A Survey of Print Permanence in the 4x6-Inch Consumer Digital Print Market in 2004–2007

Henry Wilhelm, Wilhelm Imaging Research, Inc., Grinnell, Iowa U.S.A.

Abstract

This paper gives an overview of the various factors affecting the display permanence and dark-storage stability of many types of color prints commonly found in the consumer 4x6-inch print market. The similarities and differences between inkjet prints, made with dye-based inks, pigmented inks, dye-sub prints, and traditional silver-halide (chromogenic) color prints are discussed. Print permanence test methods are described for light stability, dark storage stability, ozone resistance, waterfastness, and humidity-fastness. The effects of ozone in polluted air, or "gas-fading" as it has come to be known, is an especially important factor to consider in evaluating the permanence of dye-based inkjet prints made with "instant dry" porous photo papers. In this study, both the Wilhelm Imaging Research "Display Permanence Ratings" and the WIR "Unprotected Ozone Resistance Ratings" were found to cover an extremely wide range – the most stable prints were rated to last more than 200 times longer than the least stable prints.

Introduction

An increasing variety of printing technologies are being used in the rapidly-growing market for prints made from digital camera files. Many consumers are making prints at home with inkjet and dye-sub printers; in retail outlets using digital silver-halide minilabs, dye-sub kiosks, and inkjet kiosks. In Japan, self-service dry-toner electrophotographic printers found in Seven-Eleven convenience stores are another means for making prints from digital cameras. Consumers can also obtain prints by uploading image files to online services that employ high-volume digital silver-halide minilabs, which produce prints that are then mailed to their homes.

Consumers display digitally-printed photographs framed under glass (or display prints unframed and freely exposed to the ambient air) in their homes and offices, post prints on refrigerator doors, and/or place them in albums in the same ways that photographs have always been used. Most consumers consider digital color prints to be "real photographs." They think about them in much the same way they have always thought about photographs, and they have the same high expectations about image permanence.

In terms of the total volume of prints being made in the consumer market, 4x6-inch format prints comprise the largest segment. A variety of compact 4x6-inch dye-sub and inkjet printers have been introduced in recent years for home use. Although 4x6-inch inkjet prints can be made with larger, U.S. letter-size (A4 size) printers, this study focuses on compact 4x6-inch home printers and on the 4x6-inch retail segment. As has been the case in the traditional analog silver-halide photofinishing market of past years, most consumers continue to prefer a glossy surface for their digital prints in the relatively small, 4x6-inch size range.

For the first time in the history of photography, digital era consumers are selecting and purchasing inks and papers for making

Equivalent time of ambient ozone exposure in an accelerated ozone resistance test with Hewlett-Packard Vivera 57+ inks and HP Premium Plus Photo Paper printed with a compact 4x6-inch Hewlett-Packard Photosmart 245 home inkjet printer.

Results of the accelerated ozone resistance test with an Office Depot refilled HP 57 ink cartridge and Office Depot Professional Photo Paper printed with a Hewlett-Packard Photosmart 245 printer. The Office Depot ink and paper were purchased in January 2007.

Results of the accelerated ozone resistance test with a Staples brand refilled HP 57 ink cartridge and Staples Photo Supreme Paper printed with a 4x6-inch Hewlett-Packard Photosmart 245 printer. The Staples ink and paper were purchased in January 2007.

