Improved Water-Resistance Test Methods Utilizing a Multispectral Imaging System to Quantify Black and Color Ink Bleeding for Plain Paper Office and Legal Documents Printed with Pigment- and Dye-Based Inkjet Inks

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Abstract

Current ISO standards that pertain to water-resistance testing with inkjet prints were developed for moisture-impermeable RC photo papers and do not take into account the kinds of ink diffusion behavior that can occur with inkjet printing on highly absorbent plain papers, especially with dye-based inks. Even momentary contact of water with plain paper documents can result in significant lateral ink bleeding, migration of inks through the paper to the backside of the sheet, transfer of ink from one sheet to adjacent sheets, and two-way transfer of inks with double-sided printed documents. Shipping labels and envelopes can become illegible should they become wet, and Barcodes and QR codes may be rendered completely unreadable. This study attempts to better understand the water-resistance behavior of plain paper documents printed with dye-based and pigment inkjet inks. The use of high-resolution multispectral imaging and colorimetric analysis systems to provide a quantitative assessment of ink bleeding, migration, and ink transfer to adjacent pages is explored as an alternative to the subjective, qualitative, water-resistance evaluation methods specified in current ISO standards.

Introduction

Inkjet-printed plain paper documents are playing an increasingly important role in office applications and in the printing of legal documents that are expected to be retained in good condition in often less than ideal environments for long periods of time. The development of full-page-width array inkjet heads, automatic two-sided printing, improved dye-based and pigment ink formulations, large capacity ink cartridges and refillable ink tank systems, and other advances in inkjet printing technology have led to greatly increased print speeds together with significantly reduced cost of ownership and costs per page – and this in turn has allowed inkjet to move into market areas previously dominated by monochrome and color laser printing.

As most business documents now contain critical color information – business logos, color typography, graphs and spreadsheets, and color photographs and illustrations – printing in color has become the expectation in most plain paper office printing markets. Pigment inks, dye-based inks, and "hybrid" pigment black/dye color inksets are presently being used in office markets and there is increased interest in understanding the differences in the permanence characteristics of the different types of inks with plain paper prints. This is especially true in terms of water resistance, because plain paper documents printed with inks having poor water resistance can be catastrophically damaged in just seconds or minutes by contact with water.

Water damage can be caused by hurricanes, typhoons, tornadoes, river and stream flooding, broken water pipes, faulty sprinkler systems, water inundation resulting from efforts to extinguish a fire inside a home, office, or other building, roof leaks, basement leaks, mail exposed to rain, and so on. The current ISO standards that pertain to water-resistance test-

