Short-Term High Humidity Bleed In Digital Reflection Prints

Eugene Salesin, Daniel Burge, Douglas Nishimura and Nino Gordeladze; Image Permanence Institute, Rochester Institute of Technology, Rochester, NY, USA

Abstract

Exposure of some digital print types to high humidity can cause image colorant migration resulting in image density changes, color shift, blurring and loss of detail. The purpose of this study was to quantify the potential for colorant bleed during short-term exposures to high humidity conditions in order to develop care and use guidelines for museums, libraries and archives that may collect large numbers of these materials including many of high monetary value. Most previous work has focused on image effects, but this project also includes tests for damage to text-based documents. The potential for bleed both parallel and perpendicular to the printer paper feed direction was examined. A variety of digitally printed materials, including inkjet, electrophotographic, and dye sublimation were exposed to high humidity conditions for two and four weeks. Results are reported as Delta E for a checkerboard target, change in width for lines both parallel and perpendicular to the paper feed direction, as well as text readability which was assessed visually. The relative sensitivities of the materials are ranked and compared to the sensitivities of traditionally printed offset lithography and chromogenic photo materials.

Introduction

The purpose of this study was to determine the effects of high humidity on the stability of modern digitally printed materials. While there are many known damaging effects on printed matter by humid storage conditions (mold growth, physical deformation, sticking between objects) some digital prints experience damage resulting from migration of colorants. This can result in density changes, color shift, blurring and loss of detail. The focus of this research was on colorant bleed.

The problem is that the colorants of some printing systems are fugitive at high humidity. This has been reported by libraries and museums [1] and has also been acknowledged by manufacturers of these products. Several studies have identified the sensitivity of inkjet prints to high humidity [2,3,4,5]. Currently the ISO TC-42 committee is developing a test method to evaluate products for this tendency and it is thought that the work described in this paper might contribute to this effort.

The audience for this paper is primarily those charged with the task of caring for cultural heritage collections. The goal is to provide good information on the effects of storage and display conditions as well as the hazards that may occur during transport of materials outside of the institution. In addition, conservators who treat these materials need to be forewarned of hazards caused by procedures that include the use of high humidity to treat prints (such as print flattening).

Sample Preparation

Triplicate samples were printed with a test target. After printing, two samples were conditioned at 21°C and 50%RH for two weeks before being incubated at elevated temperature and humidity. The third sample was kept in the dark at 21°C/50% RH for reference. The test target included vertical and horizontal cyan, magenta, yellow and black lines, a simple 36 patch checkerboard pattern [2], a continuous-tone color step wedge, white text and resolution lines on a black background, black text and resolution lines on a white background, and a pictorial image.

Sample Incubation Conditions

Separate sets of samples were incubated at 30±1°C each for two and four weeks at 75±3% RH and 85%±3% RH.

Measurements

Measurements were made both before and after exposure to high humidity for color change in each of the checkerboard patches and for line width in both the vertical and horizontal cyan, magenta, yellow and black lines. The latter provided results for lines printed both parallel (vertical) and perpendicular (horizontal) to the paper feed direction. Text readability was assessed visually.

Color Change

CIELAB L*a*b* of each patch in the checkerboard target were measured with a Gretag Spectrolino/Spectroscan® spectrophotometer (D50, 2° observer, with no UV cut-off filter).

Delta E was calculated for each of the 36 checkerboard patches. The four patches (approximately 10%) with the greatest changes were averaged for each sample and reported in this study.

Line Width

Average line widths for vertical and horizontal printed lines were measured utilizing ImageXpert® image quality measurement systems. The printed samples were scanned at 2400 dpi and analyzed by taking the average line widths for the horizontal and vertical lines.

The threshold for gray value was calculated as the 60% point between the dark mode (the mode of the histogram peak formed by the foreground such as the magenta line) and the light mode (calculated from the mode of the histogram peak for the paper in the same color channel). The threshold for each colorant (CMYK) was calculated in the color channel that provided the highest contrast, i.e. blue channel for yellow (and paper for yellow), green channel for magenta (and paper for magenta) and black (and paper for black), red channel for cyan (and paper for cyan).

