Top 10 Reasons Not to Base Service Life Predictions Upon Accelerated Lab Light Stability Tests

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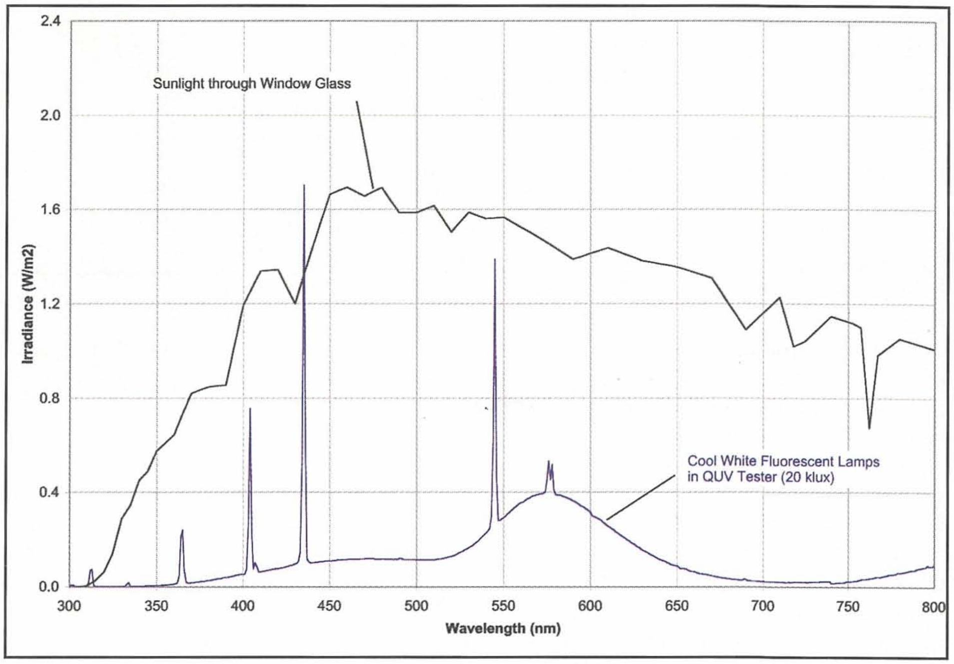

Figure 1: Cool white fluorescent lamp vs. sunlight through window glass.

The popularity of personal computers and digital cameras has ushered in an exploding new market of digital images printed from consumer printers. There is an endless combination of ink jet inks and commercial photo papers currently available in the marketplace.

However, no one is really sure how long these printed images will remain lightfast. Image permanence is a big issue. Many OEM computer printer manufacturers, ink jet ink and paper suppliers are rushing to develop a standardized light stability test protocol that will generate meaningful test data. But, this is inherently complex.

There are a myriad of factors that can cause degradation of image quality besides UV light: ozone (or gas) fade, catalytic fading, humidity, dark stability and temperature. Together or individually, each can wreak havoc on a treasured image. The following is a review of the major issues related to light stability testing of inks and substrates.

1. Light Spectra

It must first be stated that there is no standard light spectrum to replicate indoor lighting conditions. Let's review some widely-used laboratory light sources for light stability testing of printed images.

Fluorescent Lamps

Historically, light stability tests using high output cool white fluorescent lamps have been used for color photographs. For example, the standard photography test condition (low-watt cool white fluorescent light at 450 lux/12 hours a day, 60 percent RH and 70°F ambient room temperature) is not even close to approximating the variety of end-use environments of computer-generated images printed with ink jet inks. While the output of cool white fluorescent lamps may somewhat reproduce low light or office environments, the spectrum of these lamps is limited. That is, the lamp's output does not match the spectral power distribution of other commercially-used light sources or sunlight through window glass. *(See Figure 1.)*

Cool white fluorescent lamps are useful for testing products whose primary end use is in lighted display cases or in retail environments. However, making service life predictions with this lamp type for images displayed in typical indoor environments (i.e. home or office) is inaccurate at best. For example, images displayed near windows, sliding glass doors, skylights, etc. can receive up to 50,000 lux of full spectrum sunlight (i.e. UV, visible and IR) in the morning hours on a clear day.