Original Print | 3 Months | 6 Months | 1 Year | 5 Years | 10 Years | 25 Years

Table 1

WIR Print Permanence Ratings for the 4x6-Inch Digital Printer Category in 2004–2007 (Years Before Noticeable Fading and/or Changes in Color Balance Occur)[1]								
Printer/Ink/Photo Paper Printed With Inkjet, Dye-Sub, Silver-Halide Printers	**Displayed Prints Framed Under Glass**[2]	Displayed Prints Framed With UV Filter[3]	Displayed Prints Not Framed (Bare-Bulb)[4]	**Album/Dark Storage Rating at 73°F & 50% RH (incl. Paper Yellowing)**[5]	**Unprotected Resistance to Ozone**[6]	**Resistance to High Humidity**[7]	**Resistance to Water**[8]	**Are UV Brighteners Present?**[9]
HP Photosmart Express (retail inkjet kiosk printer) **HP Vivera pigment inks/HP RPS Photosmart Paper**	**>200 years**	>250 years	102 years	>200 years	>100 years	very high	high	no
Lexmark P350 Portable (4x6-inch inkjet printer) **Lexmark Evercolor 2 pigment inks/PerfectFinish Paper**	**>100 years**	>100 years	now in test	now in test	now in test	very high	high	no
Epson PictureMate (original) (4x6-inch inkjet printer) **Epson PictureMate pigment inks/PictureMate Paper**	**104 years**	124 years	65 years	>200 years	>100 years	very high	high	yes
Epson PictureMate PM-200 (4x6-inch inkjet printer) **Epson PictureMate dye-based inks/PictureMate Paper**	**96 years**	147 years	17 years	>200 years	17 years	now in test	high	no
HP Photosmart 325 and 475 (4x6-inch inkjet printer) **HP Vivera 95 dye-based inks/Premium Plus Photo Paper**	**82 years**	105 years	42 years	>200 years	>100 years	now in test	low	no
HP Photosmart 145 and 245 (4x6-inch inkjet printer) **HP Vivera 57+ dye-based inks/Premium Plus Photo Paper**	**68 years**	77 years	32 years	>200 years	>100 years	now in test	low	no
HP Photosmart A616/A717 (5x7-inch inkjet printer) **HP Vivera 110 dye-based inks/Advanced Photo Paper**	**51 years**	53 years	16 years	>200 years	16 years	now in test	high	no
Canon PIXMA 260 (4x6-inch inkjet printer) **Canon ChromaLife 100 dye-based inks/Photo Paper Pro**	**now in test**	now in test	now in test	>200 years	now in test	now in test	high	no
Canon Selphy DS700 (4x6-inch inkjet printer) **Canon BCI-16 dye-based inks/Photo Paper Pro**	**41 years**	44 years	2 years	>200 years	2 years	now in test	high	no
Fujicolor Crystal Archive (silver-halide color print) **Fuji Frontier 370 minilab/Fuji washless chemicals**	**40 years**	50 years	26 years	>100 years	>100 years	very high	high	no
Kodak PictureMaker (retail kiosk dye-sub printer) **Kodak Xtralife dye-sub printer ribbon and paper**	**26 years**	29 years	10 years	now in test	>100 years	very high	high	no
Kodak EasyShare Printers (4x6-inch dye-sub printer) **Kodak Xtralife 4x6-inch dye-sub printer ribbon and paper**	**26 years**	29 years	10 years	now in test	>100 years	very high	high	no
Dell Photo Printer 540 (4x6-inch dye-sub printer) **Dell 4x6-inch dye-sub printer ribbon and paper**	**26 years**	29 years	10 years	now in test	>100 years	very high	high	no
Fuji Xerox 7/11 (retail kiosk xerographic photo printer) **Fuji Xerox color toner/Fuji Xerox glossy photo paper**	**23 years**	25 years	21 years	now in test	>100 years	very high	high	no
Agfacolor Sensitas (silver-halide color print) **Agfa d-lab.2plus minilab/Agfa washless chemicals**	**22 years**	26 years	14 years	>100 years	>100 years	very high	high	no
Kodak Edge Generations (silver-halide color print) **Noritsu QSS-3011SM minilab/Kodak washless chemicals**	**19 years**	18 years	18 years	>100 years	>100 years	very high	high	no
Sony PictureStation (retail kiosk dye-sub printer) **Sony dye-sub printer ribbon and paper**	**18 years**	28 years est.	13 years	now in test	>100 years	very high	high	no
HP Photosmart 145 and 245 (4x6-inch inkjet printer) **HP 57 dye-based inks/HP Premium Plus Photo Paper**	**18 years**	20 years	15 years	>200 years	>100 years	now in test	low	no
Konica Minolta Impressa (silver-halide color print) **Konica R2 Super 1000 minilab/Konica washless chemicals**	**17 years**	19 years	16 years	>100 years	>100 years	very high	high	no
Lexmark SnapShot P315 (4x6-inch inkjet printer) **Lexmark 33 dye-based inks/Lexmark Premium Photo Paper**	**16 years**	18 years	10 years	>200 years	now in test	now in test	low	no
***HP Photosmart 145 and 245** (4x6-inch inkjet printer) **HP 57 dye-based inks/Kodak "100 Year" Ultima Picture Paper**	**11 years**	13 years	10 years	now in test	>100 years	now in test	low	no
Sony DPP-FP55 PictureStation (4x6-inch dye-sub printer) **Sony 4x6-inch dye-sub printer ribbon and paper**	**10 years**	18 years	6 years	now in test	>100 years	very high	high	no
Olympus P-10 Printer (4x6-inch dye-sub printer) **Olympus 4x6-inch dye-sub printer ribbon and paper**	**8 years**	10 years	6 years	now in test	>100 years	very high	high	no
Canon CP500 Printer (4x6-inch dye-sub printer) **Canon 4x6-inch dye-sub printer ribbon and paper**	**7 years**	9 years	6 years	now in test	>100 years	very high	high	no
Sony DPP-FP30 PictureStation (4x6-inch dye-sub printer) **Sony 4x6-inch dye-sub printer ribbon and paper**	**6 years**	6 years	5 years	now in test	>100 years	very high	high	no
***HP Photosmart 145 and 245** (4x6-inch inkjet printer) **Staples refilled HP 57 ink cartridge/Photo Supreme Paper**	**3 years**	3 years	3 months	now in test	3 months	now in test	high	no
***HP Photosmart 145 and 245** (4x6-inch inkjet printer) **OfficeMax refilled HP 57 ink cartridge/Professional Photo Paper**	**2 years**	2 years	2 months	now in test	2 months	now in test	high	no
***HP Photosmart 145 and 245** (4x6-inch inkjet printer) **Office Depot refilled HP 57 ink cartridge/Professional Paper**	**4 months**	4 months	2 months	now in test	2 months	now in test	high	yes