Text Readability (Visual Assessment)

The smallest readable font size (8pt to 14pt) for black letters on a white background and white letters on black background was noted visually after exposure to high humidity.

Table 1: Printer/paper combinations tested are shown below.

Printer	Paper	Number of Systems	Technology Abbreviations
Dye inkjet	Porous photo	3	IJ - Dye/Por-Ph
Dye inkjet	Polymer photo	3	IJ - Dye/Plm-Ph
Dye inkjet	Cast coat	1	IJ - Dye/Cst-Ct
Dye inkjet	Inkjet office - uncoated	1	IJ - Dye/Ofc Unctd
Dye inkjet	Inkjet office - coated	1	IJ - Dye/Ofc Ctd
Dye inkjet	Plain office	3	IJ - Dye/Doc
Dye inkjet	Fine art photo	1	IJ - Dye/FA-Ph
Pigment inkjet	Porous photo	2	IJ - Pig/Por-Ph
Pigment inkjet	Fine art photo	2	IJ - Pig/FA-Ph
Pigment inkjet	Plain office	3	IJ - Pig/Doc
B&W electrophotographic	Plain office	3	B&W EP/Doc
Color electrophotographic	Plain office	3	Color EP/Doc
Dye sublimation	Dye sublimation	2	Dye Sub
Color silver halide	Chromogenic	1	AgX
Digital press - liquid toner	Coated glossy	1	Digital Press-LT
Digital press - dry toner	Coated glossy	2	Digital Press-DT
Offset lithography	Coated glossy	1	Offset

Description of Samples

Samples of 33 printer/paper combinations were included in the test program. The last column in the table above indicates the abbreviations used in some of the charts in this paper to identify the printer/paper technologies studied (Table 1).

Results and Discussion

Inkjet pigment, electrophotographic, dye sublimation and digital press prints were resistant to bleed at high humidity, similar to chromogenic and offset prints (Figure 1).

High humidity bleed was only apparent to a minimal degree at two weeks/30°C/75% RH, as indicated by very small line width increase for three inkjet dye printers on one cast-coat paper and two polymer photo papers. Bleed was much more significant for these printer/paper combinations at 85% RH (Figure 2).

In general, prints made with inkjet dye printers, as opposed to any other types, were more likely to bleed at high humidity conditions. Magenta inkjet dye showed greater bleed than the other dyes. There was no significant difference in line width change for lines printed parallel versus perpendicular to the paper feed direction.

