ChromaLuxe Coated Aluminum Photo Panels Printed With Sawgrass XF Sublimation Inks – Print Permanence Ratings[1]

With unprecedented resistance to surface abrasion, high humidity, atmospheric ozone, and contact with water, ChromaLuxe prints – often referred to simply as "Metal Prints" and available in sizes up to 4x8 feet (122 x 244 cm) – can be safely displayed without the need for framing under glass or acrylic, face-mounting to acrylic, or application of plastic surface laminates.

ChromaLuxe prints are made by first reverse-printing an image on a sheet of thin sublimation "transfer paper" with dye sublimation inks. The transfer paper is then precisely registered – face to face – on a rigid ChromaLuxe coated aluminum panel, which is then put into a specially-designed heat press, under pressure, at a temperature of 375°F (190°C) to 400°F (205°C) for two to four minutes. During this period, the dyes in the sublimation inks that had been printed on the transfer paper diffuse into the coating on the surface of the ChromaLuxe panel. The package is then removed from the heat press, allowed to cool, and the transfer paper is removed and discarded. At this point, the printing process is complete. No mounting or framing under glass or acrylic is required.

Compared with Sawgrass 8-color SubliJet-IQ Pro Photo Inks, the Sawgrass 8-color SubliJet Pro Photo XF inks feature improved-stability black, gray (light black), and light gray (light light black) sublimation inks that provides a substantial increase in permanence, both when prints are exposed to light on display, and when prints are stored in the dark, especially in conditions of high ambient temperatures; however, the long-term dark storage behavior of the ChromaLuxe prints made with Sawgrass XF sublimation inks and stored under commonly-encountered ambient conditions is not yet well understood, and research on this is continuing at Wilhelm Imaging Research (see Note No. 6 on page 6). Sawgrass 8-ink dye-sublimation inks can be used to print on sublimation transfer paper with compatible Mutoh large-format printers, as well as with user-retrofitted Epson 8-color printers. Currently, genuine Sawgrass XF inks do not appear to be in widespread use.

Notes: Display Permanence Tests are currently being conducted with museum-quality, high CRI (color-rendering-index), 3000K LED lamps. This report will be updated with results from these LED tests as soon as they become available. The print permanence data presented here apply only to ChromaLuxe branded white and clear coated aluminum panels, which have been optimized for Sawgrass XF and Epson UltraChrome DS sublimation inks, the permanence of images printed on ChromaLuxe panels with other types of sublimation inks – or on other brands of sublimation panels – can be markedly inferior. www.chromaluxe.com www.sawgrassink.com

Display Permanence Ratings and Album/Dark Storage Permanence Ratings (Years Before Noticeable Fading and/or Changes in Color Balance Occur)[2]

Sawgrass 8-Color SubliJet-IQ Pro Photo XF Sublimation Inks (Improved)	Displayed Prints Framed Under Glass[3]	Displayed Prints Framed With UV Filter[4]	Displayed Prints Not Framed (Bare-Bulb)[5]	Album/Dark Storage Rating at 73°F & 50% RH (incl. Media Yellowing)[6]	Unprotected Resistance to Ozone[7]	Resistance to High Humidity[8]	Resistance to Water[9]	Are Optical Brighteners Present?[10]
ChromaLuxe Photo Panels, Gloss White	**64 years**	58 years	64 years	now in test[6]	>100 years	very high	very high	no
ChromaLuxe Photo Panels, Gloss Clear	**64 years***	58 years*	64 years*	now in test[6]	>100 years	very high	very high	no

*Because of the unique reflective properties of the finely brushed aluminum substrate of ChromaLuxe Clear Photo Panels, it is not possible to measure dye fading and/or staining that might occur with a spectrophotometer. However, careful visual examination of both the White and Clear Gloss versions of the product has led WIR to conclude that the permanence properties are essentially identical. WIR has acquired a sophisticated MegaVision Multispectral Imaging and Analysis System that allows direct measurements to be made with both the White and Clear versions of the product and this technology will be used with future permanence evaluations of these materials.

