Measurement of Humidity Effects on the Dark Keeping Properties of Inkjet Photographic Prints

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Abstract

ANSI Standard IT9.9-1990 is one methodology commonly recommended for predicting dark storage print life for color photographic materials. This methodology focuses primarily on measurement of changes that occur due to temperature at one relative humidity (50% ± 3%). Of greater concern for dark stability of inkjet prints, however, is humidity levels that are higher than 50% RH, especially as consumer usage of inkjet continues to expand all over the world. Ink/media combinations exist today that respond almost immediately to humidity in excess of 50% RH, even at ambient temperatures, and these instabilities are a major concern for both manufacturer and user. In addition, the effects of elevated humidity on inkjet prints vary widely between different ink/media combinations. Several quantitative measures are necessary to adequately describe the resultant behaviors. The objective of this paper is to begin to explore these relationships providing a foundation of understanding that will ultimately lead to a robust model that correctly predicts the image quality degradation as a result of exposure to variable dark keeping conditions.

Introduction

Several studies have been completed that identified the sensitivity of inkjet photographic prints to humidity.[1, 2]
As dark storage standards for inkjet are adopted, the methodologies must take into account a comprehensive understanding of the impact of indoor environmental conditions (including humidity), on inkjet photographic prints. A set of ideal test conditions and test measures that correlate specific responses with end users' subjective preferences must be assembled. In this study, we explore test conditions and objective test metrics for evaluating the humidity stability of inkjet photographic prints in relation to users' preferences.

The observed changes caused by humidity in inkjet photographic prints are complex and have been cited as: "…lateral ink diffusion, density changes (increases and decreases), color balance changes (hue shifts)…".[2] Given that the observed changes caused by humidity are numerous, a multivariate analysis is likely required. In a recent publication,[2] the color balance effect is modeled using colorimetry. After measuring the CIELAB colorimetry, the total color difference, ΔE, is calculated. This methodology works quite well as a relative measure of change for a given media/ink system; however, some questions remain before meaningful comparisons between different ink/media combinations based on ΔE are made. In this context, is ΔE sufficient to judge the acceptability of a print, especially in the presence of lateral ink diffusion?

This study will provide initial insight into the complexity of modeling humidity effects and provide new test metrics for assessing the impact of lateral ink diffusion.

Experiment

Inkjet prints made on a variety of ink-receiver systems were kept at a series of conditions to examine the effects of humidity on dark image stability. The test prints used in this study were printed using a commercially available printer, inks, and receivers. The test print itself is comprised of three major components: (1) step wedges, consisting of 20, 50, 75, and 100% area coverage, for each of the primary and secondary colors (cyan, magenta, yellow, red, green, blue, and neutral); (2) color bars, 400 microns in width, one of each of the primary and secondary colors (cyan, magenta, yellow, red, green, blue, and neutral, 100% coverage), each surrounded by unprinted area; and (3) a practical pictorial image as a sanity check.

A representative assortment of receivers (swellable, porous RC, cast coated, other coated) were selected for use in this experiment. They include the following:

1. KODAK Premium Picture Paper for Inkjet Prints
2. KODAK Picture Paper for Inkjet Prints
3. Konica QP
4. Great White Glossy Photo Paper
5. Hammermill Jet Print Photo Graphic Arts Glossy Finish
6. HP Premium Plus Glossy

The samples were stored at 24 °C and at 30, 40, 50, 60, 70, 80, or 90% RH for a period of 14 days. Several objective metrics were monitored, and data for these was collected at time intervals of 3, 7, and 14 days. The color wedges were measured by both Status A densitometry and CIELAB colorimetry (2° observer and D50 illuminant) both initially and at the specified time intervals. Both ΔD, as a percentage of starting optical density, and ΔE were calculated and then interpolated to a 1.0 initial density. Concurrently, bar width and printed edge sharpness of the each of the color bars were measured using ImageXpert, a CCD camera-based, high magnification digital analysis system.

To understand the relationship between the objective test metrics and perceived image quality, rank order psychophysics were conducted with 25 qualified observers. Each observer was asked to rank the pictorial image on the treated test print first for perceived image quality and then for hue and sharpness.

Results

Although there were some differences from receiver to receiver, some general trends were evident. Figure 1 is a graph of percent magenta density change at an interpolated 1.0 initial density verses initial, 3, 7, and 14 days. The objective test data indicates that a relative humidity level of 60% is sufficient to cause a significant change in the image quality of the printed test target. As the relative humidity increases to levels above 60% RH, a decreasing amount of time was required to elicit these changes. At 90% RH, significant and measurable changes to the test prints have occurred in only three days. In fact, the majority of the changes observed actually occurred within the first three days of the two-week test duration.

