The Optimization of Pigment Ink Set for Large Format Printer

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Abstract

Advantages of the K3 System, a pigment inkjet printer system that uses three levels of achromatic inks, were investigated. It was found that by employing these achromatic inks throughout a large area of the constructed output data, in contrast to existing printers using conventional coloring sets this system offers a level of quality of short-term color drift behavior, dependency of light source(Metamerism), consistency across multiple printers and tonal gradation that satisfies the demands of professional photo users.

1.Introductions

Pigment has become widely employed as a colorant for inks used in inkjet printers. The light fastness and gas fastness of pigment ink makes for good image stability, and the ink also has good short-term color drift behavior. For these reasons, pigment ink has gained widespread use in the high-value commercial photography and proofing fields. In such applications, output of the same image data from multiple printers in different locations is not uncommon. Just as attractive printouts are demanded of these inkjet printers, so too are the colors of the printouts expected to be the same when using different printers and light sources across different environments. There is also the ever-present demand of stable output quality of gray balance and tonal gradation. Last year we marketed a new inkjet printer that uses three levels of black ink (Epson UltraChrome K3$_{TM}$), Black (Bk), Light Black (Lk) and Light Light Black (LLk). Accordingly, we have attained a recognition that the K3 system has reached a standard that meets the exceedingly high quality demands mentioned above through further capitalization on the positive attributes of pigment ink. This paper reports the numerous advantages of the K3 system.

2.Evaluation of Print Quality

== The K3 System ==

Printers employing the K3 system use an ink set with eight colors, including the existing Black, Cyan, Magenta, Yellow, Light Magenta and Light Cyan colors, and the additional Light Black that has an ink contents lower than Black, and Light Light Black with an ink contents lower than Light Black. Each of the K3 black inks have a different pigment contents, with Lk 1/2 and LLk 1/6 that of the Photo Black [1][2]. These different contents allow for no loss in the graininess of the printed image and make it possible to employ LLk ink from the highlights of the color range. Figure 1 shows the relationship between the lightness L* values of the amounts of Bk, Lk and LLk inks used when printing on Premium Glossy Photo Paper. Assertive use of LLk in the color data range as well as the achromatic range is a design that allows for the amount of color ink used to be reduced as a whole, and helps to attain stable output. Figure 2 shows the amounts of ink used in the K3 System and the previous ink sets. The bar in the center shows the gray balance. The amount of each color that needs to be used in order to print these grays is shown by the increasing width of each color. As the figure shows, use of LLk starts from a data range of almost pure white, Lk from the middle range followed by Black; these achromatic inks are employed throughout nearly the entire range. This design enables subtle color rendering through the use of color inks in the achromatic range to respond to the demand for a small bit of color, a demand sometimes encountered among users with their own individual understanding of what true gray balance is.

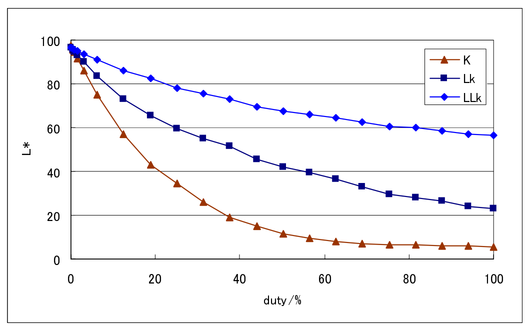

Figure 1 *Relationship between L* values of amounts of K3 inks used*

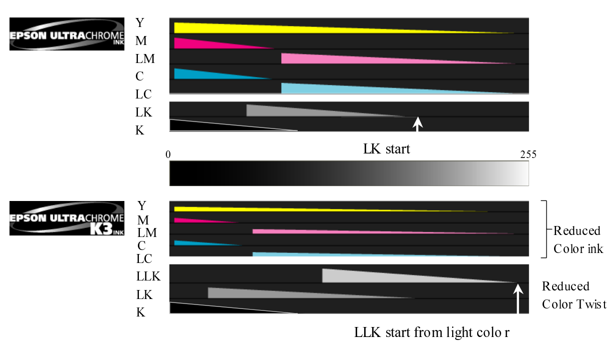

Figure 2 *Amounts of inks used throughout tone levels*

This document reports on the quality of the following items demanded by business customers.