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ChromaLuxe Coated Aluminum Photo Panels Printed With Sawgrass XF Sublimation Inks – Print Permanence Ratings[1]

Notes on These Tests:

1) The image permanence data presented here for 8-color Sawgrass PRO XF inks are based on tests done with the latest generation ChromaLuxe photo panels that were available in 2016 using sublimation transfer paper printed with Sawgrass XF Sublimation Inks . These test results with Sawgrass XF Sublimation Inks DO NOT apply to non-ChromaLuxe coated aluminum photo panels supplied by other companies. These tests were conducted in accordance with long-standing Wilhelm Imaging Research, Inc. test methods, lighting, temperature and relative humidity assumptions, and used the WIR 3.0 Visually-Weighted Fading, Color Imbalance, and D-min (Paper White) Stain Endpoint Criteria. This report is based on multiple Wilhelm Imaging Research print permanence studies conducted over the past four years (since 2014) that were commissioned by the ChromaLuxe/Unisub division of Universal Woods, Inc., headquartered in Louisville, Kentucky. www.chromaluxe.com

2) There are currently no ISO or ANSI "Specification" standards which provide a means of making "lifetime" or "noticeable change" predictions for the permanence of inkjet or other digitally-printed photographs under a standardized set of display and storage conditions (display illumination levels, spectral power distribution, ambient temperature, relative humidity, and indoor ozone concentrations) together with image-change criteria and limits (endpoints) for fading, changes in color balance, and d-min or paper white stain formation. As a member of ISO WG-5/TG-3 permanence standards group, WIR is actively involved in the development of new ISO standards for evaluating the permanence of digital prints. However, as of early 2018, no date have been announced for the completion and publication of a new consumer-oriented ISO "Specification" standard for indoor display and storage.

The WIR Display Permanence Ratings (DPR) given here are based on accelerated light stability tests conducted at 25 klux with glass-filtered cool white fluorescent illumination with the sample plane air temperature maintained at 24°C and 60% relative humidity. Data were extrapolated to a display condition of 450 lux for 12 hours per day using the Wilhelm Imaging Research, Inc. "Visually-Weighted Endpoint Criteria Set v3.0." and represent the years of display for easily noticeable fading, changes in color balance, and/or staining to occur. See: Henry Wilhelm, "How Long Will They Last? An Overview of the Light-Fading Stability of Inkjet Prints and Traditional Color Photographs," *IS&T's 12th International Symposium on Photofinishing Technologies,* sponsored by the Society for Imaging Science and Technology, Orlando, Florida, February 2002. This paper may be downloaded in PDF form at no charge from: *<http://www.wilhelm-research.com/pdf/is_t/WIR_ISTpaper_2002_02_HW.pdf>.*

For a study of endpoint criteria correlation with human observers, see: Yoshihiko Shibahara, Makoto Machida, Hideyasu Ishibashi, and Hiroshi Ishizuka, "Endpoint Criteria for Print Life Estimation," *Final Program and Proceedings: IS&T's NIP20 International Conference on Digital Printing Technologies,* pp. 673–679, sponsored by the Society for Imaging Science and Technology, Salt Lake City, Utah, November 2004.

See also: Henry Wilhelm, "A Review of Accelerated Test Methods for Predicting the Image Life of Digitally-Printed Photographs – Part II," *Final Program and Proceedings: IS&T's NIP20 International Conference on Digital Printing Technolo-*

Table 1. "Standard" Home Display Illumination Levels Used by Printer, Ink, and Photo Paper Manufacturers

120 lux/12 hrs/day	450 lux or 500 lux/10 hrs/day or 12 hrs/day
	HP
	Epson
	Canon
	Fuji
	ChromaLuxe
	Ilford
	Canson
	DNP Konica
Kodak Alaris (for Kodak silver-halide papers and Kodak dye-sub prints)	Kodak (for Kodak consumer inkjet prints)
	Ferrania
	InteliCoat
	Somerset
	Harman
	LexJet
	Lyson
	Luminos
	Hahnemuhle
	Premier Imaging Products
	American Inkjet
	MediaStreet

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ChromaLuxe Coated Aluminum Photo Panels Printed With Sawgrass XF Sublimation Inks – Print Permanence Ratings[1]

Notes on These Tests (continued from previous page):

Table 2. Filtration Conditions Used by Printer, Ink, and Paper Manufacturers with CW Fluorescent Illumination

