The Archival Quality Of Digital Print Media

by Chris Maher and Larry Berman

A Conversation With Henry Wilhelm, The "Guru" Of Image Permanence

Henry Wilhelm is a true leader in the field of image permanence. Involved in photography since childhood, Henry became interested in the preservation of photographs in 1963 while working in the hot and humid jungles of Bolivia while serving in the Peace Corps. In '66 he served as an assistant to Ansel Adams during one of Adams' photo workshops in Yosemite National Park, and in '72 he received the first of his patents on archival print washers for black and white fiber-based prints. In '81 Henry received a Guggenheim Fellowship for what became a 10-year study of color print fading.

In recent years, Henry has been a consultant to many collecting institutions, including the Museum of Modern Art in New York and Bill Gates' Corbis, where he served as an adviser on the long-term preservation of the Corbis Bettmann photography collections. Henry and Carol Brower Wilhelm are the authors of the landmark 744-page book, "The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures," published in '93.

Generally regarded as a leading authority on ink jet permanence, Henry's accelerated testing of ink jet media has given today's photographers empirical evidence of the archival quality of today's ink and paper combinations.

Shutterbug: Your work as a pioneer in the field of image permanence has shown you both the good and bad about ink jet printers. How can a photographer pick an ink jet printer that they can trust to make prints that will be around for decades?

Henry Wilhelm: The simple answer is to pick a printer for which print permanence data is available for the ink and media combinations used for that printer.

SB: Where can that data be found, and how much credence should someone give to a manufacturer who claims a given expected lifetime of a print?

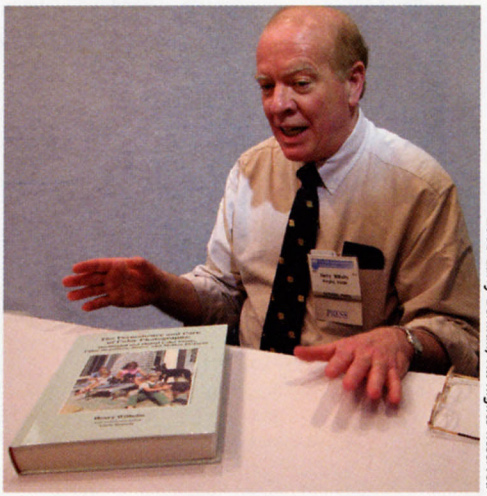
HW: I think the important thing is that first the manufacturer would describe or at least have available a description in some detail how the tests were done. In the case of HP and Epson, both of those companies have primarily relied on our company (Wilhelm Research) to do the test evaluations and then they make that information available, or steer people to our website or to publications that are quoting it. Canon, with its initial launch of its photo printer, also did that. More recently, Canon has been publishing self-generated data that uses similar but not identical test procedures. I think that one important issue here is that the paper itself, particularly with the dye-based inks, can have a significant impact on the permanence of the image, and not only in terms of light stability. In other words, there is not just one single permanence figure for a printer with its ink set.

SB: Is it safe to assume that manufacturers always use their own papers with their inks in testing?

HW: Yes, although manufacturers themselves often will publish data just for their paper that does the best, even though they have additional papers available.

SB: Would it be safe then to believe that by using the exact ink and paper one can probably achieve the same kind of archival image stability?

HW: Yes. Most of the quoted numbers have been for exposure to light on long-term display. In general, the data have been for prints framed under glass. I think we also need to talk about susceptibility to ozone for prints that may be exposed to ambient atmosphere for long periods of time. Prints that are not framed under glass—for example, the classic refrigerator display



conditions or prints tacked to the wall in your office—may have different stability figures, especially smaller prints that will never be framed under glass. There is a special concern about porous or microporous papers with dye-based inks and the greater susceptibility of these papers to ozone.

I think, from the reader's standpoint, the simple way to distinguish between porous and microporous and swellable papers is that if the paper package says "instant dry." That's pretty good assurance that it is a microporous type. And if the printer is using dye-based inks, which the majority of current desktop photo printers are using, then you can probably assume that your print on microporous paper probably has a high susceptibility to ozone. You have to be careful there.

The Squeak Test

SB: Tell us a little more about swellable vs. microporous papers and what is the squeak test that we've heard about?

