Keep Your True Colors: Lightfastness and Weatherability Testing

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by Julie Lucas

The job is printed, the spectrophotometer and densitometer readings match the specs, everyone agrees that "it looks great." Then, one day the customer calls to complain that the job you printed has faded. Perhaps the ink faded on a storefront poster exposed to sunlight, or maybe an expensive brochure that was stored under fluorescent lights in "protective" packaging changed color or faded. If, as Richard Harold says earlier in this issue, "Appearance is the foremost and most impressive product message," then a product's appearance over time—its lightfastness and weatherability—can also be crucial. In this article, Julie Lucas of Q-Panel Lab Products *(www.q-panel.com)* explains what types of tools are available for testing lightfastness and weatherability, while Ian Johnston of Inkware LLC *(www.inkware.com)* and Matt Creegan of Zeller + Gmelin *(www.zeller-gmelin.com)* describe what this kind of testing has meant to their companies.

Why should you test products for lightfastness and weatherability? Ian Johnston, director of research and development for Inkware LLC sums it up in a sentence: "It helps us to sleep better at night."

While many in the graphic arts industry still think of this kind of testing as a luxury, to Johnston and many others, it is crucial. "Weatherability is our number one concern," he says. "A lot hinges on the appearance of our products. When appearance degenerates, it leaves a bad taste in consumers' mouths and they lose confidence in your company."

Lightfastness and weatherability are obvious objectives for Inkware, since most of its products are used outdoors on large billboards, signs, and banners. A manufacturer of piezo inkjet inks, the Las Vegas-based company works hand in hand with VUTEk *(www.vutek.com),* manufacturer of inkjet printers that digitally produce massive outdoor signs.

As many industry professionals are discovering, however, it's not just outdoor materials that should be tested. Bright interior lighting and sunlight through window glass can be surprisingly damaging. "Testing for light stability really does make a difference," says Johnston. "You'd be surprised at how much light infiltrates a bottle of ink on a shelf." And, of course, durability of appearance is a big issue for inks and artists' materials. Maintaining "permanent records" or enduring works of art is not possible if your materials do not last.

Damage to products from indoor lighting and the outdoor elements cause billions of dollars in losses every year. This damage may include fading of inks and color change, hazing, cracking, peeling, delamination, gloss loss, chalking, and oxidation of substrates.

Bright indoor lighting, sunlight through window glass, and direct natural sunlight are the main causes of this damage. Different wavelengths affect materials differently. In general, longer wavelength ultraviolet (UV) and visible light are most harmful to graphic arts materials because they tend to cause fading and color change. Short-wavelength UV radiation is usually responsible for most of the degradation to more durable materials, such as many substrates.

Testing for light stability and weatherability is typically done in the research and development stage and/or the quality control stage. "We test in the R&D stage and in conjunction with our customers' ongoing test programs," says Matt Creegan, dry offset product manager at Zeller + Gmelin, producer of specialty UV-cured inks.

"Testing gives us confidence that our products will meet customer expectations. And customers do tell you what they expect, such as a product that will last at least a year in the field, for instance." Based in Richmond, Virginia, Zeller + Gmelin manufactures inks for lithography, dry offset, and flexography.

Because of the push in recent years toward graphic arts materials that are not only durable but also environmentally friendly and nontoxic, testing has become even more important. "When you are dealing with organic pigments, it's really hard to find good reds and yellows, especially yellows," says Creegan. "We must have tested a few dozen to find the right one that works with our system."

A balance between good color and good weatherability is the goal at Inkware, says Johnston. "There are nicer looking colors we could use, but it's a compromise between what will look good and what will work outdoors for the next several years. We try to make sure our colors look good and have the widest color gamut possible, while remaining weatherable," he says. The way to accomplish that goal? Testing.

Figure 1. The appearance of photos may degrade over time due to bright indoor lighting or sunlight through window glass. These photos are being exposed outdoors at a test site in Florida to check for permanency.

What are today's testing options? There are a number of them, but no single testing technique is perfect for all materials and applications. The approach you choose should depend on what you need to accomplish, your time frame, and your budget. Each technique has inherent strengths and weaknesses.

Natural Exposure Testing

Often the most accurate way to test products for lightfastness and weatherability is simply to expose them to natural sunlight. (See Figure 1.) Materials can be exposed in a variety of ways, such as under glass to simulate a bright indoor environment.

Real-time, outdoor testing is usually done in either Florida or Arizona because these areas provide extreme climates that accelerate the degradation of materials. Florida is known for high temperatures, high humidity, and abundant rainfall, while Arizona has high temperatures, high UV concentration, and extreme dryness. In fact, these areas are considered international "benchmark" locations for weathering testing. For the most comprehensive testing regimen, manufacturers will send samples to outdoor weathering sites in both Florida and Arizona.