***Figure 1**: Delta E and line width change for all printer/paper combinations.*

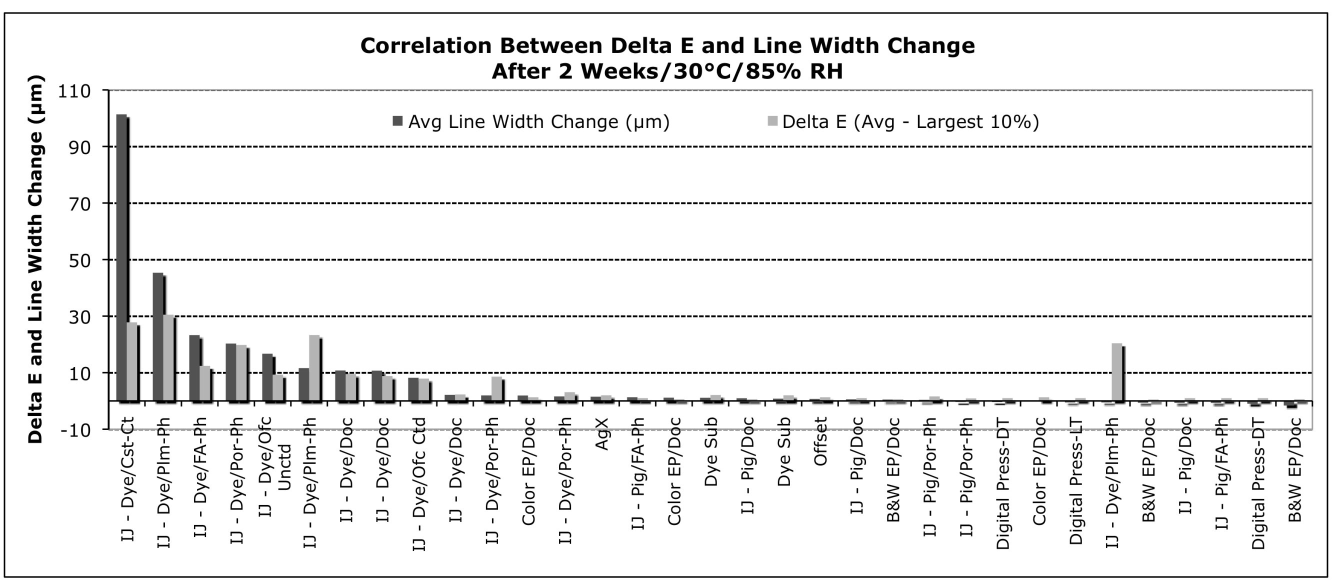
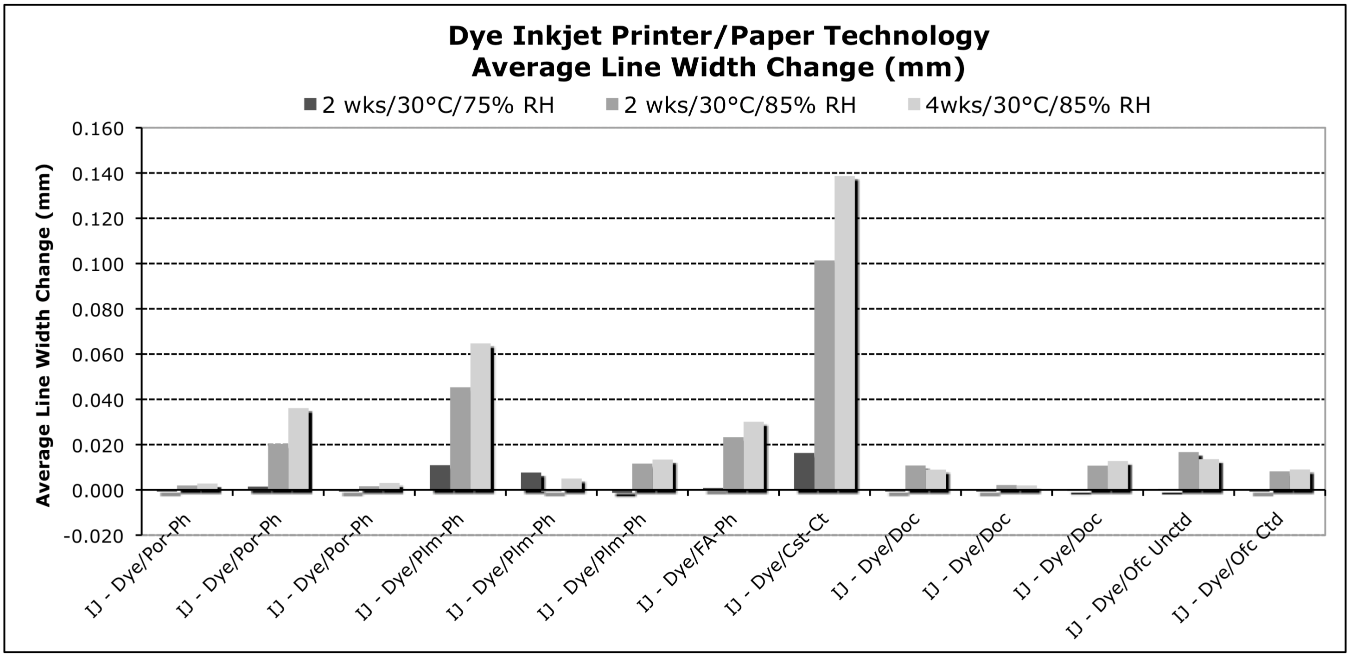


***Figure 2**: Average line width change for dye inkjet printer/paper combinations as a function of high humidity condition*



Dye inkjet prints on office paper showed considerably less bleed than those printed on photo papers. But these papers showed some bleed when viewed from the unprinted side whereas photo papers did not show this effect.