1. Short-term color drift behavior

2. Dependency of light source (Metamerism)
3. Print stability across printers
4. Tonal gradation

The ΔE used to express color differences throughout this document is ΔE_{76}.

2-1)Short-term color drift behavior

Pigment inks have been employed in large format inkjet printers used in business applications since around 2000. One advantage of pigment ink is its color stability after printing (Short-term color drift behavior). This short-term color drift behavior allows for retouch work to be done after printing and the reduction of work time, which makes pigment ink an indispensable material. Figures 3 and 4 show differences of short-term color drift behavior between dye ink and pigment ink used in inkjet printing. The evaluation was carried out in an environment of 24℃×60%RH. The primary colors of Cyan, Magenta and Yellow, and the secondary colors of Red, Blue and Green were printed on Premium Glossy Photo Paper made by Epson. The print mode was set to 1440×720dpi. Changes in color of the printed material were observed from 5 minutes after printing. The standard for color difference was set to 6 days after printing.

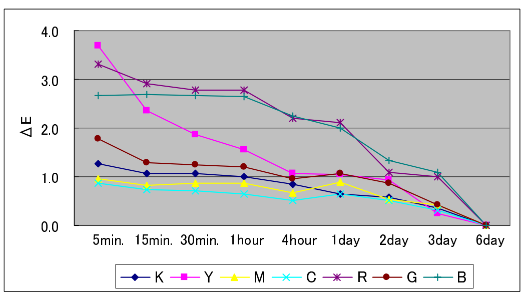

Figure 3 *The short-term color drift behavior test of Dye ink on Premium glossy photo paper*

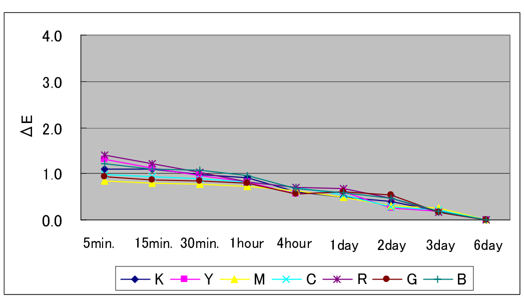

Figure 4 *The short-term color drift behavior test of Pigment ink on Premium glossy photo paper. (Stylus Pro 7800) The short-term color drift behavior test of* **Pigment ink** *on Premium glossy photo paper.*

As is evident from the figure, the pigment ink colors are much more stable. This advantage is prominently seen in pigment ink printers and is not limited to the K3 System. After the pigment ink lands on the media the colorant stops on the surface of the media and quickly separates from the ink solvent that penetrates the ink-receiving layer, which makes the colorant less likely to be effected by the drying process of the liquid. This is thought to be the reason for the stability of pigment ink [3].

2-2)Dependency of light source (Metamerism)

The colors of printed materials created in a studio look different at an exhibition. The phenomenon of colors looking different under a different light source is called the Dependency of Light Source, or Metamerism. Figures 5 shows color differences under two light sources by measuring an image with levels of gray from white to black. For this graph, the reflection factor of a printed patch was measured and calculated with the spectral power distributions of each light source to find the L*a*b* values, and the color difference ΔE of each light source was plotted [4] [5]. The graph shows results from printed materials of the K3 System model Stylus Pro 7800 compared with those of the Stylus Pro 7600 and Stylus Pro 4000. Printing was done at 1440×720dpi on Premium Glossy Photo Paper. Here, the D50 stands for daylight and F11 for fluorescent light. The SP7600 and SP4000 both have the same ink set of CMYK Lm Lc Lk, but differences are discernable because of a change in the usage rate of each color that makes up the gray. Results clearly show that color differences are reduced by the SP7800 model using LLk. In Lk and LLk inks colorants are composed of carbon black. In carbon black, the reflected spectral of the visible spectrum range is relatively flat and is therefore less likely to be affected by the wavelength of each light source. As Figure 2 shows, assertive use of Lk and LLk results in a high level of control.