HW: The squeak test is a simple means of identifying microporous high-gloss papers. Just rub your finger across it—if

More on page 130

the paper feels like it squeaks and sort of grabs your finger, that is caused in part by the paper being so absorbent that it absorbs the tiny traces of oil and moisture off your finger, which act as a lubricant on smooth surfaces. Nevertheless, I think looking for the designation "instant dry" is a good way to identify microporous paper, and will probably be more useful for most people. It is a pretty accurate way to distinguish microporous from swellable.

The swellable ink jet papers use an ink receptive coating on the surface that is more akin to traditional photographic gelatin. In fact, gelatin is one of the polymers frequently used in swellable papers—usually in combination with others. When the ink hits the surface of the print the image receptive coating literally swells up. In areas of high-density ink coverage it can take a number of minutes, or even longer depending on the ambient humidity and the paper and ink combination, before it actually feels dry to the touch. The ink and its dyes are absorbed into this now swollen layer and then, as the water evaporates, it shrinks back down to its original surface thickness with the dyes to some degree encapsulated in it. That encapsulation provides a significant amount of protection from the ambient atmospheric gases.

There is a parallel with traditional photography here. Traditional black and white photographs have an image composed of pure metallic silver, which looks black because its very finely divided filamentary structure absorbs light instead of reflecting it. But if it wasn't for the protective affect of the gelatin emulsion and the overcoat in which that silver layer resides, black and white photographs in many environments would only last a day or two before the image would become stained or discolored.

Pigment Vs. Dye Based

SB: Can you tell us about pigment vs. dyed-based inks?

HW: Traditional color photography has always used dyes in its films and print material, whether it is Ektacolor, Fujicolor, or any kind of type-C print. Even Ilfochrome or Cibachrome are dye based. It actually has not been possible to use pigments in most color photography processes. In the distant past there was tricolor carbro and a few other esoteric processes that used color pigments. But they are very difficult processes.

In a nutshell, dyes are dissolved in the ink vehicle, or dispersed in the image-forming layer, at the molecular level itself. Consequently, they are very, very small. Pigments, on the other hand, are insoluble and are much larger particles. As classes of colorants go, pigments certainly have the possibility of having much higher light stability. They are also usually much more resistant to ozone, or gas fading, as it's referred to. Pigments have other advantages as well. They have very little short-term drift. In other words, when you print the image, after just a very quick initial drying phase, the image will change very little over time. For people using color management, making profiles of each paper and ink combination, that's a very important consideration. Dye-based images tend to drift more. And if you are using a tightly based color management system, then that may create some real difficulties.

Print Dry Down

SB: Earlier you had talked about microporous instant dry papers, and compared them to the swellable encapsulating papers that take a while to

dry. Will that longer drying process actually affect how the image looks when it first comes out of the printer compared to when it is totally dry?

HW: Yes, to some degree it can. But the same problem can occur with some dye-based ink and microporous paper combinations.

SB: So you can look at a print when it first comes out of the printer, which is just great, and a couple of hours or a day later come back and say, "Wait a minute, that's not the same image that I saw before."

HW: That would be true. Now, it's a different kind of change, it's not fading, normally. But it may shift in color balance somewhat. The density may change slightly and not necessarily uniformly over the density scale.

SB: So, one can't just simply say that a print gets lighter or darker or shifts in a certain color direction?

HW: No. And it would depend very much on a particular ink set and the paper it's on. It is difficult to generalize. Some are much more stable in this respect than others.

With traditional color photography, people could not evaluate color prints until they were completely dry. Papers like Ektacolor or Fujicolor changed rather remarkably in the course of drying so there is certainly no similarity here. However, what is different is that in traditional color photography once the print is dry coming out of an RA-4 process, then it is highly stable in terms of this short-term drift phenomena. In other words, in weeks or months later it will not change. With a dye-based ink jet print that's not necessarily so, and it partly depends on the environment you're in. If you are a photographer in Miami, Florida, where the humidity is very high, this may be a more serious problem. On the other hand, pigmented ink systems have very good short-term drift behavior. Pigmented ink systems also tend to be waterproof.

Ink Sets

SB: Tell us about the differences between the systems that use four, six, or seven inks. Is there a difference in the stability or is it simply a tonal issue?