UV Filter	Glass Filter
Kodak Alaris (for Kodak silver-halide papers and Kodak dye-sub prints)	HP
	Epson
	Canon
	Fuji
	ChromaLuxe
	Ilford
	Canson
	DNP Konica
	Kodak (for Kodak consumer inkjet prints)
	Ferrania
	InteliCoat
	Somerset
	Harman
	LexJet
	Lyson
	Luminos
	Hahnemuhle
	Premier Imaging Products
	American Inkjet
	MediaStreet

gies, pp. 664–669, sponsored by the Society for Imaging Science and Technology, Salt Lake City, Utah, November 2004. Also available, with *color illustrations:* *<www.wilhelm-research.com> <WIR_IST_2004_11_HW.pdf>.* High-intensity light fading reciprocity failures in these tests are assumed to be zero. Illumination conditions in homes, offices, museums, and galleries do vary, however, and color images will last longer when displayed under lower light levels; likewise, the life of prints will be shortened when displayed under illumination that is more intense than 450 lux. Ink and paper combinations that have not reached a fading or color balance failure point after the equivalent of 100 years of display are given a rating of "more than 100 years" until such time as meaningful dark stability data are available (see discussion in No. 5 below).

Eastman Kodak licensed WIR image permanence data for the Kodak line of consumer inkjet printers, and WIR data for these printers was posted on the WIR website (see, for example, *<http://www.wilhelm-research.com/kodak/esp9.html>* WIR's tests with the Kodak consumer inkjet printers are performed using the exact same methodologies employed for all other inkjet printers and other print products posted on the WIR website.

Kodak's internally-developed print permanence test methodologies have been used by the company for many years and the company continues to base its home display-life calculations for Kodak silver-halide (chromogenic) color papers and Kodak dye-sub (thermal dye transfer) prints on 120 lux/12 hours per day, rather than the 450 lux/12 hours per day adopted by WIR. It is important to understand this and other differences between WIR's test methods and Kodak's test methods (see, for example, the article by Charlie Brewer titled "At Least For Ink Jet Print Permanence, WIR and Kodak Mend Fences," *The Hard Copy Supplies Journal,* Lyra Research, Newtonville, MA 02460, March 2008, pp. 1–2. The article is available for download at <http://www.wilhelm-research.com/hc/Kodak-WIR_Permanence2008_03.pdf>). Some of Kodak's display-life predictions for the now-obsolete Kodak Ultima Picture Paper (a swellable inkjet paper designed for dye-based inks) were *almost 15X* longer than the predictions obtained in the more conservative tests conducted by WIR for this ink/media combination, and can be accounted for by differences in the two test methodologies. For example, Kodak uses 80 klux UV-filtered cool white fluorescent illumination; WIR uses 25 klux glass-filtered cool white fluorescent illumination.

Kodak uses a starting density for fading measurements of only 1.0; WIR uses starting densities of both 0.6 and 1.0. Kodak uses the "ISO Illustrative" endpoint criteria set; WIR uses the visually-weighted WIR Endpoint Criteria Set v3.0. Kodak's display environment light exposure assumption for calculating display life is 120 lux for 12 hours per day (UV filtered); WIR uses 450 lux for 12 hours per day (glass filtered). Kodak maintains 50% RH in their accelerated tests; WIR uses 60% RH. Key aspects of Kodak's test methodology and assumptions for calculation of "years of display" are also very different from those used by most other manufacturers of printers, inks, and media. The display lux level assumption of 120 lux (see Table 1) alone makes Kodak's display-life predictions 3.75X greater than the display-life predictions provided by other manufacturers and by WIR.

With many ink/media combinations, Kodak's use of a UV filter instead of the glass filter used by other companies in accelerated light fading tests (see Table 2) further increases Kodak's display-life predictions. For a description of the

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ChromaLuxe Coated Aluminum Photo Panels Printed With Sawgrass XF Sublimation Inks – Print Permanence Ratings[1]

Notes on These Tests (continued from previous page):

