The ink obtained maintains bright hues in the green direction.

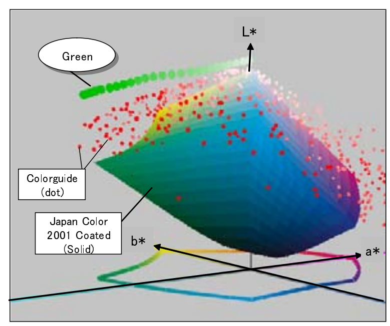

Figure 3. *Green ink hue and ICC profile of Japan Color 2001*

In the orange region, meanwhile, we knew from internal evaluations that numerous possibilities would have to be investigated in order to obtain optimum hues. Table 1 shows a simple summary of the orange pigment types and characteristics.

Table1 Orange pigment specifications

	Coloration	LF*1	ST*2
Orange I	G	100Y-	G
Orange II	G	60Y	G
Orange III	P	60Y	P

G: Good, P: Poor

*1: Lightfastness

*2: Dispersion stability

Lightfastness was evaluated in accordance with the conditions defined by JEITA Standard CP-3901 [2]. The density used in calculations, however, was the average between the value found for yellow and the value found for magenta. The results of lightfastness evaluations of the three types of orange inks are shown in Figure 4. Density remaining is plotted on the vertical axis. Life is plotted on the horizontal axis.

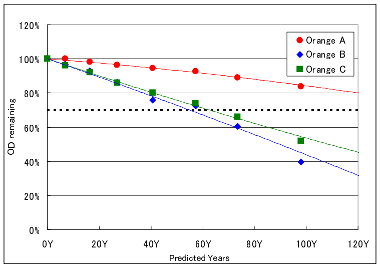

Figure 4. *Lightfastness evaluation results for orange inks*

The stability results were obtained by evaluating the storage stability of the ink, with the pigment dispersion stability serving as the primary judgment criterion. A number of other types of pigments for hues used as orange are available, but many of them cannot be used because, aside from their hues, they are not amenable to grain sizes and other quality characteristics required for inkjet grade ink.

In terms of coloration and stability, Orange I and Orange II in Table 1 are the most suitable pigments for use in proofing, but LFP applications other than proofing need to be considered. Given that lightfastness is one critical factor, Orange I, which has an estimated lightfastness life of 100 years or more, was the pigment selected. The hues of orange ink are shown in Figure 2.

A new ink set was created by adding two new colors of ink whose hues were optimized by the process described above, in addition to Vivid Magenta and the process colors. This 10-color ink set was launched with the Epson Stylus Pro 7900/9900 as UltraChrome HDR™ Ink. The color reproduction range provided by this ink set is shown in Figure 5.

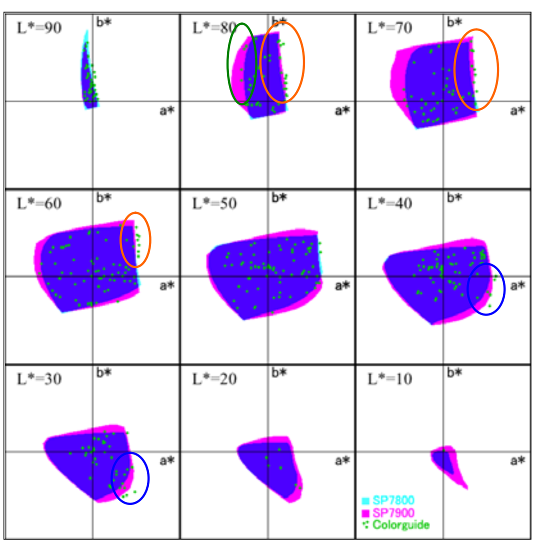

Figure 5. *SP7900 gamut chart and special color distribution chart*

Although the new ink set does not cover all the special colors, it can efficiently reproduce a fairly high percentage of them. By optimizing the CMY hues and by adjusting orange and green instead of simply combining ink colors, it became possible to achieve an effective ink set.

