Profiling Ecosolvent Inkjet Printers

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Abstract

Since 2005, so-called ecosolvent printers have come to replace aqueous dye- and UV-based pigmented inkjet printers in the production of outdoor signs and banners. These printers use ethylene glycol-based ink on polyvinyl chloride (PVC) and other media. They produce graphics with superior fade-resistance and weatherability. However, unlike aqueous inkjet printers, they require that the media be heated to facilitate ink absorption and drying. Determining the optimum print heater settings adds another dimension to profiling these printers for color management.

This paper presents a procedure for profiling ecosolvent printers. In addition to the steps that precede profiling of aqueous inkjet printers (determining optimum ink density, linearization of tone values, and setting total ink coverage), ecosolvent printer users must also determine the optimum heater settings. Too little heat prevents the ink from adhering adequately to the media and drying rapidly. Too much heat, on the other hand, causes the media to buckle. Buckling can cause the inkjet print heads to crash, ruining the print and possibly damaging the print heads.

Data are presented correlating media temperature with color gamut.

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Introduction

Inkjet has become the predominant method of printing outdoor signs and banners. Outdoor graphics must be waterproof, fade-resistant, and economical. This requires printing on uncoated media with solvent-based ink, rather than with coated media and aqueous ink as in photography and proofing.

Two types of printers have been developed for outdoor graphics. Solvent printers use ink based on aliphatic and aromatic hydrocarbons. These printers require ventilation to remove noxious fumes. Ecosolvent printers (Figure 1, 2) use ethylene glycol-based ink and can be used in an office environment.

Figures 1, 2. The Roland SolJet Pro (left) and VersaCamm are two examples of ecosolvent inkjet printers used to print durable outdoor graphics.

As with aqueous inkjet printers, the wide variety of ink, media, and front-end raster image processors (RIPs) makes ICC color profiles essential to color matching on an ecosolvent printer. The calibration and profiling procedures for ecosolvent inkjet printers is similar to aqueous inkjet printers, except that an additional step is required: adjusting the printer's onboard heaters for optimum print quality (Gundlach, 2004).

The Printer Market

Several ecosolvent printers have been introduced in the past few years. Muhto's Falcon Outdoor I & II printers use Mutoh's Eco-Solvent Plus inks. Agfa markets the Grand Sherpa Universal printer, which also uses the Eco-Solvent Plus inks. Roland's EcoSOL ink runs through both the Roland SOLJET Pro II EX printer and the Roland VersaCAMM printer/cutter. And finally, Mimaki's JV3 series can accept either solvent or Mild Solvent 2 (MS2) inks. All of these printers use Piezo printhead technology. Although the features and inks on these printers are often different, many of the basic principles of operation are similar.

Media for Ecosolvent Printing

One of the reasons solvent- and ecosolvent-based inkjet printers have become attractive in today's sign market is that they can produce durable, high-quality images on uncoated media, which is much less expensive than the coated media typically used in aqueous-based inkjet printers.

Most ecosolvent printers can take advantage of many, but not all, of the uncoated media that also work with traditional true-solvent printers. Polyvinyl chloride (PVC) media has been found to work best with ecosolvent printers because it remains flat when heated, whereas polyethylene media tends to buckle or ripple. While a harsh true-solvent will "etch" the media so the ink can penetrate the surface, an ecosolvent printer requires special heating to make the media more receptive to the ink and to assist in drying.

Compared to coated inkjet media for aqueous printers, ecosolvent media tends to be more flexible. Uncoated media can often be stretched without damaging the image, unlike the coating on aqueous inkjet media, which is prone to cracking when stretched. Also, because coatings are subject to wear and physical abrasion, uncoated media is more resistant to chemicals, solvents, water, scratching, and ultraviolet fading. This means that, even without protective lamination, it will hold up against moisture and sunlight better than most coated aqueous inkjet media.

Heating Systems

On ecosolvent printers, heat helps the ink penetrate the surface of the media and accelerates drying. If ink cannot penetrate the media, it spreads out on the surface, causing ink bleed and an artifact known as "dot-gain banding." Ecosolvent printers employ one to four heaters (Figure 3) that optimize media before, during and after ink application. Heating stages include pre-heat (applied before printing), platen-heat (applied at print stage), post-heat (applied after the print stage), and drying (applied after post-heat to speed up drying). Heaters range in maximum setting from 50–70°C.