Kodak tests, see: D. E. Bugner, C. E. Romano, G. A. Campbell, M. M. Oakland, R. J. Kapusniak, L. L. Aquino, and K. E. Maskasky, "The Technology Behind the New KODAK Ultima Picture Paper – Beautiful Inkjet Prints that Last for Over 100 Years," *Final Program and Advanced Printing of Paper Summaries – IS&T's 13th International Symposium on Photofinishing Technology,* pp. 38–43, Las Vegas, Nevada, February 8, 2004. Together with Kodak's own test data, the articles also include light stability data for Kodak Ultima Picture Paper obtained from ongoing tests conducted by the Image Permanence Institute at the Rochester Institute of Technology (Rochester, New York), and from Torrey Pines Research (Torrey Pines, California). The tests were conducted using the Kodak test procedures and included the use of a UV filter with cool white fluorescent illumination; the Image Permanence Institute and Torrey Pines Research also based print-life calculations on 120 lux for 12 hours per day.

3) In typical indoor situations, the "Displayed Prints Framed Under Glass" test condition is considered the single most important of the three display conditions listed. *All* prints intended for long-term display should be framed under glass or plastic to protect them from staining, image discoloration, and other deterioration caused by prolonged exposure to cigarette smoke, cooking fumes, insect residues, and other airborne contaminants; this precaution applies to traditional silver-halide black-and-white and color photographs, as well as inkjet, dye-sub, and other types of digital prints.

4) Displayed prints framed with ultraviolet filtering glass or ultraviolet filtering plastic sheet generally last longer than those framed under ordinary glass. How much longer depends upon the specific print material and the spectral composition of the illuminate, with some ink/paper combinations benefitting a great deal more than others. Some products may even show reduced life when framed under a UV filter because one of the image dyes or pigments is disproportionately protected from fading caused by UV radiation and this can result in more rapid changes in color balance than occur with the glass-filtered and/or the bare-bulb illumination conditions. For example, if a UV filter protects the cyan and magenta inks much more than it protects the yellow ink in a particular ink/media combination, the color balance of the image may shift toward blue more rapidly than it does when a glass filter is used (in which case the fading rates of the cyan, magenta, and yellow dyes or pigments are more balanced in the neutral scale). Keep in mind, however, that the major cause of fading with most digital and traditional color prints in indoor display conditions is visible light and although a UV filter may slow fading, it will not stop it. For the display permanence data reported here, Acrylite OP-3 acrylic sheet, a "museum quality" UV filter supplied by Cyro Industries, was used.

5) Illumination from bare-bulb fluorescent lamps (with no glass or plastic sheet between the lamps and prints) contains significant UV emissions at 313nm and 365nm which, with most print materials, increases the rate of fading compared with fluorescent illumination filtered by ordinary glass (which absorbs UV radiation with wavelengths below about 330nm). Some print materials are affected greatly by UV radiation in the 313–365nm region, and others very little.

"Gas fading" is another potential problem when prints are displayed unframed, such as when they are attached to kitchen refrigerator doors with magnets, pinned to office walls, or displayed inside of fluorescent illuminated glass display cases in schools, stores, and offices. Field experience has shown that, as a class of media, microporous "instant dry" papers used with dye-based inkjet inks can be very vulnerable to gas fading when displayed unframed and/or stored exposed to the open atmosphere where even very low levels of ozone and certain other air pollutants are present. Resistance to ozone exposure varies considerably, depending on the specific type and brand of dye-based inks and photo paper. In some locations, displayed unframed prints made with certain types of microporous papers and dye-based inks have suffered from extremely rapid image deterioration. This type of premature ink fading is not caused by exposure to light. Polluted outdoor air is the source of most ozone found indoors in homes, offices and public buildings. Ozone can also be generated indoors by electrical equipment such as electrostatic air filters ("electronic dust precipitators") that may be part of heating and air conditioning systems in homes, office buildings, restaurants, and other public buildings to remove dust, tobacco smoke, etc. Electrostatic air filtration units are also supplied as small "tabletop" devices.