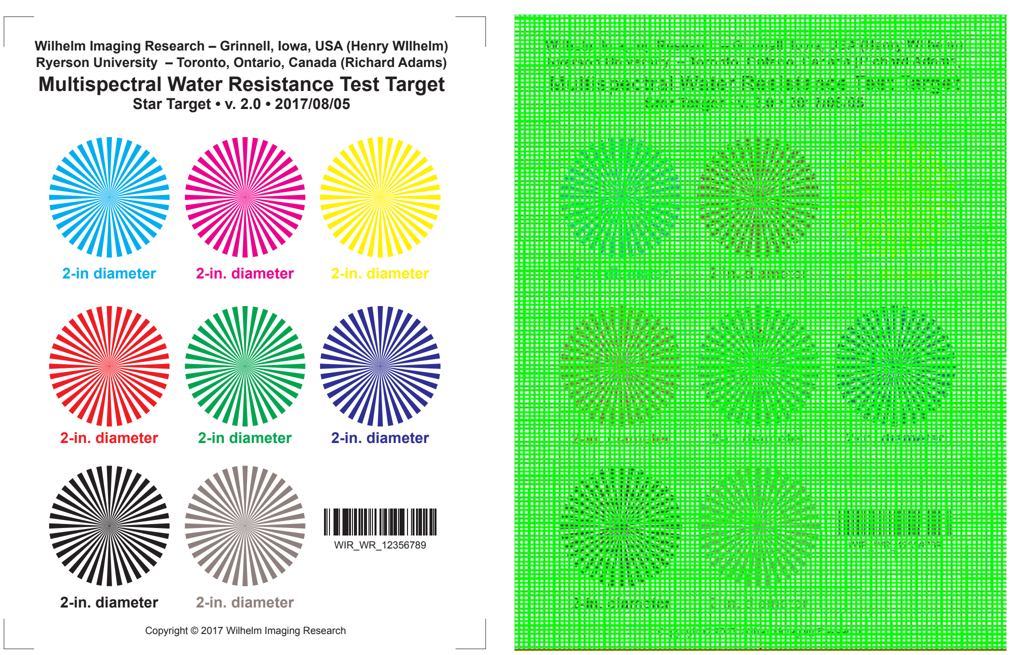

Figure 1. A circular spoke-pattern water-resistance test target designed for multispectral imaging and analysis. The ever narrowing distance between the spokes toward the center of the target can be a very sensitive indicator of ink bleed. The target is printed on an 8.5 x 11-inch letter size(or A4 size) sheet of plain paper. To the left is a newly-printed target, not yet exposed to water. The MegaVision multispectral imaging and analysis system can capture up to ten-thousand – or more – spectral data points, which can be exported in LAB space. The image to the right shows an overlay grid for 400 x 450 measurement locations – 180,000 individually addressable data points on a target. After the target has had contact with water and dried, the "before and after" images can be compared to quantify ink bleeding. To measure the amount of ink migration that takes place from the front to the back of a sheet, both sides of the sheet can be imaged and compared.

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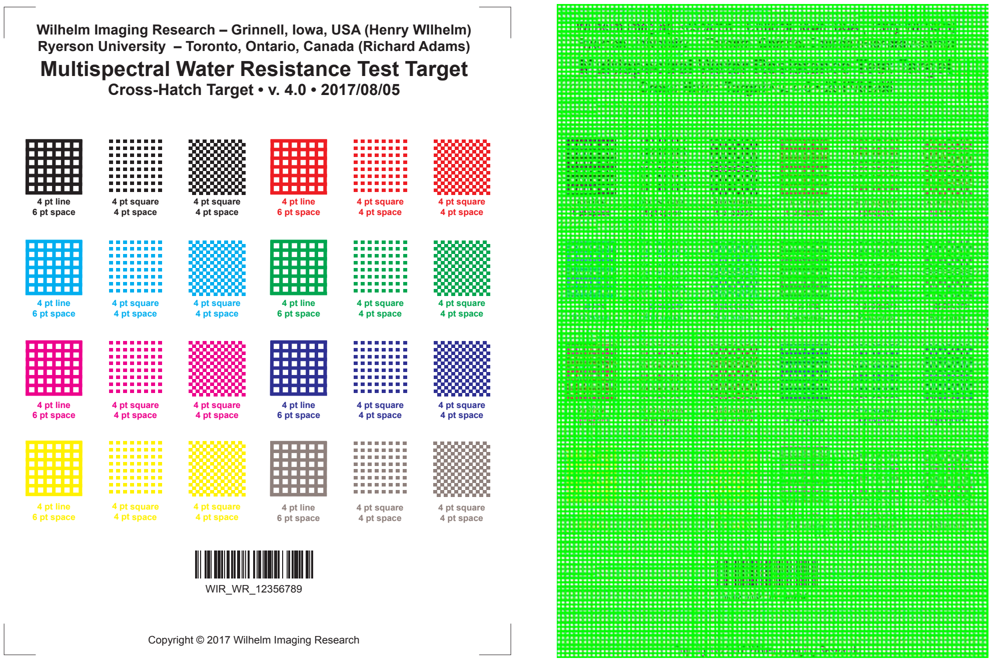

Figure 2. A square cross-hatch-pattern water-resistance test target designed for multispectral imaging and analysis. The degree of ink bleed that fills the interiors of the cross-hatch elements in the target can be measured and quantified with the multispectrical imaging and analysis system. The target, which consists of cyan, magenta, yellow, black, CMY gray, red, green, and blue segments, is printed on an 8.5 x 11-inch letter size (or A4 size) sheet of plain paper. To the left is a newly-printed target, not yet subjected to contact with water. The image to the right shows an overlay grid for 400 x 450 measurement locations – 180,000 individually addressable data points on a target. After the target has been in contact with water and dried, the "before and after" images can be compared to quantify ink bleeding. As with the circular spoke-pattern target, this target is useful to assess the amount of ink migration that takes place from the front to the back of a sheet, both sides of the sheet can be imaged and compared.

