A Study of "Unprotected Ozone Resistance" of Photographs Made With Inkjet and Other Digital Printing Technologies

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Abstract: Ozone fading (or "gas fading" as it is sometimes called) is a potential cause of image deterioration with unframed digitally-printed photographs when the prints 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. This paper discusses the effects of various relative humidity levels on the rate of ozone-induced image deterioration. Included are image stability data for a selection of "off-brand" or "third-party" dye-based inks and photo papers along with OEM products. Also discussed are differences between current densitometric analysis of fading, changes in color balance, and staining with the evaluation of print deterioration using the WIR i-Star full tonal scale colorimetric "retained image appearance" method. The WIR i-Star metric evenly weights color and tonal changes that occur anywhere along the full color and tonal scale of the image, whether the changes are manifested as fading, staining, darkening, hue shift, and/or increase or decrease in chroma (including human skin colors, which are an important part of most consumer photographs).

Introduction

Experience with prints displayed in consumer's homes and apartments has shown that, as a general class of prints, microporous "instant dry" inkjet papers printed with dye-based inks can be very vulnerable to gas fading when unframed prints are displayed 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 (framing a print under glass or plastic sheet usually protects it from ozone exposure). However, as shown in the illustrations to the right, light can also cause fading and color balance changes that are similar in appearance to that resulting from exposure to ozone. When prints are displayed unframed, the fading effects of light and ozone can be cumulative. Polluted outdoor air is the source of most of the ozone found indoors in

Equivalent years of exposure to light in home display at 450 lux for 12 hours per day in an accelerated light stability test (print framed under glass, 24°C and 60% RH) with Epson DURABrite Ultra pigment inks and Epson Premium Glossy Photo Paper printed with an Epson Stylus C87/C88 inkjet printer. The Epson inks and paper have a WIR Display Permanence Rating of 40 years.

Equivalent years of exposure to light in home display at 450 lux for 12 hours per day in an accelerated light stability test (print framed under glass, 24°C and 60% RH) with third-party Calidad brand "pigment" inks and Calidad Inkjet Glossy Photo Paper printed with an Epson Stylus C87/C88 inkjet printer. The Calidad inks have extremely poor light stability, with a WIR Display Permanence Rating of less than 1 year.

Original Print　2 Years

Equivalent years of ambient ozone exposure in an accelerated unprotected ozone resistance test (5 ppm ozone, 23°C and 50% RH) with Epson DURABrite Ultra pigment inks and Epson Premium Glossy Photo Paper printed with an Epson Stylus C87/C88 inkjet printer.

Equivalent years of ambient ozone exposure in an accelerated unprotected ozone resistance test with third-party Calidad brand "pigment" inks and Calidad Inkjet Glossy Photo Paper printed with an Epson Stylus C87/C88 inkjet printer. The Calidad inks and paper were purchased in Australia in February 2007.