Potentially harmful pollutants may be found in combustion products from gas stoves; in addition, microscopic droplets of cooking oil and grease in cooking fumes can damage unframed prints. Because of the wide range of environmental conditions in which prints may be displayed or stored, the data given here will be limited by the "Unprotected Resistance to Ozone" ratings. That is, when ozone resistance tests are complete, in cases where the "Unprotected Resistance to Ozone" predictions are less than the "Display Permanence Ratings" for displayed prints that are NOT framed under glass (or plastic), and are therefore ex-

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ChromaLuxe Coated Aluminum Photo Panels Printed With Sawgrass XF Sublimation Inks – Print Permanence Ratings[1]

Notes on These Tests (continued from previous page):

posed to circulating ambient air, the "Display Permanence Ratings" will be reduced to the same number of years given for "Unprotected Resistance to Ozone" even though the "Display Permanence Rating" for unframed prints displayed in ozone-free air is higher. For all of the reasons cited above, all prints made with microporous papers and dye-based inks should always be displayed framed under glass or plastic. For that matter, ALL displayed prints, regardless of the technology with which they are made, should be framed under glass or plastic sheets. This includes silver-halide black-and-white and color prints, dye-sub prints, and inkjet prints made with dye-based or pigmented inks on swellable or microporous papers, canvas, or other materials.

6) Prints stored in the dark may suffer slow deterioration that is manifested in yellowing of the print paper, image fading, changes in color balance, and physical embrittlement, cracking, and/or delamination of the image layer. These types of deterioration may affect the paper support, the image layer, or both. Each type of print material (ink/paper combination) has its own intrinsic dark storage stability characteristics; some are far more stable than others. Rates of deterioration are influenced by temperature and relative humidity; high temperatures and/or high relative humidity exacerbate the problems. Long-term dark storage stability is determined using Arrhenius accelerated dark storage stability tests that employ a series of elevated temperatures (e.g., 57°C, 64°C, 71°C, and 78°C) at a constant relative humidity of 50% RH to permit extrapolation to ambient room temperatures (or other conditions such those found in sub-zero, humidity-controlled cold storage preservation facilities). Because many types of inkjet inks, especially those employing pigments instead of dyes, are exceedingly stable when stored in the dark, the eventual life of prints made with these inks may be limited by the instability of the paper support, and not by the inks themselves. Due to this concern, as a matter of policy, Wilhelm Imaging Research does not provide a Display Permanence Rating of greater than 100 years for any inkjet or other photographic print material unless it has also been evaluated with Arrhenius dark storage tests and the data indicate that the print can indeed last longer than 100 years without noticeable deterioration when stored at 73°F (23°C) and 50% RH.

Arrhenius dark storage data are also necessary to assess the physical and image stability of a print material when it is stored in an album, portfolio box, or other dark place. The Arrhenius data given here are only applicable when prints are protected from the open atmosphere; that is, they are stored in closed boxes, placed in albums within protective plastic sleeves, or framed under glass or high-quality acrylic sheet. If prints are stored, displayed without glass or plastic, or otherwise exposed to the open atmosphere, low-level air pollutants may cause significant paper yellowing within a relatively short period of time. Note that these Arrhenius dark storage data are for storage at 50% RH; depending on the specific type of paper and ink, storage at higher relative humidities (e.g., 70% RH) could produce significantly higher rates of paper yellowing and/or other types of physical deterioration.

The Sawgrass 8-ink dye-sublimation inks can be used to print on sublimation transfer paper with compatible Mutoh large-format printers, as well as with user-retrofitted Epson 8-color printers.

Compared with Sawgrass 8-color SubliJet-IQ Pro Photo Inks, the Sawgrass 8-color SubliJet Pro Photo XF sublimation inks feature improved-stability black, gray (light black), and light gray (light light black) sublimation inks that provides a substantial increase in permanence, both when prints are exposed to light on display, and when prints are stored in the dark, especially in conditions of high ambient temperatures; however, the long-term dark storage behavior of the ChromaLuxe prints made with Sawgrass XF sublimation inks and stored under commonly-encountered ambient temperature conditions is not yet well understood.

Traditional dye diffusion thermal transfer (D2T2) processes such as that used by Kodak Alaris in its Kodak Picture kiosks (previously known as Kodak Picture Maker kiosks), Sony, DNP, and other letter-size (or A4) or smaller format thermal printers make use of a "thermal ribbon" with dyes in a relatively low-temperature melting point polymer which transfers under head to a specially coated, non-light-sensitive print paper. D2T2 printers are often incorrectly referred to as "dye sublimation printers." It is not possible to conduct Arrhenius tests with D2T2 prints utilizing the elevated oven temperatures normally used in the tests because the highest temperatures are above the melting point of the imaging polymer, and the dyes rapidly diffuse ("bleed") into the surrounding area. The elevated test temperatures are above what is referred to as the Glass Transition Temperature, or Tg, of the dye-containing polymer. However, it does appear possible to employ traditional Arrhenius tests to determine the yellowing of the print paper itself during aging.