Zeller + Gmelin and Inkware have the luxury of testing at their company sites, which are located in harsh climates. "We do outdoor testing on our own at branch locations in Virginia, Texas, and California," says Creegan of Zeller + Gmelin. Inkware simply takes advantage of its Nevada location. Since the company was founded seven years ago, Inkware has been able to compile a lot of outdoor test data, according to Johnston. "We have one sample still being exposed that has already been there for 6 1/2 years!" he says. "We are quite proud of that one because it's actually held up very well." (See Figure 2.)

The drawback to natural sunlight testing is the amount of time it takes. "With the long lead time you need to introduce new products, you can't always wait a couple of years to see if a material will last," says Johnston. However, if you have flexibility in terms of time, outdoor weathering tests are the most realistic—and they are usually relatively inexpensive.

Accelerating Results in the Lab

Many manufacturers have found success using accelerated laboratory light stability and weathering tests. These tests can give fast, reproducible results. And, by varying the exposure conditions, lab tests can be correlated with outdoor exposures at various locations. With the recent increases in new technology, the use of accelerated weathering is increasing proportionately.

There are a number of commonly used laboratory weathering and light stability testers. Each uses a somewhat different method to reproduce the damaging effects of sunlight and moisture. Since there are pros and cons to each tester, it's important to evaluate them individually before deciding which is best for a particular purpose.

Carbon Arcs

Enclosed carbon arc testers, the oldest form of light stability testers, have been around since about 1918. Test samples are mounted vertically on a carousel that revolves around a pair of carbon rods, which are "burned" to produce light. Because this tester is deficient in short wavelength UV and is an extremely mild test for today's durable products, it is rarely used anymore.

The sunshine carbon arc was introduced in the 1930s as an improvement to the enclosed carbon arc. The major difference between it and the enclosed carbon arc tester is the light source. The sunshine carbon arc emits extremely short-wave UV light, but this type of exposure represents an overly severe and unnatural exposure condition.

As most researchers have found, carbon arcs will give some useful data, but more accurate ways of testing are available. "In the past, we've sent samples out to be tested in a carbon arc," says Creegan of Zeller + Gmelin, "but when it was time to buy our own machine, we decided we didn't want to own a carbon arc. All of our research indicated that it's not the best tester for correlating to the solar spectrum."

Xenon Arcs

The xenon arc tester has been shown to reproduce the full sunlight spectrum most accurately. Xenon lamps emit UV, visible light, and infrared in the same way the sun does, and can therefore provide very accurate data. Xenon arc testers may also

Figure 2. This photo has been exposed at Inkware's Las Vegas, Nevada, site for the past 6 1/2 years.

be equipped with a water spray mechanism to simulate wet conditions. Xenon arc testers are especially good for evaluating resistance to color change and fading because many products fail when exposed to longer-wavelength UV and visible light. (See Figure 3.)

Both Inkware and Zeller + Gmelin use xenon arc testers as well as outdoor exposures for light stability and weathering testing. And, to be confident in their xenon tester results, both correlate their data. "So far our outdoor data compared with the Q-Sun xenon tester looks pretty close," says Creegan. Johnston says he has found similar results.

The drawback to xenon testers is that some of them can be more costly than other testers or outdoor testing.

Fluorescent UV/ Condensation Testers

Fluorescent UV/condensation testers utilize lamps that are similar to the common cool white lamps used in general lighting, but which produce UV rather than visible light or infrared. In this way, these testers expose specimens to short-wavelength UV, which is generally the most damaging portion of the sun's spectrum for durable materials such as many substrates.

UV testers can also simulate moisture through a condensation mechanism. This provides a more realistic test, since studies on outdoor materials have shown that condensation (i.e., dew) causes more wetness than rain. Some testers are also fitted with a water spray mechanism to reproduce thermal shock, which can be very damaging to some materials.

Inkware has done a lot of testing with fluorescent UV bulbs. "When the company was initially developed, we approached testing from the scientific standpoint that UV radiation tends to cause the most damage to colors as far as fading," says Johnston. "We originally used only high-intensity UV bulbs to test. We knew that if materials lasted at this intensity UV, they would most likely last outdoors. But we discovered that it's not only high-intensity UV that can be damaging, but also lower intensity light over long time periods. Accelerated testing helps you avoid a lot of pitfalls with materials, but it's not always apples to apples. Interactions that happen outdoors can lead to product failure. Moisture and chemical reactions (caused from pollution) can contribute. So, we began to also expose products outdoors as well in a Q-Sun xenon tester."

"We still use the UV bulbs to test," says Johnston. "If we need to make quick first cuts on a material, we expose them to UV first. It's an extreme test, but it's very quick. After materials last in this environment, we put them in the Q-Sun to see which holds up better."