Original Print　1 Year　5 Years　10 Years　25 Years　50 Years

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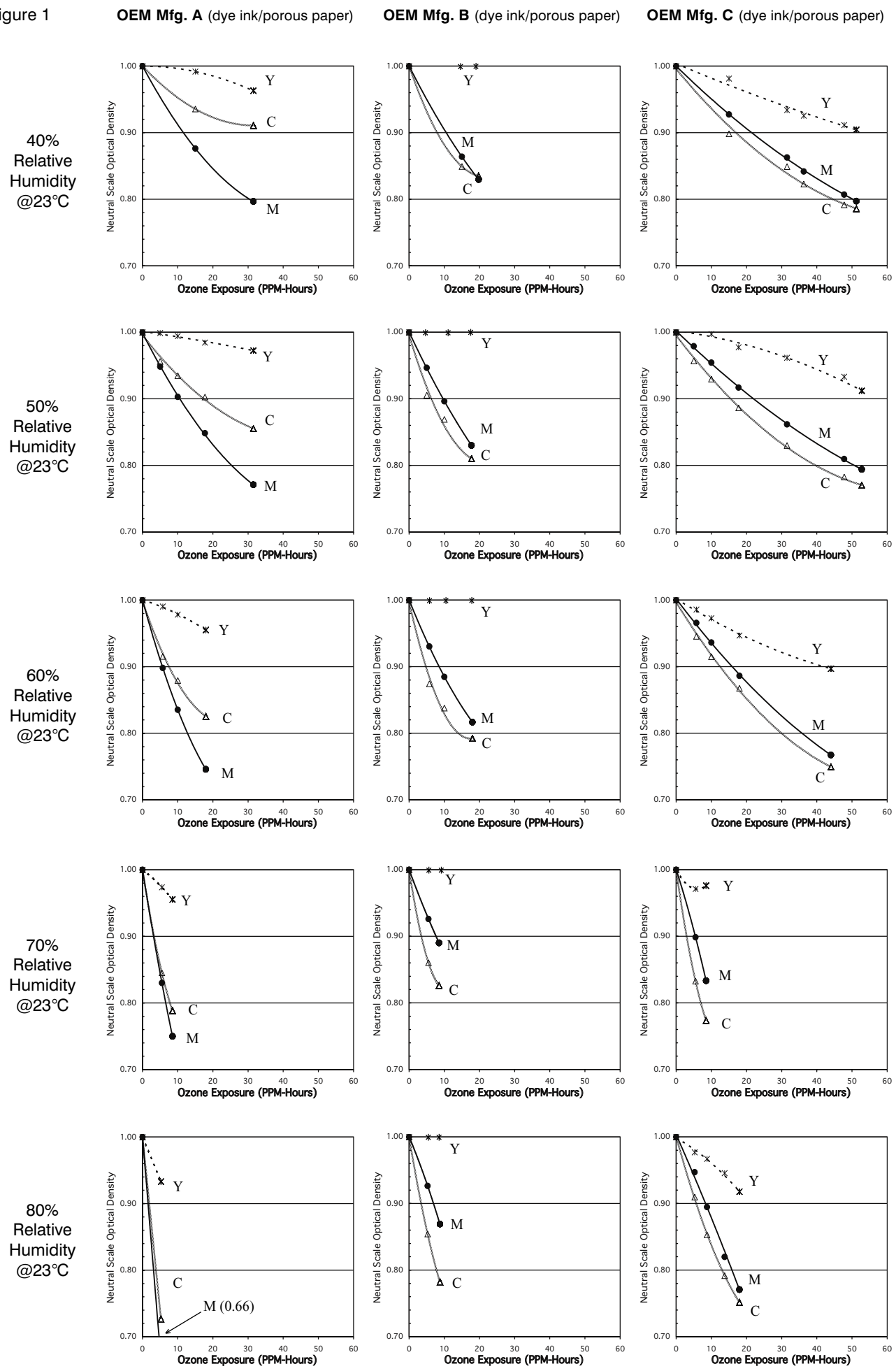
Figure 1



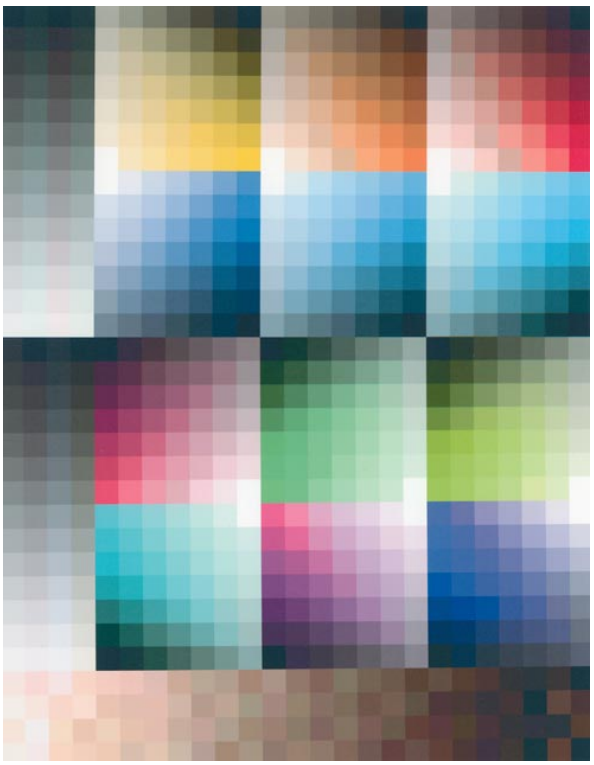


Fig. 2 WIR i-Star generic sRGB test target printed with an Epson C87/88 printer using non-OEM Calidad "pigment" inkjet inks and porous Calidad glossy photo paper.