***Note:** Products listed with an "*" have been tested with non-recommended, third-party inks and/or papers and do not represent the performance of OEM inks and papers supplied by that printer's manufacturer.

color prints themselves at home. For many of these products, no print permanence data of any kind are available and the consumer does not know how long a print made with a specific ink/paper combination or a dye-sub print might last – or how the permanence of one product compares with that of another.

The print permanence data presented here are based in part on predictive test methods developed over the past 30 years by Wilhelm Imaging Research. Table 1 gives test results for 28 different products in the 4x6-inch consumer print category. Included in the table are inkjet prints made with dye-based and pigmented inks, silver-halide color prints, dye-sub prints, and a xerographic color photographic process. These products were available in the marketplace from 2004 through January 2007. Countless millions of prints made with these materials are displayed and stored by consumers throughout the world.

As can be seen in Table 1, the WIR Display Permanence Ratings of these products vary over an extremely wide range. For example, pigmented inkjet prints made with a Hewlett-Packard Photosmart Express retail kiosk were rated more than 200 times longer lasting than prints made with Office Depot store-brand ink in refilled HP 57 ink cartridges printed with Office Depot Professional Photo Paper. The Display Permanence Rating of Staples store-brand refilled HP 57 cartridges and Staples Photo Supreme paper was also very poor. As shown in Table 1 and in the accompanying illustrations, the ozone resistance of the Office Depot ink and paper combination was also found to be extremely poor. Both the Staples and Office Depot refilled HP 57 ink cartridges and photo papers were purchased in January 2007 and were the highest-quality and most expensive store-branded products available at the two stores. The HP Vivera 57+ inks and HP Premium Plus Photo Paper were the highest quality, most expensive HP inks and photo paper available for the Photosmart 245 printer at the time this article was written in January 2007.

Epson, Hewlett-Packard, and Lexmark now manufacture inkjet printers, inks and photo papers for home printing that have higher WIR Display Permanence Ratings than traditional silver-halide color prints. Kodak was found to have the longest-lasting dye-sub prints of those tested in that category. Fujicolor Crystal Archive prints had the highest Display Permanence Rating among silver-halide color prints made with digital minilabs and available from retail outlets and online print providers; all of the silver-halide prints tested had excellent ozone resistance.