No generalization can be made comparing dye inkjet prints on polymer versus porous and fine art photo papers. Some printer/paper combinations are more prone to bleed than others, apparently due to the different formulations of the individual papers. The printer/paper combination that produced the most significant bleed was inkjet dye on cast-coated paper.

Changes in line width and Delta E with high humidity treatment of the printed papers were in general agreement, with the exception of one sample. The R^2 semi-log line width/Delta E correlation was 0.82, including this sample (Figure 1).

Cross-sections of this particular sample, an inkjet dye print on a polymer photo paper, showed that dye which saturated the receiving layer in some of the checkerboard patches spread laterally with high humidity treatment whereas the dye in the printed lines did not saturate the receiving layer and spread deeper into the layer rather than laterally (Figure 3). This did not cause increased line width with high humidity treatment but did produce a significant Delta E result. This indicates that bleed effects are likely to be more severe in shadow areas of some prints as compared to highlight areas, and that Delta E is probably a better measure of the effects of high humidity than line width change.

Text printing was legible after incubation at high humidity with all printer/paper combinations even with the smallest type size tested (8pt). Inkjet dye prints on photo and cast-coated papers showed the largest change, as might be expected, but even these were legible after the most severe incubation condition. For this situation, white letters on a black background were considerably more difficult to read than black letters on a white background (Figure 4).

***Figure 3**: Cross-sections of a magenta line and a checkerboard patch before and after exposure to 30°C/85% RH for two weeks.*

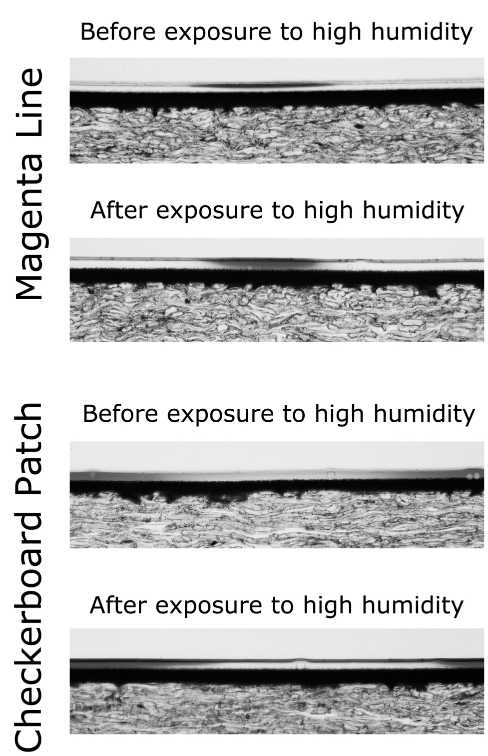
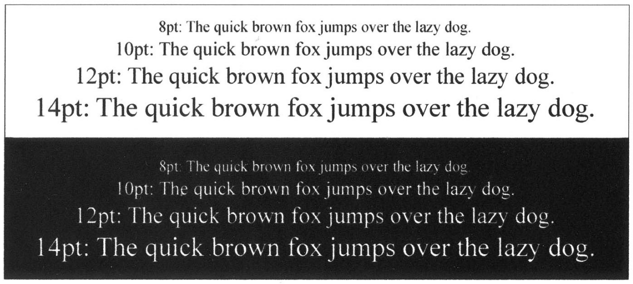
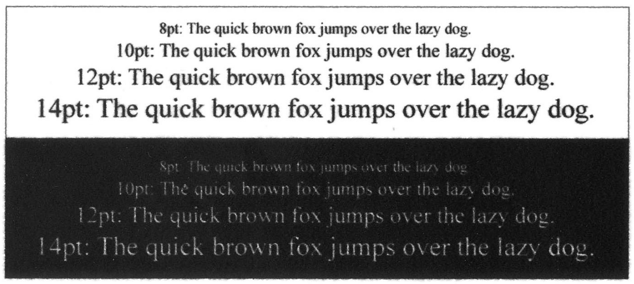