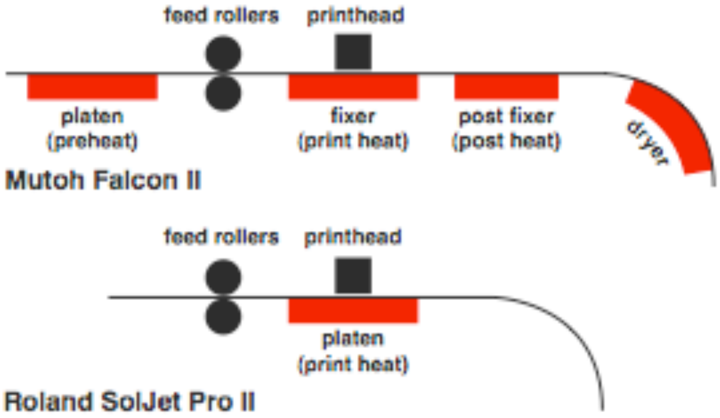

Figure 3. PVC media must be heated prior to printing with ecosolvent inkjet ink. Examples of heating systems include those on the Mutoh Falcon II (top), which has four independently-controlled heaters; and the Roland SolJet Pro, which has one heater.

The Tradeoff Between Color, Quality, and Speed

Ecosolvent printing involves a tradeoff between heat, ink density, and print speed (Adams and Gundlach, 2004; Figure 4). Higher heat levels enable faster printing at greater ink densities. However, excess heat may cause the media to buckle, which in turn causes vertical banding. It may also cause the media to rise above the platen to a sufficient height to contact the print heads, which ruins the print and may cause a print head crash. As a result, the user, who wants high quality and high speed, may not be able to achieve both.

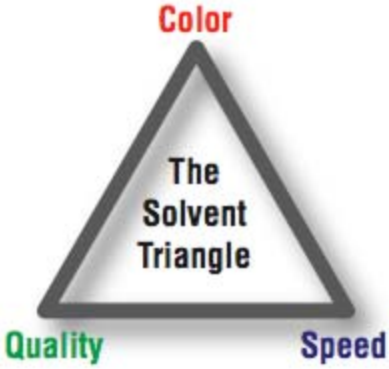

Figure 4. Ecosolvent inkjet printing involves a tradeoff between color, quality, and speed. Maximum color density (therefore, gamut) may be achieved at maximum heater temperature, but media buckling and the resultant vertical banding will adversely impact quality. Likewise, the highest color density is achieved at lower print speeds, which adversely affect throughput. Maximum quality (resolution, sharpness, freedom from artifacts) will be achieved with reduced ink density and speed.

Steps in Profiling an Ecosolvent Printer

1. *Setting Heaters.* On an ecosolvent printer, heat must be sufficient to reduce horizontal dot-gain banding but not so much as to cause media buckling, vertical banding, and in extreme cases head crashes. Some printer manufacturers provide special targets for evaluating heater settings, or the user can create a target consisting of solids, overprints, and gray values (Figure 5).

Figure 5. A color test form consisting of solids and 2- and 3-color overprints can be used to set optimum printer heat. This image facilitates observation of ink mottling, vertical and horizontal banding

2. *Setting Ink Restrictions.* As with aqueous inkjet printers, ecosolvent printers eject droplets of ink onto the media with a wide range of adjustability. Optimum ink density depends upon the ink, media, and printer settings such as resolution, print speed, number of print passes, and dot pattern. This must be determined for each media and RIP setting utilized. Ink density is determined by printing an ink limit target, consisting of tone values from 0–100% (Figure 6), and visually or densitometrically evaluating the color.

   Setting ink restrictions on an inkjet printer is similar to assessing ink mileage on a lithographic press. As the amount of ink applied increases, density increases, then at some point levels off and may subsequently decline (Figure 7). The optimum ink restriction setting is that which produces maximum density with the minimum amount of ink.

Figure 6. To set ink restrictions, a test chart with ink amounts varying from 0–100% is printed and then evaluated visually. The ink restriction is set at the point where maximum density is achieved with the minimum amount of ink.