Xenon Arc Lamps

The xenon arc was adapted for accelerated weathering in Germany in 1954. Xenon arc testers, such as the Q-Sun Xenon Test Chamber, are appropriate for photostability of materials because they provide the best available simulation of full spectrum sunlight: UV, visible and IR light.

Xenon arcs require a combination of filters to reduce unwanted radiation and to achieve the appropriate spectrum (e.g., outdoor sunlight or sunlight filtered through window glass). The Window Glass Filter simulates sunlight through window glass. It is typically used to test products whose primary service life will be indoors. Figure 2 shows the SPD of noon summer sunlight behind glass compared to a xenon arc with a Window Glass Filter.

The bottom line is that fluorescent lamps produce a much different light spectrum than sunlight or xenon-arc lamps. A lab light source should be selected to best match the product's actual service environment. To help illustrate the significance of lamp selection, let's consider the following example:

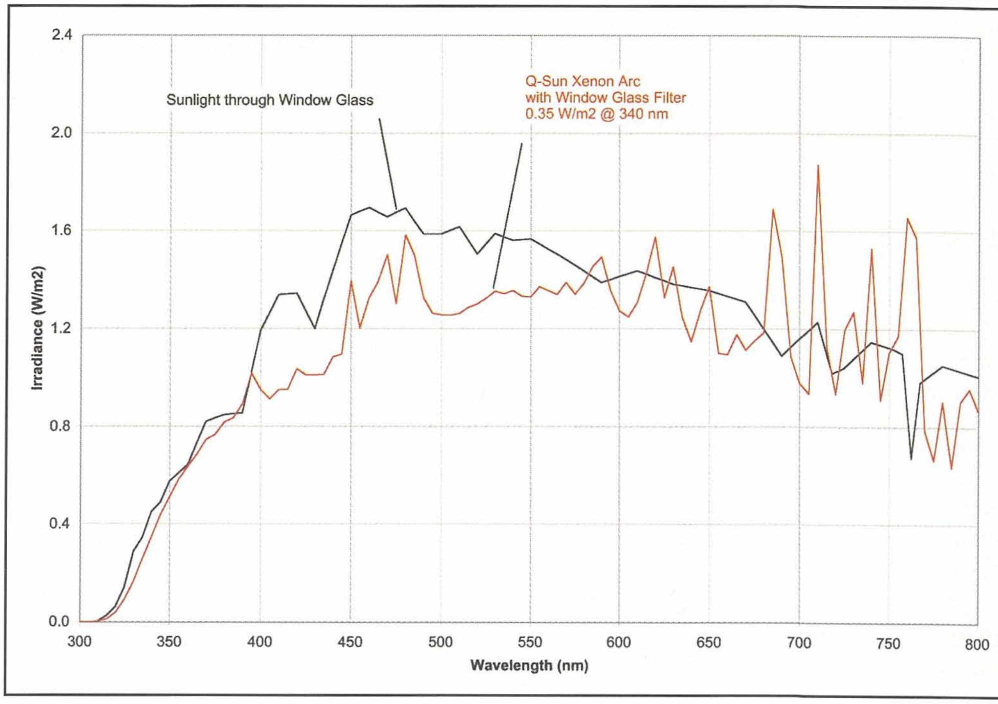

Figure 2: Q-Sun Xenon Arc with Window Glass Filter vs. sunlight through window glass.

An ink predicted to last 35 years by using a cool white fluorescent lamp (450 lux/12h per day) will only last for one year at 50,000 lux at three hours per day (equivalent to morning sunshine penetrating through a window). The explanation for this discrepancy is that the spectral output of the cool white fluorescent lamp source is very different than the spectral power distribution of window-glass filtered sunlight.

This example clearly demonstrates the danger of making service life predictions using a low intensity light source that does not account for high intensity, full-spectrum sunlight.

Figure 3 compares the spectral power distributions for the cool white fluorescent lamp and xenon arc with Window Glass Filter vs. sunlight filtered through window glass.

2. Light Intensity

There is no standard light intensity (irradiance) for indoor environments. As noted already, there are dozens of possible indoor environments, each with its own unique lighting conditions. As such, there is not one specific lab irradiance level to address all of these situations. In-service lux levels can range from 100 lux to 100,000 lux, depending upon the light source(s).