***Figure 4**: Most severe text print change – inkjet dye with cast-coat paper.*



Before exposure to high humidity



After exposure to 4 weeks/30°C/85% RH

Conclusions

1. High humidity bleed was apparent at 2 weeks/30°C/75% RH, but only to a minimal degree and only with a very few printer/paper combinations. Bleed was much more pronounced at 85% RH.
2. Shadow areas of inkjet dye prints are more likely to bleed than highlight areas.
3. Magenta inkjet dye showed greater bleed than the other inkjet colorants.
4. There was no significant difference in line width change for lines printed parallel versus perpendicular to the paper feed direction.
5. Changes in line width, Delta E, and text readability with high humidity treatment of the printed papers were usually consistent, but some exceptions can occur.
6. Delta E is probably a better measure of the effects of high humidity as compared to line width change.
7. In general, prints made with inkjet dye printers, as opposed to any other types, were more likely to bleed at high humidity conditions, but there were some dye printer/paper combinations which did not follow this rule. For example, inkjet dye prints on office paper showed no significant bleed even at 4 weeks/30°C/85% RH.
8. No generalization can be made comparing dye inkjet prints on polymer versus porous and fine art photo papers. Some of each is more prone to bleed than others, apparently due to the different formulations of the individual papers.
9. Inkjet pigment, electrophotographic, dye sublimation and digital press prints were the most resistant to bleed at high humidity and are similar in this respect to chromogenic and offset prints.
10. Text printing was legible after incubation at high humidity with all printer/paper combinations. Inkjet dye prints on photo and cast-coated papers showed the largest change, as might be expected, but even these were legible after the most severe incubation condition. For this situation, white letters on a black background were much more difficult to read than black letters on a white background.

Recommendations

Collection care personnel need to be aware of the types of prints in their collections to be able to separate those prints that are especially vulnerable to the effects of high humidity in order to provide special protection for them. Prints produced by inkjet dye printers on photo and cast-coat papers must be kept from exposure to high humidity even for short periods of time. All other prints are much less prone to bleed under conditions of high humidity.

References

[1] Daniel Burge, Douglas Nishimura and Mirasol Estrada, "Summary of the DP3 Project Survey of Digital Print Experience within Libraries, Archives, and Museums," IS&T's Archiving 2009 Final Program and Proceedings, IS&T, Arlington, VA, May 4-7, 2009, pp133-136.

[2] Hideki Kaimoto and Yoshihiko Shibahara, "Test Methods of Humidity Fastness of Inkjet Printing Materials," IS&T's NIP23: International Conference on Digital Printing Technologies, 2007, pp. 728-731.

[3] P. Hill, K. Suiter, P. Artz, "Measurement of Humidity Effects on the Dark Keeping Properties of Inkjet Photographic Prints," IS&T's NIP16: International Conference on Digital Printing Technologies Final Program and Proceedings, IS&T, Springfield, VA, Oct. 15-20, 2000, pp. 70-73.

[4] S. Carlson, R. Reed, C. Rundle and R. Kellett, "Environmental Effects on Image Bleed with Various Ink Jet Imaging Substrates," Proceedings of IS&T's 46th Annual Conference, Cambridge, MA, May 9-14, 1993.

[5] Shilin Guo, Nils Miller and Dan Weeks, "Assessing Permanence of Inkjet Prints," IS&T's NIP18: 2002 International Conference on Digital Printing Technologies, San Diego, CA, Sept.29-Oct. 4, 2002, pp319-325.

Author Biography

Dr. Gene Salesin, Research Assistant, received a B.S. in chemical engineering from the University of Michigan in 1958 and an M.S. and Ph.D. in chemistry from Case Western Reserve University in 1960 and 1962, respectively. He retired in 1997 after 36 years of employment in the research laboratories and several manufacturing divisions at Kodak. He held a mid-management position during his last few years there, leading the staff involved with providing the technical instructions and specifications for the manufacture of black-and-white films. Dr. Salesin joined IPI in 2004 and has been involved in the permanence properties of magnetic tape and digital prints.