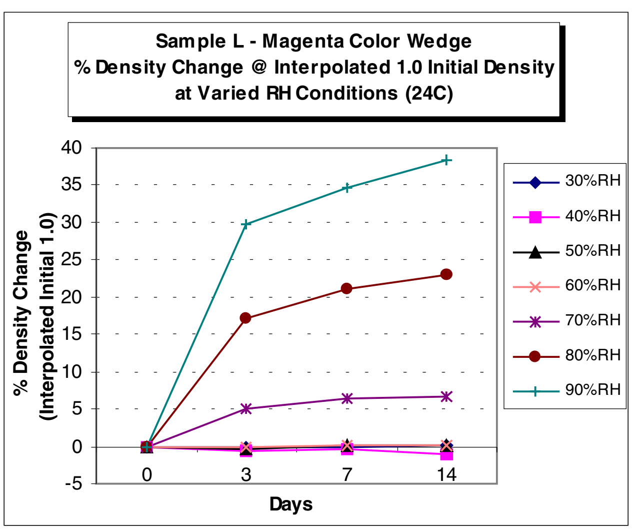


Figure 1. Impact of test conditions as reflected by magenta density change, Sample L

In this particular experiment, the most pronounced signal always came from the magenta dye. The reader should make note that other ink and media combinations may yield stronger signals in one of the other primary colors.

Next, the ΔE data was compared to the subjective image quality rankings. Figure 2 is a graph of ΔE and subjective image quality rank verses sample identification.

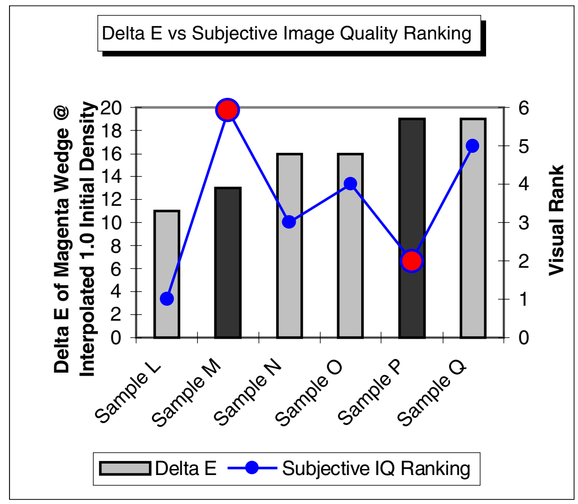
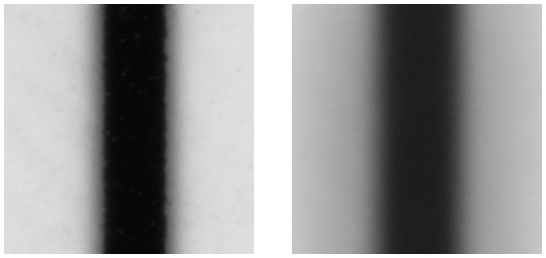


Figure 2. Ascending order of ΔE as compared with ranking of samples for perceived image quality (1-6, 6 is worst)

What is apparent from the graph in Fig. 2 is the pronounced discrepancies between the subjective image quality rankings and quantitative ΔE measurements of two of the six test prints, M and P. Test print M has a small ΔE, yet the observers decisively ranked the pictorial image the lowest for overall print quality. Similarly, in the case of test print P the ΔE is large, yet observers consistently rated this test print high in overall image quality. Hence, more information is needed to explain the unusual results involving these two test prints.

The trends in Fig. 2 show that while Sample P and Sample Q had similar ΔE values, the observers preferred Sample P. Closer examination of the practical images revealed the prints looked blurry in addition to changes in color. Like the practical prints, the magenta bars in the test print were blurry. This blur effect is due to lateral ink diffusion sometimes referred to as dye smear.

High magnification images of color bars featured on each of the two test prints were captured using ImageXpert CCD camera. After 14 days of treatment at 24°C and 90%RH, the two samples show a marked difference. Figure 3 consists of two photos, one of the Sample P magenta bar and one of the Sample Q magenta bar.



Sample P **Sample Q**

Figure 3. 24 °C 90%RH 14 days, ImageXper™ 50X Magnification of Magenta Bar (Green Channel of Color CCD Camera)

The magenta bars were measured for “sharpness” using the commercially available ImageXpert (IX) Analysis System. Sharpness was characterized by measuring the average gradient of a printed edge in a specific region of interest. The IX scans, on a pixel by pixel basis, the gray levels in the region of interest, in a direction perpendicular to the printed edge. The IX determines the printed edge by locating the greatest gray level change occurring over a distance of three adjacent pixels. The more distinct the printed edge transition is, the higher the average gradient value will be. Thus a higher average gradient value distinguishes the “sharper” of two printed edges. Concurrently, the actual width of the printed bars was also measured with the IX system, but only as a data integrity check. As the image quality degrades, the measurable width of the printed bar increases. The relationship between average gradient and line width is inverse.