Sawgrass 8-color SubliJet Pro Photo XF sublimation inks and other dye sublimation inks used to make ChromaLuxe prints utilize an entirely different thermal imaging technology (there is debate as to whether or not this actually is – technically speaking – a true sublimation process). Currently it is not clear that the

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Notes on These Tests (continued from previous page):

transferred dyes in a ChromaLuxe print actually have a specific glass transition temperature (Tg); no studies have been yet published on this. What is clear, however, is that in Arrhenius tests conducted WIR in the range of 57°C (135°F) to 78°C (173°F), both dye fading and, to some degree, dye diffusion ("bleeding") with the Sawgrass XF sublimation inks. Research on this is continuing at Wilhelm Imaging Research with long-running tests conducted at both 104°F (40°C) and 50°C (122°F) at 50% RH are now in progress. The goal is to determine what the maximum temperature is, that below which, dye fading and/or bleeding no longer occurs. Such a maximum temperature does exist for D2T2 thermal prints.

Until more conclusive information becomes available, it is important to avoid subjecting ChromaLuxe prints to prolonged conditions of high ambient temperatures; that is, do not keep the prints in hot attics or in cars with windows closed in the warm or hot months of summer.

7) Tests for "Unprotected Resistance to Ozone" are conducted with an accelerated ozone exposure test using a SATRA/Hampden Test Equipment Ltd. Model 903 Automatic Ozone Test Cabinet (with the test chamber maintained at 23°C and 50% RH) and the reporting method outlined in: Kazuhiko Kitamura, Yasuhiro Oki, Hidemasa Kanada, and Hiroko Hayashi (Seiko Epson), "A Study of Fading Property Indoors Without Glass Frame from an Ozone Accelerated Test," *Final Program and Proceedings – IS&T's NIP19: International Conference on Digital Printing Technologies,* sponsored by the Society for Imaging Science and Technology, New Orleans, Louisiana, September 28 – October 3, 2003, pp. 415–419.

WIR test methods for ozone resistance are described in: Henry Wilhelm, Kabenla Armah, Dmitriy Shklyarov, Barbara Stahl, and Dimitar Tasev, "A Study of 'Unprotected Ozone Resistance' of Photographs Made with Inkjet and Other Digital Printing Technologies," *Proceedings: Imaging Conference JAPAN 2007, The 99th Annual Conference of the Imaging Society of Japan,* June 6–8, 2007, pp. 137–140. See also: Michael Berger and Henry Wihelm, "Evaluating the Ozone Resistance of Inkjet Prints: Comparisons Between Two Types of Accelerated Ozone Tests and Ambient Air Exposure in a Home," *Final Program and Proceedings: IS&T's NIP20 International Conference on Digital Printing Technologies,* pp. 740–745, sponsored by the Society for Imaging Science and Technology, Salt Lake City, Utah, November 2004. The IS&T article is also available in PDF format from <www.wilhelm-research.com> <WIR_IST_2004_11_MB_HW.pdf>.

8) Changes in image color and density, and/or image diffusion ("image bleeding"), that may take place over time when prints are stored and/or displayed in conditions of high relative humidity are evaluated using a humidity-fastness test maintained at 86°F (30°C) and 80% RH. Depending on the particular ink/media combination, slow humidity-induced changes may occur at much lower humidities – even at 50–60% RH. Test methods for resistance to high humidity and related test methods for evaluating "short-term color drift" in inkjet prints have been under development since 1996 by Mark McCormick-Goodhart and Henry Wilhelm at Wilhelm Imaging Research, Inc. See: Mark McCormick-Goodhart and Henry Wilhelm, "New Test Methods for Evaluating the Humidity-Fastness of Inkjet Prints," *Proceedings of "Japan Hardcopy 2005" – The Annual Conference of the Imaging Society of Japan,* Tokyo, Japan, June 9, 2005, pp. 95–98. Available in PDF format from <www.wilhelm-research.com> <WIR_JapanHardcopy2005MMG_HW.pdf>