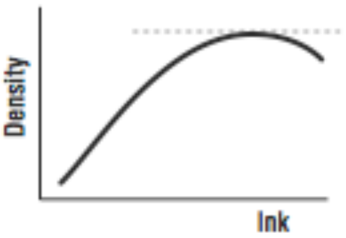

Figure 7. Establishing ink restrictions is similar to an ink mileage curve. As ink is increased, density increases, levels off, and may decline.

3. *Linearization.* Most inkjet printers are inherently nonlinear. A regular series of tone values does not always print with increasing density. Linearization creates a smooth curve of measure tone value vs. printed dot value. This results in a smooth, repeatable image, with good highlight and shadow contrast. Linearization is performed by printing a tone scale to density-limited values (Figure 8), measuring with a densitometer, and creating a correction curve to achieve the desired linearization. The effect of linearization can be visualized by plotting the LAB values of tone scales that have been printed with and without linearization.

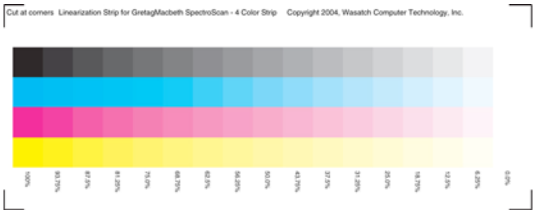

Figure 8. After optimizing ink density, the printer is linearized by reading the density values of a 0–100% tone scale. The RIP then calculates a correction curve to create smooth gradations.

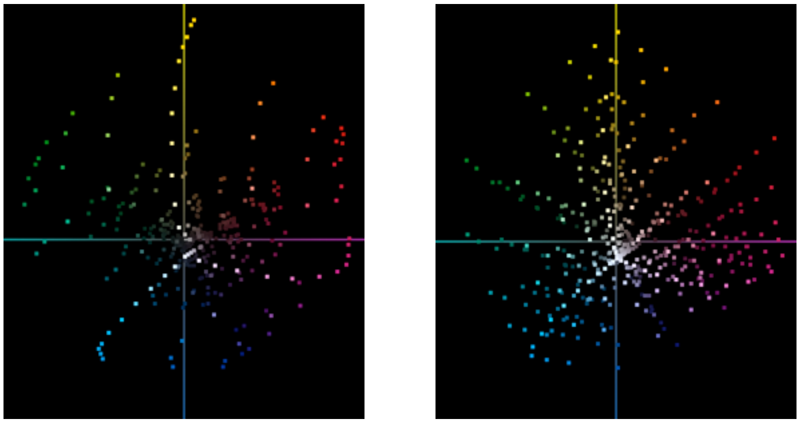

Figure 9. The effect of linearization can be seen in these two LAB plots of CMY 0–100% tone scales printed without (left) and with (right) linearization. The LAB values of the linearized target are distributed more uniformly through the color space than those of the unlinearized target.

4. *Total ink coverage.* As in lithographic printing, it is not always necessary or beneficial to utilize 100% of all inks to achieve the darkest density. Gray component replacement (GCR) benefits inkjet printers by reducing total ink coverage, thus minimizing ink bleed and reducing drying time. Total ink coverage is determined by printing an ink coverage target (Figure 9), measuring values with a densitometer or evaluating visually, and entering the desired ink coverage value into the RIP software.

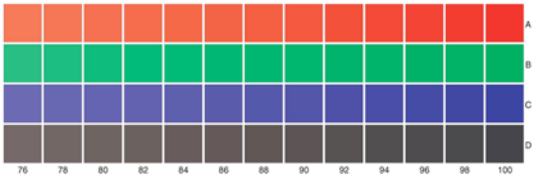

Figure 10. After linearizing, the optimum total ink coverage is determined using an ink coverage chart. The chart is evaluated visually for the maximum color density at minimum total coverage. Ink coverage is set using the RIP or in the profile.

5. *ICC Profile.* After the printer has been optimized with proper heater settings, ink limits, lienarization, and total ink coverage, an ICC profiling target can be printed and used to generate an ICC profile of the ink, media, and printer.

Experimental Procedure

An experiment was conducted to determine the extent to which the color gamut of an optimized ecosolvent printer is affected by heater settings and the resulting ink restrictions that were achievable.