HW: Well actually, it's both. Historically the use of dilute magenta and dilute cyan inks would typically cut the light stability or display permanence by a factor of two or even three times. Those inks were more susceptible to fading on exposure to light. Now, with Hewlett-Packard's newest system used in the Photosmart and other HP printers using dilute magenta and cyan inks, that is no longer true. In fact, the six-ink implementation of that is much more stable than the HP four-ink implementation on HP's photo papers.

The rational for using the dilute inks, whether it's dye based or pigment, is to improve smoothness of tone. When you see a printer rated at 1440x720dpi, those dpi figures or resolution numbers are actually true only at maximum image density. The only way an ink jet printer can make lighter tones from darker inks is to leave droplets out, or to some degree by varying the droplet size. In an image produced even with a nominally high-resolution printer using only four inks, that leaves a feeling of granularity or lack of smoothness to the image. This is especially true of the tonal gradations in lower densities, like the highlights in someone's face, for example.

SB: Is that why you can see a dither or some kind of dot pattern in some four-color printers?

HW: It's a feeling of what I call a granularity or texture that doesn't have the same smoothness. The use of dilute inks, the

More on page 134

magenta and cyan, allows many more dots to be laid down by the printer for the same density and that means there is less white space in the lower densities. In addition, all other things being equal, color saturation is also improved with six-ink systems because in middle and lower densities there is less desaturation of colors because of the visual mixing of the white space between ink droplets that occurs with four-ink systems. This is particularly important for portraits or landscapes that have subtle skies. Many types of images benefit greatly from this. And that is why the dilute inks were developed in the first place. It's better for photographic reproduction. Yellow ink is very low in image contrast, so there really hasn't been any perceived benefit to having a dilute yellow.

Now, with the newest printers, there is a seventh ink, a dilute black, which gives two benefits. One is that in the near neutrals it allows significant replacement of the color inks with black inks through much of the tonal scale. It's called GCR, or "Gray Component Replacement." That allows for a more accurate and linear reproduction of the neutral scale. Also, because the black ink, especially in pigments, tends to have higher stability, it can increase the overall stability of most images, especially in terms of color balance shift. It also allows a satisfactory printing of black and white images, which was more difficult before. It also reduces what is called metamerism or metameric failure, in which a color print may look significantly different when viewed under different light sources, for example, daylight vs. tungsten, halogen vs. fluorescent. You certainly want to minimize that to mimic what human vision does. The use of the dilute black has improved that significantly.

Making Choices

SB: What other factors should photographers consider when they choose a printer, paper, and ink?

HW: I think there are several other performance distinctions between dye-based inks with microporous papers, dye-based inks with swellable papers, pigmented inks with microporous papers, and pigmented inks with swellable papers. One is that at this point in time there really isn't a completely satisfactory high-gloss media for pigmented inks. They are certainly satisfactory in terms of image permanence, but they do exhibit what is referred to as differential gloss. In other words, the gloss of the image is to some degree a function the density of the ink. If you look at the reflection of light off the surface of a print, you will notice that. This is something traditional color photographs never had a problem with. The gloss of your Ektacolor or Fujicolor print, if it's a high-gloss surface, looked completely smooth. Dye-based ink jet is capable of printing on high-gloss papers, either swellable or microporous, and exhibiting little if any differential gloss.

At this point in history it's difficult to say, overall, which system is better, particularly for small prints—what we think of as 4x6 photofinishing prints—where most people seem to prefer high-gloss prints. That's been a tradition, certainly in this country. If that is what your goal is, at this point in ink jet technology you're pretty much restricted to dye-based inks. And with the microporous or instant dry papers, which have wonderful image quality, very good water-resistance, and the instant dry feature, the shortcoming, which is potentially very serious, is susceptibility

to ozone or other airborne pollutants.

Again, pigmented ink sets like those used with the Epson professional photo printers or the Hewlett-Packard large format printers, in general have better light stability, and good water-resistance. But again, from a photographer's point of view, one of the biggest drawbacks is the lack of a completely satisfactory high-gloss paper. Now for larger prints, this is not so much of a problem for many photographers because they prefer the sort of semigloss or luster surfaces anyway. So this gets down to a personal preference question, and I think you do see a sort of split in both the printers and the way photographers are using them. In general, for people who use small prints—traditional photofinishing snapshots—dye-based inks may be preferred or even essential in order to get the perfectly smooth high-gloss surface.