Figure 4 is a graph of average gradient and subjective image quality rank verses sample identification. As shown in Fig. 4, the ImageXpert measurement of AVERAGE GRADIENT (AG) is inversely correlated to visual (perceived) sharpness and to the steepness of the rise time curve in a light-to-dark transition area. The average gradient value for Sample P and Sample M seems to account for the discrepancy between ΔE and the Subjective IQ ranking shown in Fig. 2. The average gradient value for Sample P, which had comparable ΔE to Sample Q but comparable subjective image quality ranking to Sample L, is correctly positioned after Sample L. Likewise for Sample M, which had comparable ΔE to Sample L, has a low average gradient value. The average gradient measure as applied to printed edge sharpness appears to be exponential relationship. Efforts to characterize this measurement curve continue.

Conclusion

Modeling humidity effects is complex. As demonstrated, ΔE does not always correlate to print acceptability. To perform a meaningful evaluation in our experiment, a combination of test metrics was needed. The ImageXpert average gradient measurement was discussed as an effective tool to quantify the sharpness loss caused by lateral ink diffusion. This was a well-behaved system in that the magenta dye was consistently the bad actor across all test prints. The magenta signals were predictive of overall image

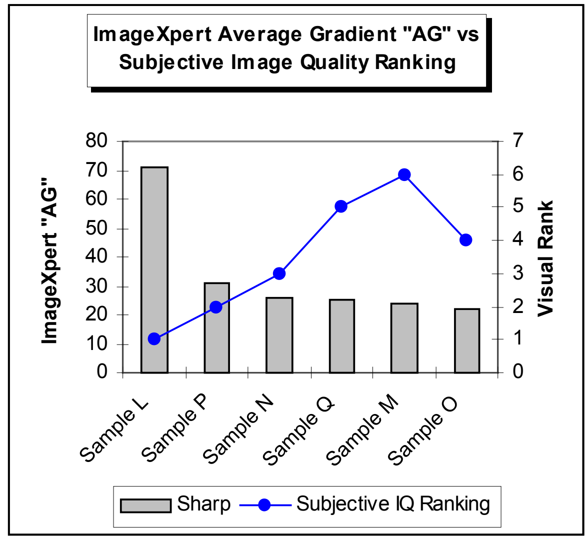


Figure 4. Ascending order of samples relative to ImageXpert Average gradient sharpness as compared with ranking of samples for perceived image quality (1-6, 6 is worst)

quality preferences. In general, all colors should be monitored until they can be eliminated from the analysis. ImageXpert average gradient was verified for other systems and dyes.

At this point in our work, we are not recommending a specific measure to characterize inkjet stability in humidity conditions. Rather, we offer this study as a starting point and recommend more studies to incorporate this information about ΔE and ImageXpert average gradient into a combined metric with proper weightings to reflect the relative contribution of color change and dye smear. Until further work is completed, the measurements for ΔE and average gradient must be confirmed visually with the sample or test print before blanket comparisons between different systems can be made.

Specifically, future work will be to verify these findings through a more comprehensive examination of how these measures correlate to a greater population of scenes covering all photospace. Another future goal is to establish thresholds of acceptability as a function of a multivariate model. The usefulness of density measurements compared to CIELAB colorimetry must be examined. If the lightness component, L*, of CIELAB colorimetry is used then density might provide redundant information. ΔE is a much easier to use than R, G, B densities because there is less data to manage, only a single channel per primary color, secondary color, and neutral. However, ΔE gives a magnitude of color change. By itself, unlike density, ΔE does not describe the direction of the color change nor describe which component contributes most to the degradation. Finally, more studies are in progress to examine application of Arrhenius methodology to predict print life of inkjet photographic prints due to temperature at constant absolute humidity.

References

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Biography

Pam Hill joined Eastman Kodak Company in 1997 following completion of a B.S. degree in Chemical Engineering from The University of Texas at Austin. Her research has focused on coating process improvements and more recently inkjet media development including performance assessment and measurement development. Karen Suitor has worked at Eastman Kodak Company for 17 years in various engineering positions. Currently, Ms. Suitor is an Inkjet Systems Engineer. Peter Artz is an Inkjet Testing Technician at Eastman Kodak.