Simulating Accelerated Commercial In-Window Display: Predicted print longevity for pigment ink systems on a range of media types

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Abstract

The digital printing industry has largely adopted a standard approach to predicting print life for nominal indoor conditions (i.e. no direct sunlight, potentially glass-covered print). However, currently there is no standard calculation method in wide use for Indoor, "In-Window" display longevity estimates. The actual location of the print could be directly in contact with the window, or near the window (within a meter or two); what these "In-Window" displays have in common is a very high average light intensity—with cyclic exposure—and strong UV spectral component. Thus, simulation methods need to address these conditions.

The accelerated light exposure used in this investigation used high intensity Xenon Arc illumination, with a cycled dark / light exposure at controlled temperatures and humidities using a commercially-available device. Inkjet media substrates included nanoporous photo paper, coated paper, "photorag", and inkjet-coated canvas; the effect of lamination was also examined. A range of pigment-ink printers were used to generate the prints.

Based on an earlier survey by one of the authors of actual commercial in-window display environments in Southern California, a 12-hour average lux assumption of 6,000 lux was used to convert the simulated exposure optical density loss data to a predicted lifetime in 'year or month' units. As expected, the results were significantly lower than the predicted lifetimes based on the nominal indoor lifetime estimates based on 450 lux / 12-hour average assumption. Different pigment ink systems showed very different levels of fade resistance; lamination was found to potentially increase resistance to fading by a significant factor.

Introduction

The purpose of this study was to evaluate the performance of a range of inkjet media and pigment inkjet printers in a simulated and accelerated Indoor commercial window display environment. The study focused on digitally produced inkjet prints, with the goal of characterizing the performance of these inkjet solutions in a commercial or store-front window display, where an actual print would be exposed to indirect and direct sunlight. This accelerated simulation differs from much of the historical Indoor print life longevity methodology and claims, in that the goal is to understand the behavior of these systems in a harsher commercial window display environment, where samples are exposed to significant amounts of Ultraviolet (UV) and Infrared (IR) wavelength natural daylight.

The study used commercially available filtered-Xenon arc test equipment at Q-Lab, Corporation. The samples were exposed to elevated levels of Xenon Arc illumination, cycling between light (light on) and dark (light off) exposure, to simulate day and night; cyclic changes in temperature and humidity were also included in the accelerated in-window simulation.

Currently, there is no standard indoor "in-window" industry test method that specifies accelerated equipment requirements, test simulation set points / parameters, assumptions and calculations to communicate meaningful "print display longevity estimates" to end users. However, there are a handful of standard methods that do exist for accelerated xenon apparatus requirements, as well as sample preparation and conditioning; nevertheless, these are not all-encompassing nor designed for this industry and subsequent technologies. Thus, in this study HP has used a cyclic Xenon Arc illumination program to attempt to simulate the typical exposure a printed sample would be subjected to in an actual commercial or store window display. This paper will document how the test was performed, the samples included, assumptions used during the data analysis and the results of the study.

The Xenon Arc light source has been shown to replicate well the spectral power distribution of natural daylight; thus, the often harsher UV and IR sections of the light spectrum are also included. The Xenon Arc test chamber was used to replicate exposure of samples to daylight with both direct and indirect sunlight as an actual print would be exposed to when it is displayed in or near a commercial window, in an indoor environment.

The primary sample focus of this study was to evaluate pigment inkjet technology on a range of inkjet coated media substrates. Media substrates included inkjet-coated: porous photo papers, coated papers, digital fine art canvas material and digital fine art paper. Approximately 20 unique inkjet systems (printer/ink/media) were included in this study (primarily HP pigment inkjet systems and several competitive pigment inkjet systems). Three of the unique systems were also laminated to evaluate any impact film and/or liquid lamination could have on the print life longevity estimates for Indoor In-Window Light Stability.

The In-window print life longevity estimate calculations were based on a 6klux per 12 hr day light exposure assumption and using the Wilhelm Imaging Research, Inc. Endpoint Failure Criteria Set v3.0. This end point failure criteria set is based on densitometry changes over time, and signifies once a print has reached a point of "just noticeable fade"[3].