SB: Is lamination a possible solution?

HW: Lamination can be a very good solution. It's just that, certainly on the desktop, and even for fairly large-scale use of small prints by photographers, it's an extra and potentially expensive step. The laminator itself may cost more than the printer.

Surfaces

SB: Going back to glossy surface vs. luster, can it be roughly broken into two camps—the amateurs who are shooting for snapshots and passing prints around to their friends and the professionals who are shooting something that they would like to have outlive them?

HW: I think that's a good point. We can draw an analogy from traditional photography where the wedding/portrait business historically has not used high-gloss photography papers, but rather the luster or semigloss. And the transition to ink jet with pigmented inks is much easier. It's the same kind of surface basically that's been used all along. And once large prints are framed under glass, it's much harder to see the surface reflections.

SB: What about fingerprints?

HW: Fingerprints, as far as we can tell with these products, do not have a major impact on ink jet permanence.

Fingerprints certainly did affect the initial types of dye sublimation prints before the manufacturers began protecting them with a clear coating after the image layers were in place. Over time the oils from your fingers could cause the dyes to start migrating physically. The early dye sub prints were also extremely susceptible to contact with plasticized PVC sleeves, such as people have in their wallets or PVC notebook pages.

I think all of this shows a parallel to the completely new modes of deterioration, such as susceptibility to ozone that are possible in any new imaging technology. Traditional black and white RC prints are another example of this. They suffer from a kind of deterioration in which low-level oxidants are generated by the top polyethylene layer of the paper, especially when framed under glass, which then in turn attack the silver image. That's a mode of deterioration that did not exist with traditional fiber-based black and white prints.

It's really easy to forget that the entire ink jet printing field, at the photographic quality level, is a very young field and could be dated to 1994 on the desktop when Epson introduced the first 720dpi printer. For a field that is less than 10 years old I think that an astonishingly amount of progress has been made.

Most of us in the image permanence field, including myself, never really expected to see a six-ink dye-based photo printer with the level of light stability that HP has achieved with their newest ink set and paper. That was a major breakthrough. I think that there was sort of a foregone conclusion that pigments would be the ultimate answer, and I think that's not so clear now. On the most stable paper combinations, in these cases HP Premium Plus Photo Paper, the light stability of prints on display is comparable to the pigmented inks in the UltraChrome ink set by Epson.

Color Gamut

SB: Now that gets us to the next question, which is about the color gamut or

Continued on page 188

From page 136

the color range. The consensus has long been that the colors in the pigment sets were not as rich or as vibrant as the dye-based ink sets. Is technology changing that?

HW: The previous pigmented ink sets that the Epson used, which was known as the archival ink set and used in the 2000P and the 7500 and 9500 large format machines, was what we considered an extremely high light stability pigmented set. With many types of media it would go past 200 years in our standard display conditions test. Epson came to believe, in part because of the very question you've asked about the color gamut of pigment vs. dyes, that photographers wanted higher color saturation and larger gamut and sacrificed some of the light stability of the previous set to achieve that. And that's sort of a classic tradeoff that color photography's always dealt with at one level or another, that if you could ignore permanence completely that virtually every system would have a larger gamut and higher saturation than actual systems on the market do.

The initial pigmented sets used by HP on their large format machines, like the 5000 or 5500, are extremely high stability six-ink systems that are capable of being used for a reasonable length of time, even in outdoor graphics. Epson's UltraChrome ink set could be thought of as the first pigmented ink set introduced by a major producer designed for indoor use with a reasonable gamut, which takes advantage of the permanence advantage that the pigments have. They also have advantages like short-term color drift, resistance to high-humidity environments, and so on. I think we are seeing very interesting developments in the field right now where there are viable pigment systems that most photographers feel have adequate color gamut. If any difference is really noticed with the UltraChrome ink set it's probably not so much the color gamut as it is maximum density, or the depth of the blacks, which kind of anchors the sense of brilliance of the image.

Fade Factors

SB: What is the single biggest factor that causes print fading with today's ink jet printers?