1. Using Avery MPI-3100 PVC media, an ink limit target, consisting of relative ink percentages of 0–100%, was printed at different heater temperatures (25, 35, 45, 55°C).

2. Ink density limits were set by visually evaluating the target for maximum density without mottling, dot-gain banding, vertical banding, or other artifacts.

3. A 432-patch X-Rite/GretagMacbeth TC 3.5 test chart was printed at the ink density set in step 2.

4. The target was measured with an X-Rite/GretagMacbeth i1 iSis automated spectrophotometer.

5. An ICC profile was made from the printed target.

6. Using Chromix ColorThink Pro, the color gamut of the profile was graphed in CIE xyY color space to determine its size.

7. Density was measured with a color reflection densitometer and graphed as a function of ink application.

8. Print samples of 20% black ink from the 25° and 55°C ink restriction targets were examined with a scanning electron microscope to look for signs of ink penetration and other physical behavior on the surface of the media.

Results and Discussion

From visual evaluation of the ink limit target, maximum density (Table 1) was achieved at 55 C. However, this temperature caused the media to buckle in the feed direction, resulting in vertical banding of the print. High density was also achieved at 25 C, but ink mottling and banding in the direction of printhead travel were noticed due to the low temperature. At 45 C a high density was achieved without media buckling.

Temp	C	M	Y	K	Gamut Vol.
25 C	2.86	1.57	0.99	2.59	518
35 C	2.31	1.50	0.96	2.42	501
45 C	2.32	1.59	0.96	2.52	507
55 C	2.47	1.65	0.99	2.58	528

Table 1. Ink Restriction at Print Temperature

The relationship between heat and ink density is shown in Figure 11. Highest density is achieved at the coolest temperature (25°C). This observation is consistent with ink not penetrating the media surface, which results in mottling and poor print longevity.

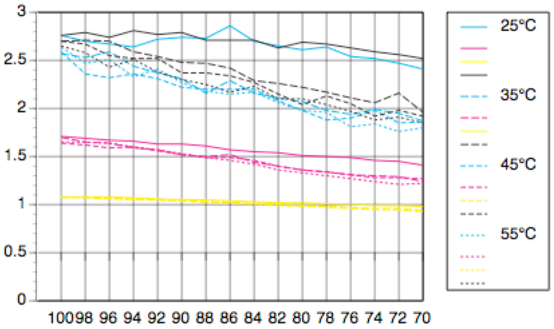

Figure 11. Relative size of color gamuts for media printed at 25, 35, 45, and 55°C.

The maximum 3D gamut in cubic delta-E (cde) was achieved at 55 C (528 cde), but with the drawback of vertical banding due to media buckling. The next-largest sized gamut (518 cde) was achieved at 25 C, but with the disadvantage of incomplete ink penetration and resulting mottling and horizontal dot-gain banding. The optimum density with minimum artifacting was observed at 45 C, at which the gamut measured 507 cde.

A gamut plot in CIE xyY (Figure 12) shows that maximum 2D gamut size is achieved at 55°C, followed by 25 C, 45 C, and 35°C.

Scanning electron micrographs (Figure 13) of 20% black tint patches printed at 25 and 55°C showed that, when printed at the 25°C, the ink droplets spread out on the media surface and formed irregularly shaped dots. This is consistent with the mottled appearance and higher density observed on the 25°C prints. Dots printed at 55°C maintained a more uniform, compact shape. This is consistent with the observation that higher-temperature media facilitates ink penetration and drying.

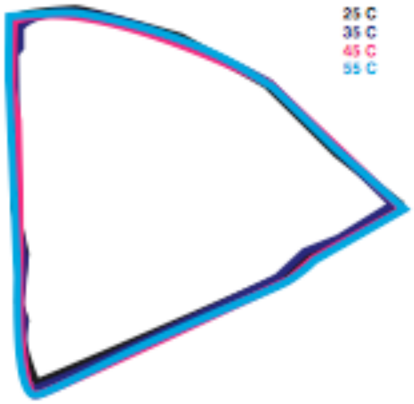

Figure 12. Relative size of color gamuts for media printed at 25, 35, 45, and 55°C. The highest density and largest gamut were achieved at 55°C. However, the print exhibited vertical banding caused by media buckling due to excessive heat.