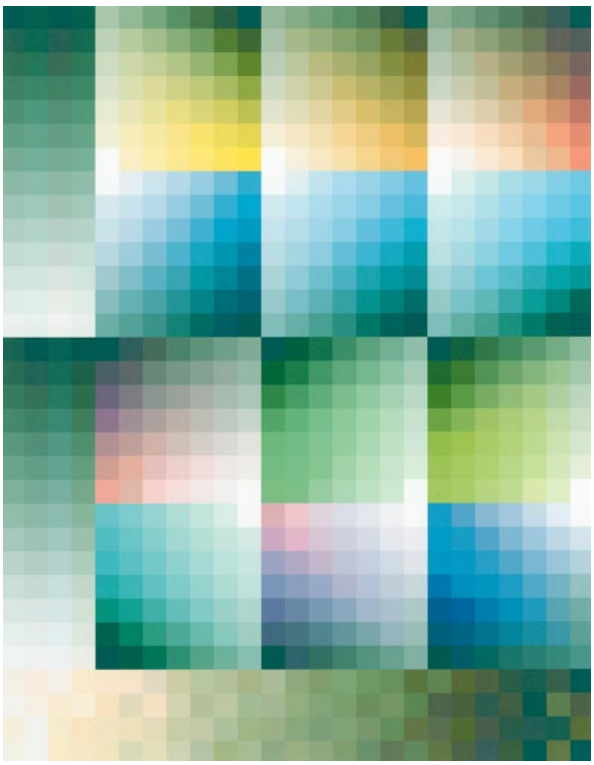


Fig. 3 The same target as shown in Fig. 2 after the equivalent of 10 years unprotected exposure to ambient ozone. Note the pronounced loss of the magenta ink.

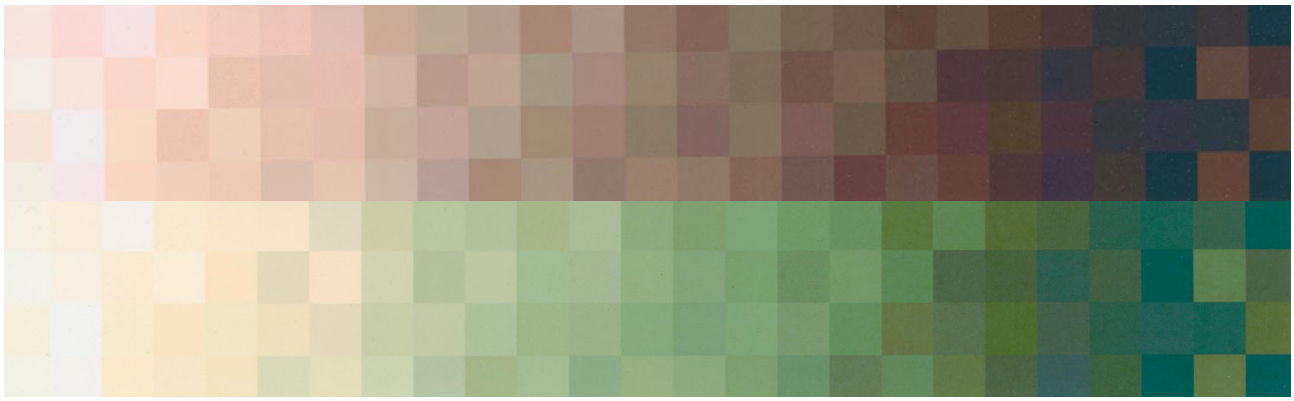


Fig. 4 A comparision between the general skintone sections of the above WIR i-Star test targets, before and after the ozone test. The fading of the Calidad magenta ink was non-linear as a function of initial density levels (L*). The percent retention of initial color (green lines) and tonescale (black line) are plotted in the WIR i-Star graph below (see Reference 3).