Temperature Sensitivity of Materials

Photochemical responses are material-dependent and influenced by temperature. In combination with UV light, high temperature will accelerate the photodegradation of many materials.

3. Standard Temperature

There is no standard indoor ambient temperature level. Ambient temperatures vary greatly between different regions of the world and this can affect image durability. Images may degrade faster in a subtropical location like Miami, but remain relatively lightfast in a cool location like London.

4. Humidity

Like temperature, there is no standard ambient humidity level for indoor environments. Humidity levels can range from very low (air-conditioned home in Arizona) to very high (un-air-conditioned home in New Orleans). For inks, high humidity levels may cause dyes to migrate, causing uneven densities on substrate, resulting in color hue shifts (e.g., "Blue Shift") or dye smear.

Humidity can also affect the substrate an image is printed on. This may result in yellowing from photochemical reactions taking place in the ink receiving layers. A non-porous media is less sensitive to light and ozone, but is more sensitive to humidity. Conversely, a porous media is more sensitive to light and ozone, but is less sensitive to humidity.

5. Dark Stability

An image not only has to remain lightfast, but it must be also darkfast. Photochemical dye reactions can continue in the absence of light.

These photochemical reactions are accelerated by temperature. An unstable ink may therefore "fade" in the dark.

6. Linearity of Degradation

Some images fade or change color in

a linear fashion, while others may show very little change over an extended period of time. Then, suddenly there can occur a dramatic color shift in the image.

7. Reciprocity Failure

"Reciprocity failure" refers to the condition when inks fade faster exposed at a lower light intensity for a longer time period than inks exposed to higher-intensity light for a shorter time period. One explanation for this phenomena is that, over a longer time period, inks are also susceptible to other stressors besides light (i.e., ozone and humidity).

8. Gas (Ozone) Fading

Photooxidation of inks and media causes fade and color shift. Indoor air quality is yet another stressor to image permanence. Inks applied to porous media (e.g. paper) are more susceptible to gas fading than "swellable" or gelatin-based media where the inks are encapsulated.

9. Catalytic Fading

This phenomenon occurs when a particular combination of inks fades quickly, even though the individual inks are lightfast.

10. Lux vs. UV

Photography test standards specify the use of lux as a means to time radiant dosage. But, lux is not a useful measurement tool when evaluating light stability of printed images. While it would seem logical to use lux because it is based upon the human eye's response to light (centered around 520 nm), significant photodegradation may result from the shortwave UV region which goes undetected when one uses lux as a measurement device, especially for substrates. A more appropriate measurement would be to use radiant energy measured in watts per square meter (W/m^2).