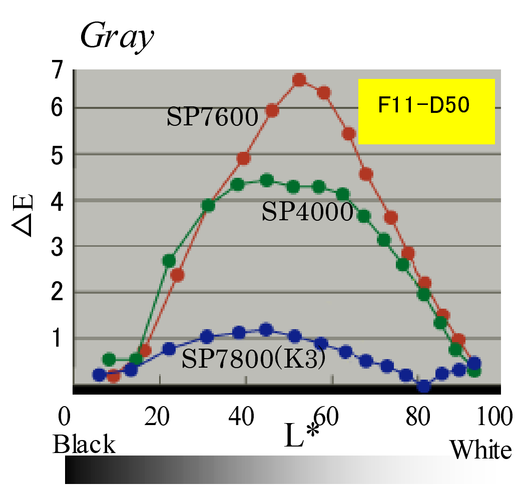

Figure 5 *Color differences under varying light sources (F11-D50)*

2-3) Color differences across printers

During proofing and other tasks, the printing company and their client check printed materials in different locations. With today's networking capabilities the same image data can be managed on one network and printed and checked separately at each site. This is called remote proofing, a method which helps reduce proofing costs and shortens delivery date [6]. Two issues inherent in the construct of this network flow are the aforementioned dependency of light source (or metamerism) and having the printers at each site print the same colors. In actuality, factors that cause small variations of color between inkjet printers, such as various production discrepancies and differences in the environment in which the printers are set, are surprisingly common. Because of this, users make calibrations daily to compensate for differences in working environments to preserve the accuracy of colors. One factor that contributes to variations in colors is a discrepancy of the ink volume ejected from the head. Figures 6 and 7 show color differences in a gray scale of white (RGB=255) to black (RGB=0) between a CMYK Lc Lm 6-ink printer and a K3 System printer with CMYK Lc Lm plus Lk LLk, when the ink volumes are purposely changed by 10 percent. Printing was done on Premium Glossy Photo Paper at a resolution of 1440×720dpi.

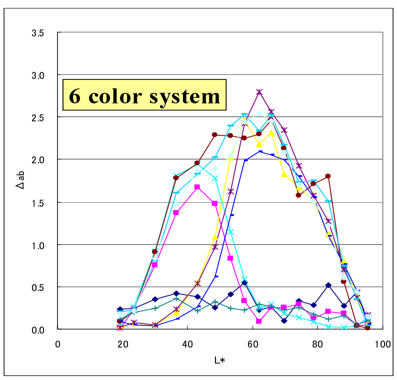

Figure 6 Color differences with 10% variation in ink volume (6-color system)

As is evident from the graphs, fluctuations in color when using the K3 System are greatly reduced. The reason lies in the following structure. As shown in Figure 2, until now gray scales have been expressed by printing with the three primary colors of CMY. Because of this, color inks contributes largely to the gray and due to the effects of the environment even the slightest fluctuation in ink volume is likely to change the printed colors. However, when a large part of the printed colors are constructed with achromatic inks, and color inks are therefore limited to small amounts used only to make fine color adjustments, variations in colors will also be small. This helps to nullify not only discrepancies in ink volumes but also differences in location and environment, which can all be factors in color differences.

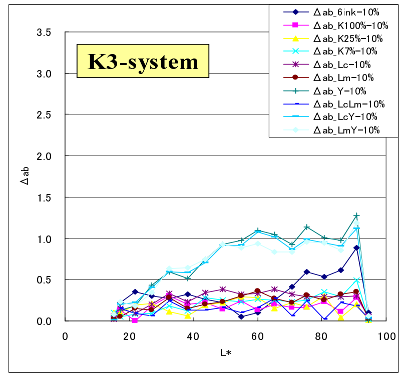

Figure 7 Color differences with 10% variation in ink volume (SP7800)

2-4)Tonal gradation

When expressing skin colors and gray image data, tone jumps and variations in color can occur. This phenomenon is called color casting and is one of the most problematic issues encountered by high end users dealing with digital data. The K3 System uses a very small amount of color ink, with Lk and LLk compensating for the areas where color ink had been previously used. This sort of control makes it easy to manage changes of only a small amount of color and to control tones. This was examined by the following evaluation. As shown in the graph of Figure 8, a* values were plotted against the L* values when printing data changed at each tone level between white (RGB=225) to black (RGB=0).