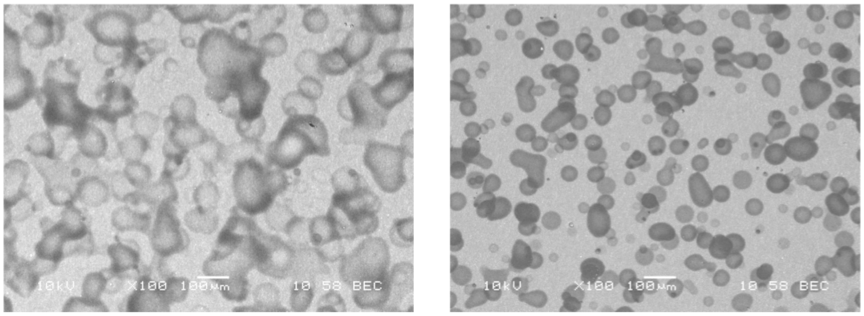

Figure 13. Scanning electron micrographs of 20% black tints printed at 25°C (left) and 55°C (right). The cooler-temperature prints showed large, irregularly shaped dots, while those printed at the higher temperature were smaller and more regularly shaped. This is consistent with better ink penetration into the media and faster drying.

Conclusion

This experiment documents the tradeoff in ecosolvent inkjet printing between ink density and print quality at a specified speed. The highest ink density and color gamut are achieved at the maximum print temperature, but media buckling and resulting vertical banding adversely affect quality. Although ink density is also high at close to room temperature (25 C), incomplete ink penetration adversely affects print quality by causing dot-gain banding and mottling.

With this printer and media, the difference in color gamut between low- and high-temperature prints is not as great as the authors have observed on other printer-media combinations. This may be due to the ink's tendency to spread out on the surface at low print temperatures, rather than to penetrate into the surface.

Further investigation could be done to document the effects of temperature, ink density, and print quality on other media. Also, the appearance of ink on the media surface could be further studied using scanning electron microscopy.

Literature Cited

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Appendix

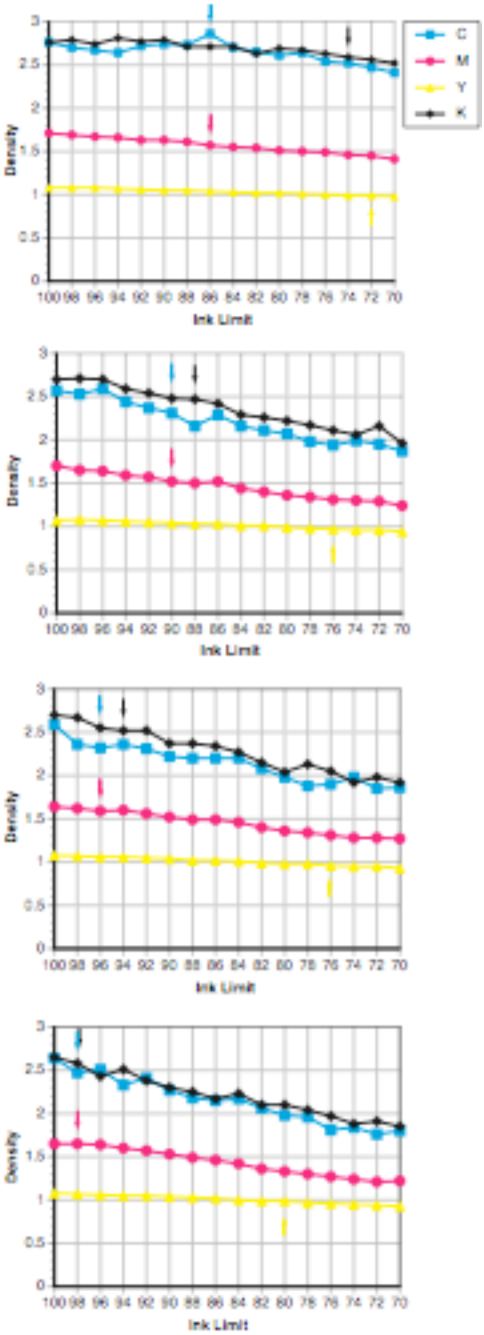

Figure 11. Individual plots for 25, 35, 45, and 55°C of ink density as a function of ink amount applied to the media.