See also, Henry Wilhelm and Mark McCormick-Goodhart, "An Overview of the Permanence of Inkjet Prints Compared with Traditional Color Prints," *Final Program and Proceedings – IS&T's Eleventh International Symposium on Photofinishing Technologies,* sponsored by the Society for Imaging Science and Technology, Las Vegas, Nevada, January 30 – February 1, 2000, pp. 34–39. See also: Mark McCormick-Goodhart and Henry Wilhelm, "Humidity-Induced Color Changes and Ink Migration Effects in Inkjet Photographs in Real-World Environmental Conditions," *Final Program and Proceedings – IS&T's NIP16: International Conference on Digital Printing Technologies,* sponsored by the Society for Imaging Science and Technologies, Vancouver, B.C., Canada, October 15–20, 2000, pp. 74–77.

See also: Mark McCormick-Goodhart and Henry Wilhelm, "The Influence of Relative Humidity on Short-Term Color Drift in Inkjet Prints," *Final Program and Proceedings – IS&T's NIP17: International Conference on Digital Printing Technologies,* sponsored by the Society for Imaging Science and Technology, Ft. Lauderdale, Florida, September 30 – October 5, 2001, pp. 179–185; and: Mark McCormick-Goodhart and Henry Wilhelm, "The Correlation of Line Quality Degradation With Color Changes in Inkjet Prints Exposed to High Relative Humidity," *Final Program and Proceedings – IS&T's NIP19: International Conference on Digital Printing Technologies,* sponsored by the Society for Imaging Science and Technology, New Orleans, Louisiana, September 28 – October 3, 2003, pp. 420–425.

9) Data from waterfastness tests are reported in terms of three subjective classes: "high," "moderate," and "low." Both "water drip" tests and "standing water droplets/gentle wipe" tests are employed. See also: Henry Wilhelm (Wilhelm Imaging

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Notes on These Tests (continued from previous page):

Research, Inc.); Richard Adams (Ryerson University); Ken Boydston (MegaVision, Inc.); and Charles Wilhelm (Wilhelm Imaging Research, Inc.): "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," *Technical Program and Proceedings: IS&T NIP33: The 33rd International Conference on Digital Printing Technologies and IS&T Digital Printing for Fabrication 2017,* Denver, Colorado; November 5–9, 2017.

10) Fluorescent brighteners (also called "UV brighteners," "optical brighteners," or "optical brightening agents" [OBA's]) are white or colorless compounds added to the image-side coatings of many inkjet papers – and nearly all "plain papers" – to make them appear whiter and "brighter" than they really are. Fluorescent brighteners absorb ultraviolet (UV) radiation, causing the brighteners to fluoresce (emit light) in the visible region, especially in the blue portion of the spectrum. Fluorescent brighteners can lose activity – partially or completely – as a result of exposure to light. Brighteners may also lose activity when subjected to high temperatures in accelerated thermal aging tests and, it may be assumed, in long-term storage in albums or other dark places under normal room temperature conditions. With loss of brightener activity, papers will appear to have yellowed and to be "less bright" and "less white." In recent years, traditional chromogenic ("silver-halide") color photographic papers have been made with UV-absorbing interlayers and overcoats and this prevents brighteners that might be present in the base paper from being activated by UV radiation. It is the relative UV component in the viewing illumination that determines the perceived "brightening effect" produced by fluorescent brighteners. If the illumination contains no UV radiation (for example, if a UV filter is used in framing a print), fluorescent brighteners are not activated and, comparatively speaking, the paper appears to be somewhat yellowed – and not as "white." This spectral dependency of fluorescent brighteners makes papers containing such brighteners look different depending on the illumination conditions. For example, prints displayed near windows are illuminated with direct or indirect daylight, which contains a relatively high UV component, and if an inkjet paper contains brighteners, this causes the brighteners to strongly fluoresce. When the same print is displayed under incandescent tungsten illumination, which has a low UV component, the brighteners have little effect. Another potential drawback of brighteners is that brightener degradation products may themselves be a source of yellowish stain. These problems can be avoided by not adding fluorescent brighteners to inkjet photographic papers during manufacture. When long-term image permanence is of critical importance – with museum fine art collections, for example – papers with fluorescent brighteners should be avoided where possible.