Equipment

Samples were exposed in the Q-Sun XE-3-HC and Q-Sun XE-3-H devices; the "C" designation represents the addition of a "chiller" component retrofitted onto the Xenon chamber in order to achieve the desired lower temperatures during some of the exposure cycle. The Q-Sun Xenon unit (manufactured by Q – Lab Corporation) is compliant with ASTM G155 and the following parameters are controlled by the system: Black Panel Temperature (BPT), Air temperature: ± 3 °C (or 5% target); Relative Humidity: RH: ± 5%; and Irradiance: ≤ 10% IRR (from center to edge of sample plane);

All 32 samples (per Xenon chamber) were adhered to a 1mm (thick) powder coated Aluminum sample holder, with solid backing (per ASTM G155). Replicates of each unique system were placed within a single chamber and also a few in both machines to evaluate both intra – and cross – machine reproducibility as well as the impact of the chiller, or a lower BPT, on light stability longevity predictions.

Sample Preparation

The print samples, or "print targets" consisted of 4 color ramps, Cyan, Magenta, Yellow and Black. Each color ramp is a step-wise increase in optical density. The color ramps included patches with lower initial optical densities and higher optical densities [approximate ranges: 0.3 – 2.2]; the ramp is intended to capture the different inkjet systems colorant capabilities used in creating a digital print. A white square (non-imaged, "dmin" or the lowest density spot on the media sample) is also included in the print target analysis to evaluate any substrate changes over time.

All samples were printed by Hewlett-Packard, San Diego and sent to Q – Lab, Florida's testing facility where the samples were conditioned in a climate controlled room (23 °C / 50% RH) according to ASTM G147 with minimum air movement and free from direct sunlight for at least 4 hours prior to the first measurement with a Gretag Macbeth Spectroscan/Spectrolino. Q-Lab repeatedly measured and exposed the samples for predetermined exposure intervals, and sent the data to HP for analysis. The cumulative exposure was recorded for each interval in terms of "cumulative machine hours" [hours] and "cumulative exposure", in units of "X watts per square meter * hours" [W/m² -hr].

Testing Conditions

The addition of the chiller component allows the Q-Sun XE-3HC to achieve a lower Black Panel Temperature (BPT), as requested in the dark cycle when the humidity and air temperature naturally raise the BPT. The BPT is the "assumed temperature on the sample surface", although this assumption is open to further improvement. The test chambers were located in a climate-controlled laboratory, and all samples were measured in a climate-controlled room per TAPPI conditions.

The following tables define the test set up for each respective Xenon Arc chamber.

Table I. Q-Sun XE-3-HC (includes chiller): Cycling Conditions for Indoor Light Stability – Commercial Window Display Test (100 Klux)

Exposure Conditions	Light Cycle	Dark Cycle
Light/Dark cycle duration [=] hrs	3.8	1.0
Chamber Air Temperature [=] ° C	40 ± 5	25 ± 5 (with chiller)
Chamber Relative Humidity [=] % RH	40 ± 10	70 ± 5
Black Panel Temperature [=] ° C	65 ± 10	25 ± 5 (with chiller)
Filter Type	Window – B/SL with UV cut off at 300 nm	Window – B/SL with UV cut off at 300 nm
Light Source	Air cooled Xenon Arc 1800 Watt	"off"
Irradiance [=]	1.10 W/m^2 @ 420 nm (equivalent to 100klux)	0
Water spray duration [=] hrs	None	None

Table II. Q-Sun XE-3-H (no chiller): Cycling Conditions for Indoor Light Stability – Commercial Window Display Test (100 Klux)

Exposure Conditions	Light Cycle	Dark Cycle
Light/Dark cycle duration [=] hrs	3.8	1.0
Chamber Air Temperature [=] ° C	40 ± 5	40 ± 2 (without chiller)
Chamber Relative Humidity [=] % RH	40 ± 10	70 ± 5
Black Panel Temperature [=] ° C	65 ± 10	40 ± 2 (without chiller)
Filter Type	Window – B/SL with UV cut off at 300 nm	Window – B/SL with UV cut off at 300 nm
Light Source	Air cooled Xenon Arc 1800 Watt	"off"
Irradiance [=]	1.10 W/m^2 @ 420 nm (equivalent to 100klux)	0
Water spray duration [=] hrs	None	None

Note: At the initialization of the test, new lamps were installed and all sensors recalibrated.