Figure 3. Test samples printed with pigment-based and dye-based inkjet inks undergoing the 24- hour "edge immersion" water-resistance test specified in Sec. 6.5 of ISO 18935:2016(E). This test was originally designed for RC-base and other multi-layer-structure photo papers and, in terms of applicability to commonly encountered types of water damage, the test may not be well-suited for evaluating the water-resistance of inkjet-printed plain paper documents.

ing were not developed to evaluate inkjet printing on plain paper. ISO 18935:2016(E),[1] originally published in 2005, is intended primarily for use with digital and analogue printed RC-base and other photographic materials; text is not included in the test target design. ISO 11798:1999(E),[2] published eighteen years ago in 1999, was developed primarily for offset printed book papers, xerographic printing on copy papers, and manual pencil and ink writing on writing papers – and was intended for books and other documents intended to be stored in libraries, archives, and "other protected environments."

Goals of This Project

1. A principal focus of this research is to better understand the types of water damage that can occur to inkjet-printed plain paper documents in real world conditions. This includes momentary exposure to water resulting from a spill that is wiped with a paper towel or other absorbent material, or rain drops that might contact a mailing envelope or shipping label; longer-term partial or total water exposure that could occur to an inkjet print in a plastic sleeve restaurant menu should a customer spill water on it during a meal; rain exposure on a "lost dog" or other plain paper signs posted outdoors; or prolonged, "total immersion" water exposure to documents caused by hurricanes, floods, broken water or sewer pipes, faulty sprinkler systems, and similar calamities.
2. Design new water exposure tests that take into account the specific behaviors of dye-based inkjet inks printed on plain papers and pigment-based inkjet inks printed on plain papers.

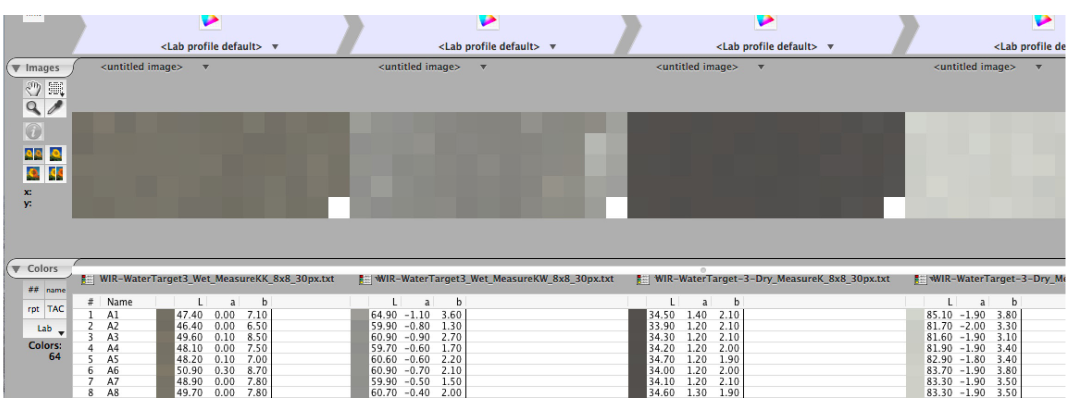

Figure 4. From the MegaVision LAB values, Delta-E was computed with Chromix ColorThink software to compare the test targets overall, or in areas of particular interest, before and after they were subjected to contact with water, including short-term or long-term total immersion in water.

Figure 5. Water resistance of envelopes, shipping labels, barcodes, and QR codes is of critical importance, as ink bleed can easily render them unreadable. In this example, a FedEx shipping label printed on plain paper with an inkjet printer is shown on the left. The label has not yet been subjected to contact with water. The image to the right shows an overlay grid for 200 x 250 measurement locations – which amounts to 50,000 individually addressable data points. After contact with water, at what point a barcode or QR code is no longer readable is a very useful way to evaluate water resistance of different plain paper printing systems, inks, and xerographic toners. A multipectral analysis provides a way to characterize barcode failure in a quantitative way.

This includes evaluation of ink "bleed-through" to the backside of a page printed on one side, and "bleed-through" of inks in two directions for pages printed on both sides. The authors designed two color targets intended to quantify the effects of water exposure to inkjet and other printed materials with a multispectral imaging and analysis system. The Multispectral Water Resistance Cross-Hatch Target consists of a series of finely-spaced, 4-point lines and squares that can be imaged in CMYK, RGB, and gray colors. The Circular Spoke-Pattern Target, with its ever-narrowing distance between the spokes toward the center of the target can also offer a sensitive indication of lateral ink bleeding or diffusion. In designing these targets, the authors sought a method of assessing water resistance through color comparisons of the solid-color lines with the white spaces in between. The presumption was that, if an ink was soluble or suspendable in water, molecules of color dye or pigment particles could migrate from solid to white areas, thereby lightening the solids and darkening the white spaces in between. Thus, the evaluation strategy was to compare the colorimetric values of the solids with those of the white areas. From the MegaVision LAB values, Delta-E was computed in Chromix ColorThink comparing the black and magenta inked patches to the surrounding paper (see Fig. 4).