As with the products tested for Display Permanence Ratings, the WIR Unprotected Ozone Resistance Ratings were found to vary over an extremely wide range; pigmented inkjet, silver-halide, and most dye-sub prints rated more than 200 times longer-lasting than the Staples and Office Depot refilled inks printed with their respective store-brand photo papers.

How the Prints Were Tested

To obtain a comprehensive evaluation of the permanence of any type of photograph – both traditional and digital prints – they must be tested for their resistance to all factors that can cause deterioration. These factors include exposure to light on display, and storage in albums or other locations away from light.[1] Included are accelerated light fading tests ("WIR Display Permanence Rating Tests") for prints framed under glass,[2] framed with UV absorbing glass or plastic,[3] or displayed without framing under glass or plastic.[4] Prints are also tested for permanence in dark storage, or "thermal stability" at a specified relative humidity ("Album/Dark Storage Rating Tests").[5] These tests utilize the Arrhenius test method long employed by Kodak, Fuji, and others in the photographic industry. The WIR Visually-Weighted Endpoint Criteria Set v3.0 was used as the basis for predictions made for prints stored at 23°C (73°F) and 50% RH.

Many display and storage environments have levels of ambient ozone in the air that are sufficient to harm prints exposed to the open air over time. This is especially the case for certain types of dye-based inks printed on "instant-dry" porous papers. A test for "Unprotected Resistance to Ozone"[6] is provided; years of exposure ratings are based on an Epson study, which indicated that exposure to 40 ppm of ozone for one hour is equal to 1 year of unprotected display or storage in areas with relatively high levels of ozone pollution. (Refer to images on the first page of this article for a graphic portrayal of the comparative ozone resistance of three ink/paper combinations printed with an HP Photosmart 245 printer.)

Also of concern is the resistance of prints to changes in color and/or density as a result of exposure to high humidity.[7] In addition, some types of prints are very susceptible to damage from even momentary contact with water.[8]

Although work has been underway for a number of years to develop a comprehensive group of ISO print permanence tests, including predictive light stability tests, dark storage tests, ozone resistance tests, and humidity-fastness ranking tests, methods and specifications standards for these tests had not yet been published at the time this article was written in January 2007.

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Notes and References

[1] Wilhelm Imaging Research Display Permanence Ratings are based on accelerated light stability tests conducted at 35 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 under the standardized conditions of these tests. 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: <www.wilhelm-research.com> <Wilhelm_IS&T_Paper_Feb_2002.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 Technologies,* 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 fad-

ing 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).

[2] 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.

[3] 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.

[4] 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 exposed 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.

[5] 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.

[6] 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 ozone concenration in the accelerated test set at 5 ppm) 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: 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. Also available in PDF format from <www.wilhelm-research.com> <WIR_IST_2004_11_MB_HW.pdf>.

[7] 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 30°C (86°F) and 85% 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_Japan Hardcopy2005MMG_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.

[8] 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.

[9] 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.

Author Biography

Henry Wilhelm was one of the founding members of American National Standards Institute (ANSI) Committee IT-3, which was established in 1978 and developed the ANSI IT9.9-1990 image stability test methods standard published in 1990 (revised in 1996). For the past 20 years he has served as Secretary of the group, now known as ISO Working Group 5/Task Group 3 (a part of ISO Technical Committee 42). Wilhelm serves as Chair of the Indoor Light Stability Test Methods Technical Subcommittee of WG-5/TG-3.

Wilhelm has been a consultant to many collecting institutions, including the Museum of Modern Art in New York, on various issues related to the display and preservation of both traditional photographic prints and digital print media. Since 1995, he has been an advisor to Corbis on the long-term preservation of the Corbis Bettmann photography collections in a high-security underground storage facility to be maintained at minus 20 degrees C (minus 4 degrees F) and 35% RH. With more than 65 million images, it is one of the world's largest privately held photography collections. Corbis is a private corporation owned by Bill Gates.