Due to the spectral power distribution (SPD) of Xenon illumination and the desire to replicate the actual SPD of daylight it is necessary to use a filter to achieve the desired ‘daylight through window glass’ spectrum. The “Window B/SL” (Boro-Silicate) meets the ASTM requirement for “sunlight for window glass” with a cut-off at 300nm.

Finally, unlike traditional Cool White Fluorescent testing which has often been used for Indoor (home) Light Stability print life estimates, Xenon light sources cannot be optimally controlled or calibrated using “lux”. “Lux” cannot read the UV region (wavelengths below the visible region of 400 nm) and since many materials are most susceptible to degradation in the UV region, Irradiance is used to do accurate measurements in the 300-400nm range. Thus, this study was controlled at 1.10 W/m^2 at 420nm which has been shown to be approximately equivalent to 100 klux. This (~100klux) is a much higher exposure than traditional Indoor print life display longevity estimates which often use much lower set points, a different illuminant and significantly lower daily exposure assumptions (450lux/12hr day) to simulate an alternative Indoor (home – like) display environment. Again, this study (and publication) was designed to evaluate an accelerated simulation for Indoor In-Window Display conditions.

Measurement Equipment

The samples consisted of four colorant ramps, C, M, Y, K and a white patch. All samples were read prior to initial exposure, time, t = 0; and were re-measured using the same instrument after specified exposure intervals.

The measurement tool used was Gretag Macbeth Spectroscan (Spectrolino). This reflective instrument uses directional 45°/0° geometry; a D50 illuminant, CIE Standard Observer viewing angle of 2° (D50/2°) and ANSI A response status was used to measure all samples throughout the duration of the test.

Exposure Assumptions & Calculations

The following exposure assumption was used for all calculations for predicted Indoor (Commercial) In-Window Print Display estimates: 6 Klux per 12 hr day.

The sample plane was controlled at an Irradiance level of: 1.10 W/m^2 at 420 nanometers and is equivalent to 100klux.

Since the accelerated exposure has a ratio of 3.8 light hours for every 1.0 hours in darkness, an “illumination ratio” of 79.16% is used in the calculation of predicted print longevity estimates for the Indoor In-window Display.

Accelerated correlation to real time, calculation:

Let:

R = Predicted (real time) exposure equivalent [years]

L = Average accelerated exposure illuminant intensity [lux]

D = Cumulative duration of exposure in machine time [hours]

A = Real time light exposure model assumption [lux*hours/day]

Then, $R = (L * D) \div A$ (1)

Example:

At a cumulative exposure of 600 total machine hours:

= (100 Klux * 600 machine hrs * 0.7916 illumination ratio) ÷ (6 Klux * 12 hrs/day * 365 days/year) = 1.8 years

Results

The media samples included in this study were predominantly printed on the HP Designjet Z2100, which uses the same 8 HP Vivera Pigment inks as the HP Designjet Z6100; thus this data directly applies to the same media printed on the HP Designjet Z6100. Media samples were also printed on the HP Designjet 5500 using HP 83 uv (pigment) inks and three competitive printers (Competitive Printer A, Competitive Printer B and Competitive Printer C).

The inkjet media included were HP Premium Instant-dry Photo Gloss, HP Super Heavyweight Plus Matte Paper, HP Professional Matte Canvas, and HP Hahnemühle Smooth Fine Art Paper (“Photorag”) as well as four competitive media, Media W, Media X, Media Y, and Media Z.

Assuming a 6klux per 12 hour day nominal Indoor In-Window exposure assumption and using WIR endpoint criteria set v3.0, the HP system solutions in-window print life longevity estimates range from 1 to 3 years (see Figure 1). The three competitive printer systems’ in-window print longevity estimates range from 0.5 to 1.3 years (see Figure 2).