3. Technology for maximizing the performance of the 10-color ink set

3-1) Creation of an optimum LUT

As explained above, orange and green were selected in addition to the process colors for a new ink set to efficiently obtain special colors used in package printing. The potential that these new inks have for color reproduction can be seen in Figure 5. Nevertheless, simply adding these two colors does not allow the full performance of the ink set to be tapped. UltraChrome K3™ Ink already has eight colors of ink: Cyan, Magenta, Yellow, Black, Light Magenta, Light Cyan, Light Black, and Light Light Black. When Orange and Green are added, the 10-color ink set has a huge number of color combinations that are capable of expressing the same colors. As an example, the combinations of multiple ink to reproducing the greens of a thick growth of leafy trees was simulated. Figure 6 shows three example simulations. Five main colors of ink are used to reproduce the greens of the leaves, but a variety of ink combinations can be used to produce the same color.

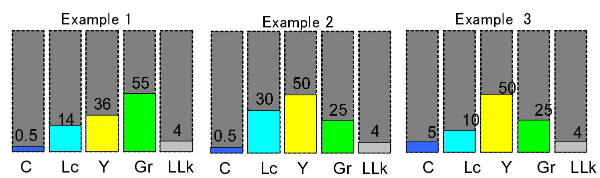

Figure 6. *Examples of ink combinations that produce the same color*

UltraChrome HDR™ Ink and other ink sets used in LFPs have inks that are perceived as being dense, such as Cyan and Black, as well as colors that are perceived as being faint, such as the light inks. Errors in combining inks with substantially different levels of brightness will result in images with a significant lack of light-to-dark balance, the effects of which immediately spill over into graininess and smoothness.

To counter this, Epson has created a system for estimating and outputting the ideal combination of colors by logically computing factors such as ink spectral characteristics, graininess, which is affected by lightness/darkness, and color inconstancy. This system enables stable high-quality images to be effectively obtained [3].

Epson calls this system "AccuPhoto™ HDR Screening Technology."

This technology derives a target function E_0 by performing calculations so as to minimize 'Color Inconstancy', 'Graininess' and 'Smoothness'. The equation is shown below.

$$E_0(\psi) = \min[\omega_1 CII(\psi) + \omega_2 GI(\psi) + \omega_3 SI(\psi)] \qquad (1)$$

CII Color Inconstancy Index
GI Graininess Index
SI Smoothness Index

3-2) Color inconstancy

Technology for effectively using multiple colors performs computations that optimize color inconstancy (the dependence of a color on the light source). HDR ink has reached a certain level of constancy under different light sources thanks to the use of the ”K3” system [1], and the addition of Orange and Green must not harm this constancy.

Figure 7 shows this ink set’s grayscale color differences under fluorescent lighting (F11) and daylight (D50).

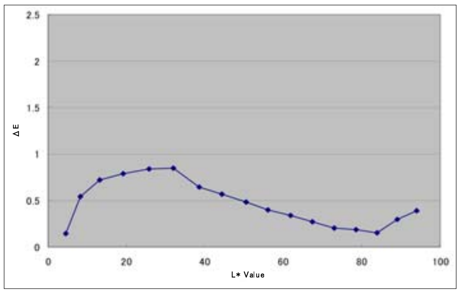

Figure 7. *Color differences under varying light sources (F11-D50)*

The color inconstancy is only about 1 ΔE, demonstrating that the intrinsic performance of the ink set is not impaired.

4. Conclusion

The ”colors” used in a new ink set for LFPs has been described. Special colors are efficiently covered by adding two new colors, Orange and Green, to the existing process colors. An overview of the image processing technology needed to functionally employ the 10 colors of ink in the ink set has been presented.

These technologies provide the quality necessary for applications in the new LFP field of package printing.

A look around various stores across the globe reveals a vast variety of printed materials. We recognize that we have to continue to engage these markets and consider new areas for development.

References

[1] T. Sano et al, NIP22th., pg215 (2006).

[2] JEITA Standard CP-3901 - Digital Color Photo Print Stability Evaluation, Japan Electronics & Information Technology Industries, Tokyo, Japan (2007).

[3] The Institute of Image Electronics Engineers of Japan, ’Color Manegiment Technology’, Tokyo Denki Univ. Press, pg83-97 (2008).

Author Biography

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