3. Develop new methods to characterize and quantify ink transfer from one printed page to an adjacent page when a stack of pages (e.g., pages in a bound report, between pages stapled together, and between multiple pages placed together in a file folder) are partially or totally immersed in water for both short or extended periods of time.
4. Develop new methods to measure color ink bleeding, intermixing, and to quantify ink spread (bleeding) using a camera-based multispectral imaging system and associated software.[3] The longer-term goal of this research is to develop

Figure 6. To simulate the effects of immersion in water of multi-page plain paper documents or of multiple pages in a file folder, lightly spraying a blank unprinted sheet with water and then placing a printed test target page on top of it and lightly spraying and, finally, placing another blank page on top of it and spraying it proved to provide better assessments of ink bleeding, ink migration through to the back of the page, and ink transfer to an adjacent page proved to be more meaningful than completely immersing a whole stack of pages in water at the same time.

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meaningful, quantitative standards for water resistance tests with inkjet-printed plain paper documents that will replace the types of subjective evaluations currently used in water resistance tests.[1,2,4] An imaging-based measurement system can enable characterization and quantification not practical – or even possible – with single-point measurement devices.

5. Work with ISO, other standards groups, archive and library organizations, and manufacturers of inkjet and xerographic printer, ink, toner and paper manufacturers to develop improved test methods, specifications and standards.
6. In a future research project, the authors plan to conduct paired-comparison tests with selected inks and plain papers using various surface and deep-well municipal sources, seawater, and distilled water to understand what effects different kinds of water might have on water-resistance behavior in both short-term and long-term contact with water.

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Author Biographies

Henry Wilhelm is Founder and Director of Research at Wilhelm Imaging Research, Inc. Grinnell, Iowa. With work beginning in 1971, Wilhelm and his colleagues have assembled the world's largest reference collection of analog and digital color print materials and associated permanence data. Wilhelm has authored or co-authored more than 25 technical papers that were presented at conferences sponsored by the Society for Imaging Science and Technology (IS&T), the Imaging Society of Japan (ISJ), and the American Institute for Conservation (AIC). He has been involved with ANSI and ISO print permanence test methods standards development since 1978. With contributing author Carol Brower Wilhelm, he wrote "The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures," published in 1993. The complete 761-page book is available in PDF-A format at no cost from www.wilhelm-research.com. Wilhelm is currently serving with Shigeo Suga of Suga Test Instruments Co., Ltd., Tokyo, Japan, as Co-Project Leaders for the development of the new ISO 18937-4 accelerated test methods standard for LED illumination sources.

Ken Boydston is the President and Chief Color Scientist of MegaVision, Inc., Santa Barbara, California. Boydston led the development of the high-resolution, MegaVision Multispectral Imaging and Analysis System which was introduced in 2007 and, with Boydston's collaboration, has been used to image, monitor with very large colorimetric data sets, and conduct forensic analysis of The Dead Sea Scrolls in Israel, President Abraham Lincoln's handwritten draft of the Gettysburg Address, and many other cultural heritage treasures in the United States and throughout the world.

Richard M. Adams II, Ph.D., is an Associate Professor in the School of Graphic Communications Management at Ryerson University, Toronto, Canada. He teaches courses in document design, web design, and material science for print. His research focus include color management, electronic documents, and web design. Before coming to Ryerson University, Adams was a color management specialist with the training division of X-Rite, Inc., and he was also a research scientist at the Graphic Arts Technical Foundation (now the Printing Industries of America). After completing his Ph.D., he went on to study for a master's degree in printing technology from the Rochester Institute of Technology. Adams has recently been collaborating with Wilhelm Imaging Research on a number of research projects.

Charles Wilhelm is the manager of testing operations at Wilhelm Imaging Research in Grinnell, Iowa. Wilhelm is a 2015 graduate of Grinnell College, having majored in Chinese language and culture, with significant study of Japanese language and Japanese culture, and music, calculus, and statistics.

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