Figure 1: *HP pigment inkjet Indoor In-window predicted print longevity using 6klux per 12hour day assumptions and WIR v3.0 endpoints (Q-Sun XE-3-HC).*

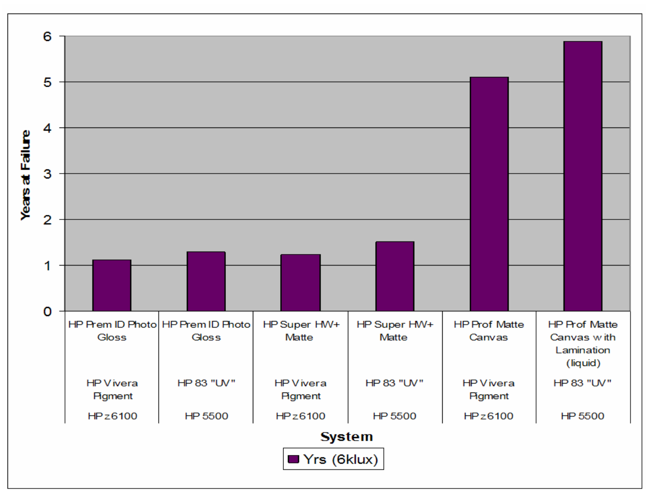
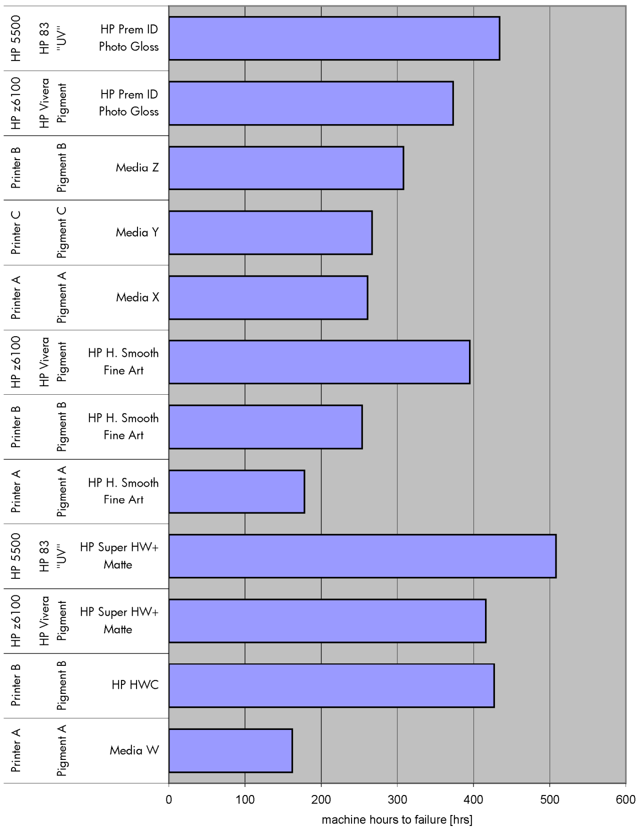


Figure 2: *HP and Competitive System Performance Comparison for In-window predicted print longevity estimates (Q-Sun XE-3-HC).*

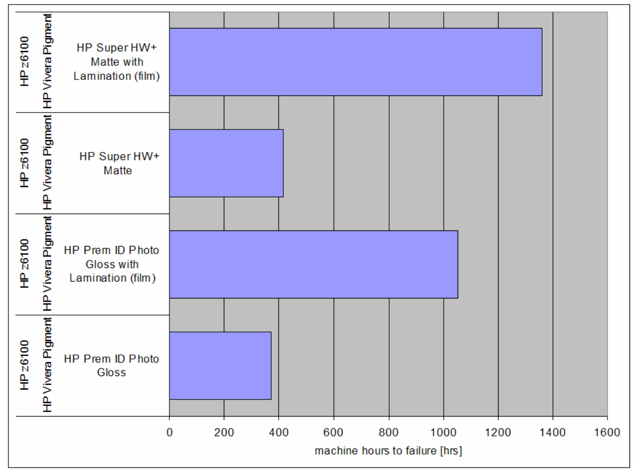


Compared to other (fluorescent – based) Indoor (home) display print life ratings of 100 to 200 years for several ink/media systems, HP believes the testing methodology used in this study complements the Indoor light stability methodology for this alternative commercial in-window display condition that often includes direct sunlight. HP believes this is a justified and well-researched set of assumptions and exposure conditions that accurately accelerate and simulate an actual In-window display environment.