In 1966 Wilhelm served as an assistant to Ansel Adams in one of Adams's photography workshops in Yosemite National Park in California. Discussions with Adams further increased Wilhelm's interest in the long-term preservation of photographs. In 1972 he received the first of two U.S. Patents for the design of archival washers for black-and-white fiber base prints. In the early 1980's, Wilhelm served as volunteer technical advisor to film director Martin Scorsese in his successful efforts to persuade motion picture film manufacturers to improve the dark storage permanence of their products and to promote cold-storage technology for the preservation of color and black-and-white motion picture films.

Wilhelm received a one-year Guggenheim Fellowship in 1981 for what became a ten-year study of color print fading and staining under low-level tungsten illumination that simulates museum display conditions.

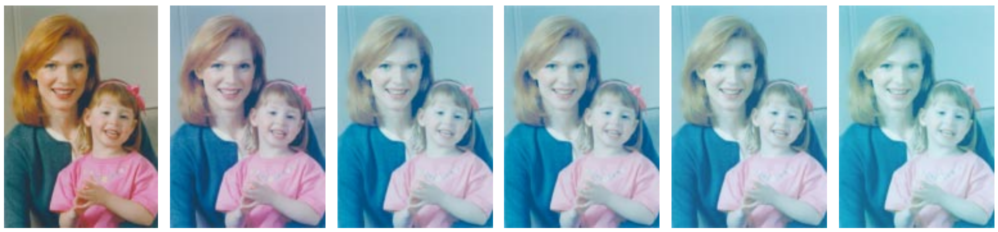
With contributing author Carol Brower Wilhelm, he wrote "The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures," published in 1993. The complete 758-page book is available in PDF form at no cost from <www.wilhelm-research.com>.

Wilhelm is the recipient of the Photoimaging Manufacturers and Distributors Association (PMDA) "2007 Lifetime Achievement Award" for his work on the preservation of photographs and motion pictures.

Wilhelm Imaging Research Display Permanence Rating Tests (Glass-Filtered) with Hewlett-Packard Vivera 57+ Inks And HP Premium Plus Photo Paper, Staples and Office Depot Refilled HP #57 Ink Cartridges and Photo Papers

Predicted years of display in a WIR indoor light stability test with Hewlett-Packard Vivera 57+ inks and HP Premium Plus Photo Paper printed with a compact 4x6-inch Hewlett-Packard Photosmart 245 home inkjet printer.

Predicted years of display in a WIR indoor light stability test with an Office Depot refilled HP 57 ink cartridge and Office Depot Professional Photo Paper printed with a Hewlett-Packard Photosmart 245 printer. The Office Depot ink and paper were purchased in January 2007.



Predicted years of display in a WIR indoor light stability test with a Staples refilled HP 57 ink cartridge and Staples Professional Photo Paper printed with a Hewlett-Packard Photosmart 245 printer. The Staples ink and paper were purchased in January 2007.

Original Print | 2 Years | 5 Years | 7.5 Years | 10 Years | 15 Years

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Note: The progressive pictorial light fading comparison reproduced above was not available in time to be included in the IS&T paper, however it was shown as part of the presentation given at the IS&T TDF Symposium in Las Vegas, Nevada on March 5, 2007.

Paper by Henry Wilhelm (Wilhelm Imaging Research, Inc.) entitled:

"A Survey of Print Permanence in the 4x6-Inch Consumer Digital Print Market in 2004–2007"

Paper presented by Henry Wilhelm on March 5, 2007

Paper published on pages 43–47 in:

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Note: Accelerated print permanence tests for some of the products reported in Table 1 were still in progress at the time the initial version of this paper was submitted to IS&T prior to the Symposium. Additional data had become available by the time the paper was presented on March 5, 2007 and Table 1 was updated to include these new data points. This version of the paper, including the illustrations on page 43 and Table 1 on page 44, are reproduced here exactly as presented at the Symposium.

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7003 Kilworth Lane
Springfield, Virginia 22151 U.S.A.
Phone: 703-642-9090; Fax: 703-642-9094
www.imaging.org (e-mail: info@imaging.org)