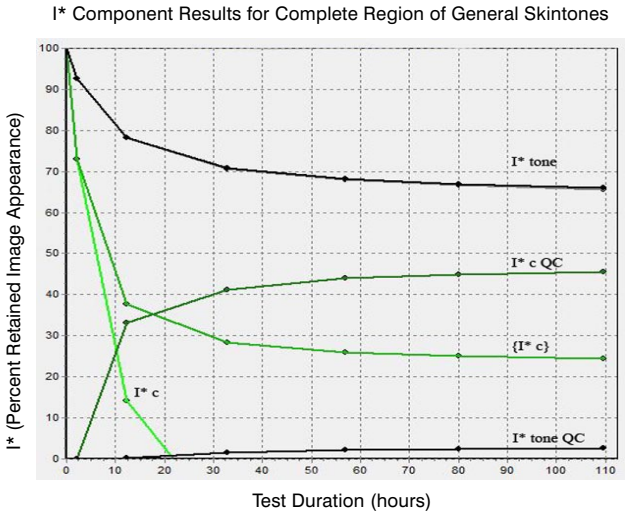


Fig. 5 WIR i-Star graph showing color and tonescale changes in the skintone region of the test target.

homes, offices and public buildings. Ozone can also be generated indoors by electrical equipment such as electrostatic air filters. The tests described in this paper 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 level measured by a Horiba Ambient Ozone Monitor APOA-360).

Predicted "years of exposure" are based on the first endpoint to be reached in the WIR Visually-Weighted Endpoint Criteria Set v3.0.[1] An ambient ozone exposure assumption of 40 ppm/hours equals one year is based on the study reported in a 2003 paper by Kazuhiko Kitamura, Yasuhiro Oki, Hidemasa Kanada, and Hiroko

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)

Printer/Ink/Photo Paper Printed With Inkjet, Dye-Sub, Silver-Halide Printers	Displayed Prints Framed Under Glass	Unprotected Resistance to Ozone
HP Photosmart Express (retail inkjet kiosk printer) HP Vivera pigment inks/HP RPS Photosmart Paper	>200 years	>100 years
Lexmark P350 Portable (4x6-inch inkjet printer) Lexmark Evercolor 2 pigment inks/PerfectFinish Paper	>100 years	now in test
Epson PictureMate (original) (4x6-inch inkjet printer) Epson PictureMate pigment inks/PictureMate Paper	104 years	>100 years
Epson PictureMate PM-200 (4x6-inch inkjet printer) Epson PictureMate dye-based inks/PictureMate Paper	96 years	17 years
HP Photosmart 325 and 475 (4x6-inch inkjet printer) HP Vivera 95 dye-based inks/Premium Plus Photo Paper	82 years	>100 years
HP Photosmart 145 and 245 (4x6-inch inkjet printer) HP Vivera 57+ dye-based inks/Premium Plus Photo Paper	68 years	>100 years
HP Photosmart A616/A717 (5x7-inch inkjet printer) HP Vivera 110 dye-based inks/Advanced Photo Paper	51 years	16 years
Canon PIXMA 260 (4x6-inch inkjet printer) Canon ChromaLife 100 dye-based inks/Photo Paper Pro	now in test	now in test
Canon Selphy DS700 (4x6-inch inkjet printer) Canon BCI-16 dye-based inks/Photo Paper Pro	41 years	2 years
Fujicolor Crystal Archive (silver-halide color print) Fuji Frontier 370 minilab/Fuji washless chemicals	40 years	>100 years
Kodak PictureMaker (retail kiosk dye-sub printer) Kodak Xtralife dye-sub printer ribbon and paper	26 years	>100 years
Kodak EasyShare Printers (4x6-inch dye-sub printer) Kodak Xtralife 4x6-inch dye-sub printer ribbon and paper	26 years	>100 years
Dell Photo Printer 540 (4x6-inch dye-sub printer) Dell 4x6-inch dye-sub printer ribbon and paper	26 years	>100 years
Fuji Xerox 7/11 (retail kiosk xerographic photo printer) Fuji Xerox color toner/Fuji Xerox glossy photo paper	23 years	>100 years
Agfacolor Sensitas (silver-halide color print) Agfa d-lab.2plus minilab/Agfa washless chemicals	22 years	>100 years
Kodak Edge Generations (silver-halide color print) Noritsu QSS-3011SM minilab/Kodak washless chemicals	19 years	>100 years
Sony PictureStation (retail kiosk dye-sub printer) Sony dye-sub printer ribbon and paper	18 years	>100 years
HP Photosmart 145 and 245 (4x6-inch inkjet printer) HP 57 dye-based inks/HP Premium Plus Photo Paper	18 years	>100 years
Konica Minolta Impressa (silver-halide color print) Konica R2 Super 1000 minilab/Konica washless chemicals	17 years	>100 years
Lexmark SnapShot P315 (4x6-inch inkjet printer) Lexmark 33 dye-based inks/Lexmark Premium Photo Paper	16 years	>100 years
***HP Photosmart 145 and 245** (4x6-inch inkjet printer) HP 57 dye-based inks/Kodak "100 Year" Ultima Picture Paper	11 years	>100 years
Sony DPP-FP55 PictureStation (4x6-inch dye-sub printer) Sony 4x6-inch dye-sub printer ribbon and paper	10 years	>100 years
Olympus P-10 Printer (4x6-inch dye-sub printer) Olympus 4x6-inch dye-sub printer ribbon and paper	8 years	>100 years
Canon CP500 Printer (4x6-inch dye-sub printer) Canon 4x6-inch dye-sub printer ribbon and paper	7 years	>100 years
Sony DPP-FP30 PictureStation (4x6-inch dye-sub printer) Sony 4x6-inch dye-sub printer ribbon and paper	6 years	>100 years
***HP Photosmart 145 and 245** (4x6-inch inkjet printer) Staples refilled HP 57 ink cartridge/Photo Supreme Paper	3 years	3 months
***HP Photosmart 145 and 245** (4x6-inch inkjet printer) OfficeMax refilled HP 57 ink cartridge/Professional Photo Paper	2 years	2 months
***HP Photosmart 145 and 245** (4x6-inch inkjet printer) Office Depot refilled HP 57 ink cartridge/Professional Paper	4 months	2 months