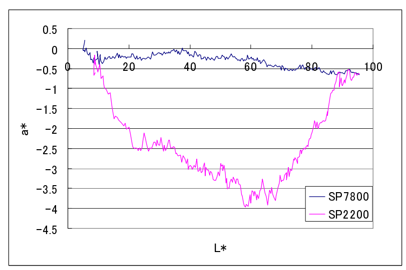

Figure 8 a* values at each gray scale level

This compares the K3 System of the Stylus Pro 4800 with the Stylus Photo 2200. The SP2200 comprises the CMYK Lm Lc Lk inks. The graph shows that the SP2200 curve bends from end to end in contrast to the K3 System. This reflects certain intentions during the design of the SP2200 and is not a major issue in this evaluation. In contrast to the K3 System however, the SP2200 line is jagged. These jagged parts indicate where tone jumps are prone to occur. In contrast, the K3 line is smooth. The K3 System achieves smooth tonal gradation through the effective employment of achromatic inks.

2-5)Enhancing work efficiency

This report has shown that K3 System printers can easily achieve accurate color control. In actual business applications, the improvement of subtle color gradation is often pursued as a process that increases the value of printed works. Difficulties sometimes arise when the RGB data of an image being retouched is expressed one way on the screen but yields different results when printed. This is a consequence of dealing with digital data and is not limited to inkjet printers. Because the K3 System allows for fine levels of color control it becomes easier to have the effects of retouch work done on an image be reflected in printed materials. It is easy to imagine how this could also reduce the amount of time it takes to retouch an image. Much feedback has actually been received from users in the workplace who use the new model, citing the ease of retouch work and the shorter work process.

3.Gloss Control

In Section 2 the advantages of the K3 printing method were introduced. As previously explained, the contents of pigment inks Lk and LLk in the K3 System are 1/2 and 1/6 of Bk, respectively. But simply lowering the pigment contents levels will cause another issue with the glossiness on photo type media. Figure 9 shows a glossiness at 20° on Premium Glossy Photo Paper printed with an ink whose pigment contents was simply set at 1/2 and 1/6 of Bk and the viscosity was adjusted with glycerin. Notice the peaks under the arrows in the graph. It has been confirmed that in actual prints the eye perceives the ranges pointed out by these arrows as having different glossiness.

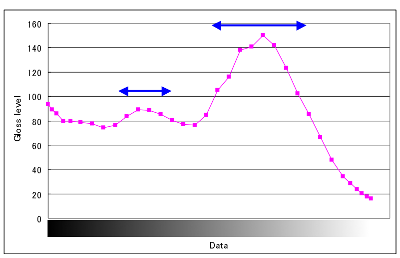

Figure 9 *K3 System gloss differentials (before improvements)*

Comparing Lk and LLk it is clear that LLk with its low pigment contents has a greater gloss differential, and depending on the light source its reflection on printed materials can sometimes give an unusual metal-like glare. As previously explained, in the K3 System the Lk and LLk are dominant inks. It therefore stands to reason that if improvements were made focusing on the glossiness of these two colors, the glossiness of the entire image could be improved. Based on this, gloss control of the Lk and LLk inks was investigated using a composition chart, where the glossiness of each ink were not dependent on the amount of ink used and were kept as uniform as possible [1]. Figure 10 shows the glossiness of Lk and LLk inks before and after these improvements were made.

Figure 11 graphs the results of printing conducted in the same manner as in Figure 9, but with inks whose glossiness have been improved as aforementioned. This shows vastly improved gloss differentials. Also when comparing actual printed materials it is rare to see gloss differentials similar to those before improvements, and it was determined that these levels are capable of photographic applications.

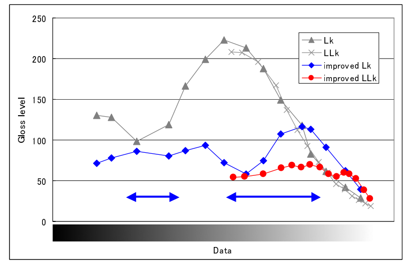

Figure 10 *glossiness of Lk and LLk inks before and after improvements*

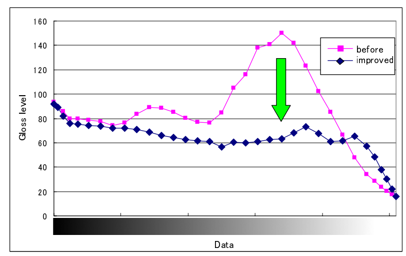

Figure 11 *Gray scale glossiness when using improved ink*

4.Conclusion

As discussed, it was found that the quality of prints printed out by a K3 ink system printer results in little color discrepancies and that printed materials can be controlled with very fine precision. Great improvements over existing inkjet printing in regards to metamerism and tonal gradation were also seen.

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Author Biography

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