UV testers are easier to operate and much less expensive than the carbon arc or the xenon arc testers. Their main weakness is that they do not emit visible light or infrared. This limitation can be important for evaluating material colorfastness and fading, which

Figure 3. The Q-Sun Xenon Test Chamber is an accelerated weathering tester that uses xenon arc lamps to simulate the entire spectrum of sunlight. The Q-Sun 3100 (left) has a large specimen capacity that will accommodate 3D parts, and is also available with relative humidity control. Q-Panel donated a Q-Sun 1000 Xenon Test Chamber (right) to GATF. The realistic simulation of sunlight in both chambers is especially useful for testing printing inks that are sensitive to longer-wave UV and visible light.

often occur due to exposure to longer-wavelength light.

Choosing a Testing Regimen

The best testing regimens take into account that the more tests you perform, and the more types of tests you perform, the better you'll understand your products and their strengths and weaknesses. Both Zeller + Gmelin and Inkware rely on comprehensive testing regimens that include both outdoor and accelerated lab tests. "We have had some cases where materials did well in accelerated tests, but degraded rapidly outdoors," says Johnston. "You can be most confident by doing a wide range of testing." In addition, by choosing more than one testing method, you can compare results between them, and learn which methods work most accurately and efficiently for your materials.

It's also important to understand that the kind of substrate on which you test can make a big difference. "We've found that substrates have a dramatic role in the lifetime of an ink," says Johnston. "The ink needs to stay on the substrate, and so the substrate itself must be very durable. When comparing substrates in accelerated testing, we've found that they often brown or yellow due to the UV, or the surface layer deteriorates. We work closely with the substrate manufacturers to improve these surfaces so that our customers can buy the inks and the substrates as a package that's known to work well together."

Creegan and Johnston both say that, the best thing to do when you're new to testing is to test as much as possible, as many ways as possible. "When you are first starting out, you probably want to test all of your product lines," says Creegan. "Start slowly with the process. Keep your eyes open for differences in cure condition and substrates when testing. Expect it to take several years for really meaningful data. On the other hand, you will reap some immediate benefits. You will know what's not going to work for you."

"To those new to testing, my advice would be to test, test, test," says Johnston. "There is no substitute for a credible range of testing. I would say you need to get involved in some sort of accelerated testing because quick results are so essential. But then I would also get some samples exposed outdoors, even if it's on your own roof."

Of course, customer feedback is critical as well. "We have inks in about 60 countries in all sorts of climates," says Johnston. "We're at the point where we can get a lot of data from customers about the durability of our products and under which conditions they last best and worst.

"On the other hand, if we relied completely on customers using our products to find out if they last, it could be catastrophic!" he says.

In the long run, a comprehensive testing regimen will pay for itself. Not only will you avoid the costs associated with putting out bad products, but also customers will give you repeat business, knowing that your products will last. And, like Johnston, you too will be able to sleep better at night. ■

What causes fading of outdoor inkjet images?

"Fading" of inkjet images can be viewed as a simple reduction in color density over a period of time. The chemistry of fading, however, is not so straightforward. Each pigment has a different chemical composition. A black ink made from carbon black will actually protect the vinyl from cracking and never fades. Most good process cyans are made from organometallic compounds that are almost as stable as carbon black. They generally show little fading over time.

The real fading problems in four-color process inks come from the magenta and the yellow. Yellow pigments absorb primarily blue light, which is at the high-energy end of the visible spectrum. Without any protection, yellow will show a greater loss in density than any other color.

Clear coats containing a UV absorber to reduce the amount of UV light penetrating to the ink layer are being used to try to decrease the fading of the yellow.

Magenta has a different problem. It absorbs green light, and the intensity of visible sunlight peaks in the green. UV absorbers have little effect on magenta fading because they do not absorb green light. Magenta fading is due largely to absorption of green light. Small changes in magenta density are more visible to the human eye than similar changes in yellow density.

Color density loss is not only caused by the discoloration of pigments by absorption of light, it also occurs as the direct result of the loss of pigment by physical abrasion. Abrasion by particles of grit carried by the wind slowly grind away the outer layer of pigment. Areas of an image with the lowest density will be affected first because there is less pigment there to start with. A clear coat will not completely eliminate fading, but it will slow down the process. For outdoor use in wet climates, a clear coat containing an effective water repellent, such as a fluorocarbon, is highly recommended.

Rainwater, as it falls, does not have much effect on an image printed with a good solvent-based ink, but the chemistry changes dramatically as the rain begins to dry. When the water evaporates, the concentration of pollutants increases until at the last second of drying, the concentration of pollutants approaches infinity. The effect on a printed image will depend on the type and level of air pollution. In any case, it would be better if the rain drops were repelled by the clear coat and ran off, rather than drying on the image.

Information adapted from Inkware's website: *www.inkware.com/html/vol2_1.html*

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