***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.

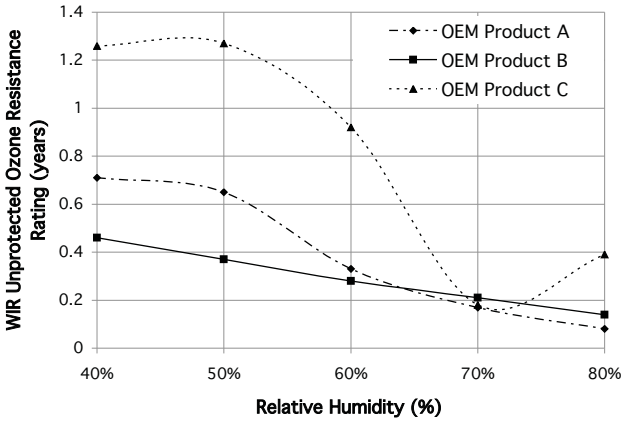


Fig. 6 The relative humidity of the environment can have a major impact on the rate of ozone fading and both the magnitude and changes in color balance vary depending on the product. The individual CMY fading curves for these three OEM dye ink and porous paper combinations are shown in Fig. 1. Elevated temperature can also increase the rate of ozone fading. Based on these studies, the author recommends 60% RH and 28°C for ozone resistance tests.

Hayashi of Seiko Epson.[2] See Table 1 for display permanence (light stability) and ozone resistance ratings for prints made with dye-based inks and microporous papers; dye-based inks and swellable papers; pigmented ink and microporous papers; silver-halide color prints; dye-sub prints; and xerographic color prints.

Current densitometric endpoint criteria sets such as WIR v3.0 and the non-visually weighted "Illustrative" endpoint criteria set included in ISO 18909 do not allow evaluation of the full range of colors and tones found in photographs. Nor do these endpoint criteria sets include human skintones or "near neutral" colors. These deficiencies can result in poor psychophysical correlation and product ranking between various products and printing technologies. The WIR i-Star retained image appearance evaluation method was developed to provide improved correlation to observed fading, color shifts, tonescale changes, and stain formation in photographic images.[3]

References

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2) Kazuhiko Kitamura, Yasuhiro Oki, Hidemasa Kanada, and Hiroko Hayashi, "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*, September 28 – October 3, 2003, pp. 415–419.
3) Mark McCormick-Goodhart, Henry Wilhelm, and Dmitriy Shklyarov, "A 'Retained Image Appearance' Metric for Full Tonal Scale, Colorimetric Evaluation of Photographic Image Stability," *Final Program and Proceedings – IS&T's NIP20: International Conference on Digital Printing Technologies*, October 31 – November 5, 2004, pp. 680–688.

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