The data suggest that for the systems evaluated, the chiller, which allows for a lower BPT in the dark cycle, does not significantly impact the print life longevity estimates. The addition of the chiller allows for dark cycle BPT to be controlled at 25 ± 5 °C (versus a BPT set point of 40 ± 2 °C without a chiller). Half of the samples had at least one replicate in each test chamber, and the addition of the chiller increased the In-window print longevity estimates by an average of 7% (minimum of -1% increase and maximum of 18%), assuming a initial Optical Density of 0.6.

Despite the test chambers being in a climate controlled test environment, post-print lamination was shown to double (2x) the print life longevity estimates (see Figure 3). This predicted print longevity increase is assumed to be due to the UV filtration provided by the laminate.

Figure 3: *Illustration of the effect of lamination on predicted Indoor In-window print life longevity estimates (Q-Sun XE-3-HC).*



All HP Indoor print longevity ratings are also available at: www.hp.com/go/supplies/printpermanence .

Conclusion

This study was designed to evaluate the performance of pigment inkjet systems in an indoor commercial "in-window" display environment using an accelerated Xenon Arc test chamber. The accelerated exposure cycled through light and dark cycles, as well as high and low temperature and humidity conditions in order to simulate an actual commercial in-window print display condition. This publication includes a documented set of Xenon-Arc test chamber set points, illumination and climatic cycles and filters used to simulate and accelerate a commercial in-window display environment. Also included are the set of assumptions and calculations used to analyze the densitometric changes over time of the unique pigment inkjet systems included. The calculation assumptions are based on an earlier HP study of average exposure (light, temperature and humidity - levels) in (or near) real commercial store fronts.

HP claims published starting in 2007 for prints made with printing systems such as HP Designjet Z6100 use the following test conditions and calculation assumptions. Xenon-arc lamp, "window" glass filtered (Boro-Silicate 300 nm UV cut-off), cycled temperature and humidity (3.8 hours per light cycle – air held at 40˚C & 40%rH, 65˚C Black Panel Temperature, 1.0 hour per dark cycle – air held at *25˚C* & 70%rH,. Key calculation assumptions include 6,000 lux for 12 hours per simulated day, and Wilhelm Imaging Research v3.0 endpoint failure criteria [7].

HP pigment inkjet system solutions exceed predicted in-window print life longevity estimates compared to the included competitive pigment inkjet solutions on equivalent OEM branded media. Moreover, when HP pigment inks are used with HP media, the prints have greater in-window display longevity estimates compared to the competitors inks (Competitive 'Printers A' and 'Printer B') printed on the same HP media. This is a reaffirmation that HP printers & inks are designed with and for HP media, and using the complete HP system solution will provide the customer with long lasting prints.

References

[1] *ANSI IT9.9 – 1996*, *American National Standard for Imaging Media – Stability of Color Photographic Images – Methods for Measuring,* American National Standards Institute, Inc. , New York, New York, 1996.

[2] Henry Wilhelm, "A Review of Accelerated Test Methods for Predicting the Image Life of Digitally-Printed Photographs", Proceedings of "Japan Hardcopy 2004" – The Annual Conference of Imaging Society of Japan, pg. 81, Tokyo, Japan, (2004)

[3] http://www.wilhelm-research.com/

[4] *ASTM G155 – 98: American Society for Testing and Materials, "Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials", 1998.*

[5] *ASTM G147 – 96, American Society for Testing and Material, "Standard Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests", 1996.*

[6] www.hp.com/go/supplies/printpermanence

[7] Dr. Nils Miller, "HP's Commitment to Rigorous Permanence & Durability Testing"; available at: www.hp.com/go/supplies/printpermanence

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