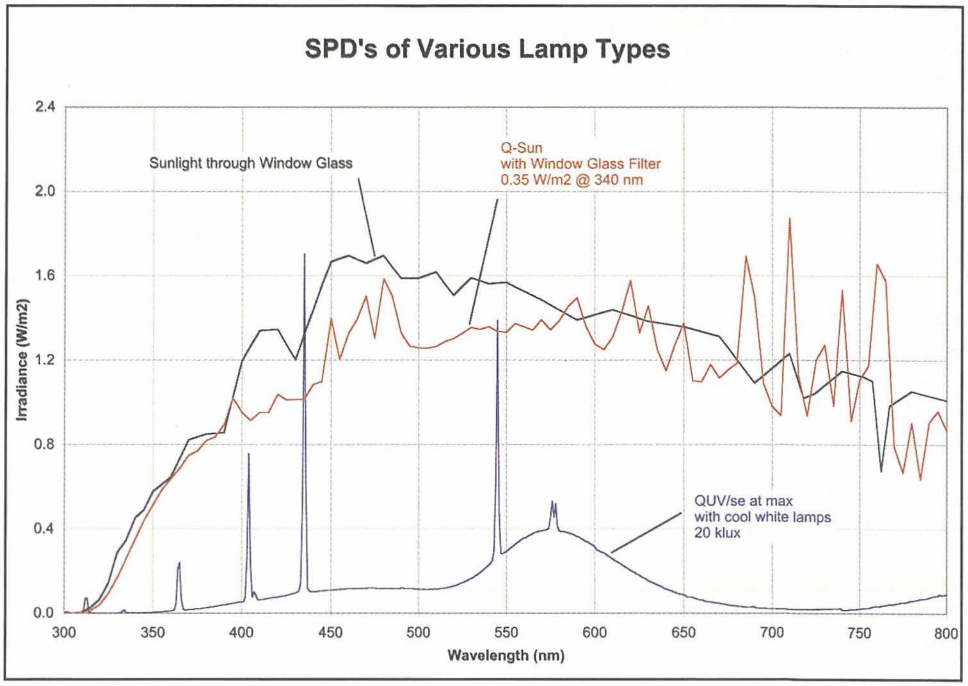

Figure 3: Q-Sun Xenon Arc with Window Glass Filter and cool white fluorescent lamp vs. sunlight through window glass.

Light Stability Testing Standards

There is work underway within the ANSI IT 9.3 Stability of Color Images Subcommittee to write test standards for indoor light stability and outdoor durability. The subcommittee is also developing standards addressing humidity fastness, ozone fade and thermal degradation/dark stability.

The proposed ANSI indoor light stability standard will specify three test conditions: (1) cool white fluorescent lamps, (2) xenon arc and (3) tungsten lamps. These three light sources were chosen to cover various indoor lighting conditions. Xenon arc with a Window Glass Filter is intended to simulate sunlight filtered through window glass. This standard is in the early draft stages and will probably not be approved and published for at least one to two years.

The ASTM D01.56 Printing Inks Subcommittee recently revised one of their existing test methods that addresses light stability of printing inks. ASTM D3424, "Lightfastness and Weatherability of Printed Matter," specifies outdoor behind glass exposure in Florida, xenon arc with Window Glass Filter and cool white fluorescent lamp exposure in accordance to ASTM D4674, "Color Stability of Plastics." Radiant dosage for the natural outdoor exposure is 1260 mJ @ 300-400 nm, while the xenon arc exposure is 510 kJ @ 340 nm.

There are several accelerated light stability testing options available depending upon one's needs. For example, fluorescent UV testing in a QUV using cool white lamps is appropriate for simulating some indoor lighting conditions. Xenon arc testing with a Window Glass Filter is appropriate for simulating sunlight through a window, while xenon arc testing with a Daylight Filter is appropriate for simulating direct outdoor exposure to sunlight. In addition to accelerated laboratory testing, natural outdoor exposure testing should always be conducted (i.e. direct and behind glass exposures) to establish an appropriate benchmark for end use applications and service environments.

Conclusion

These "top 10" reasons confirm that predicting a printed image's service life is difficult, at best. Because of the multitude of environmental factors that can work independently or in tandem with UV light, one should be extremely cautious when estimating an image's lightfastness. In addition, there is a complex inter-relationship between coating/ink/substrate.

One cannot simply input data in the form of absolute values into a mathematical equation to generate accurate lifetime predictions. However, by using rank order correlation, one can compare the relative performance of one particular ink/substrate to another. In correlating accelerated and real exposure tests, the rank performance of the materials exposed to both environments is compared, and the strength of the association between the tests is therefore established.

With the correct choice of operating conditions, accelerated laboratory lightfastness testing can provide extremely useful results that are typically much faster than natural, real-time testing. These results can be used to rapidly assess probable product performance.

Comparative data is powerful. While accelerated testing of any type is not capable of producing the "silver bullet" to determine absolute correlation with real world results, the benefits of comparative data cannot be ignored. It can be used to (1) new or existing printing ink sy (2) develop ink/substrate refo tions that have improved lig ness and/or durability, (3) expec approval process to bring a nev uct to market, (4) establish ba QC requirements, and ultima establish an industry stand printing of digital images.

Accelerated testing can quick vide critical information about or substrate's durability unde ing service environments, wl essential to meeting the ever-ing demands of this new and dynamic industry. ■

Eric T. Everett is a technical specialist for Q-Panel Lab Products Co. With more than 10 years of experience in standards development, he is responsible for coordinating Q-Panel's participation on numerous ANSI, ASTM, ISO and SAE industry standards-writing committees dealing with weathering and testing of color images, printing inks, packaging, textiles and other materials. He is secretary for ASTM G03 Committee on Weathering & Durability and ASTM D01.27 Subcommittee on Accelerated Tests for Protective Coatings. His e-mail is eeverett@q-panel.com.