HW: Especially with any of the dye-based printers, whether it's Epson, HP, or Canon, one really needs to be aware that the choice of paper can have a huge affect on the outcome as far as permanence. It's not just an image quality question.

An example that we always cite is our tests with Staples Premium Glossy Photo paper. The new HP printers with their ink set and HP Premium Plus Photo Paper received a 73 year rating. The same printer and ink with the Staples paper was rated as lasting only two years on display! It can be that dramatic.

Our company, as a matter of policy, has pretty much stayed away from the image quality questions, leaving that to people like yourselves. I will say that it's a very multi-parameter problem.

SB: Experimenting with different ink and paper combinations can yield a rich range of image tones, but can yield unexpected image stability issues. I found I really liked the way Canon printers produced black and white images on Epson Heavyweight Matte Paper, but the images were not very stable.

HW: Yes, I think a good example of that is if you like the flat matte papers as many photographers do, that if you were to print on Somerset Enhanced using dye-based inks, you can produce absolutely stunning prints with a high D-max. However resulting prints are extremely unstable with dye-based inks on every platform, including the Iris printer. After you make the print and look at it you'll say great, but six months of display later it may look anything but great. There's no way to know that out of the box—it gets back to the point where if you don't have specific information available about the permanence of your ink media combination, you're potentially going to have a disaster.

I think one of the real differences that has developed in photography in the past few years is the ability of the average photographer to have the ability to make their own color prints. That was simply not possible before without a major investment in equipment. Most photographers took their film to a lab. It could have been a minilab or a higher-end professional lab. But the choice of paper usually was not one that the photographer made. They might make a choice of surface, like high gloss, semigloss, or luster, but the paper was the same. Now that has completely changed.

If you walk into CompUSA or Best Buy, there's a huge shelf full of paper and the end user is now actually choosing and buying paper to make color prints, and that never existed before in photography. That's one of the things that's become confusing because people have been offered a huge array of different papers at different prices, most of them claiming to be excellent in every respect. You even see it on the Kodak Ultima ink jet papers, which, on the front of the package, says it makes "long-lasting prints" as sort of a general statement.

Certainly one thing I would advise people to be very aware of is that the papers made by Kodak and the other third-party companies—that is other than the printer manufacturers themselves—are all advertised, without exception, as being suitable for all printers. It means that in the formulation that they are not optimized for any particular ink set or printer. They are using a "one size fits all" approach and that means that they don't fit any of them well compared to what the printer manufacturers can do because they design their papers specifically for their ink sets.

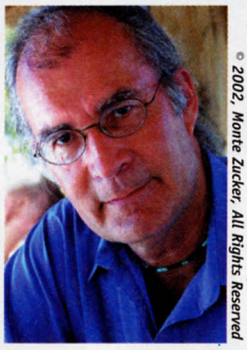
I think that nowhere is that more evident than in HP's new photo inks and Premium Plus Photo Paper, which is available in both a gloss and matte surface. At this point in history, I would consider that ink and media match to be the most highly engineered match of an ink set to a paper in terms of permanence. And it kind of points where I think the field is going. These are highly specialized products and, particularly with the dye-based inks, a proper match between ink and media is critically important.

This is all something we didn't have to deal with in traditional photography. People were buying process RA-4 color prints and they were made with either Kodak or Fuji paper, or it might have been Konica or Agfa paper. But whatever the lab used, that's what you got. Now you have almost infinite combinations of inks and papers that can be used. And I think many photographers will do exactly what you just described. They will try different papers looking for a certain surface or tonal quality at a price they like and when they find that combination that's what they will print on. But image permanence is sort of a hidden thing. You can't see how long an image will last just by looking at the print. ◀

Henry Wilhelm's informative website is www.wilhelm-research.com.

Chris Maher and Larry Berman are photographers, writers, and web designers. Visit their websites www.BermanGraphics.com and www.InfraredDreams.com.

editor's notes



The issues surrounding the archival keeping qualities of photographic materials have always dogged us. During the development of the photographic process in the 19th century the problem was not capturing a moment but keeping it from fading once it was again exposed to light when viewed. Only when "hypo" was discovered could the undeveloped silver halides be removed from the light sensitive emulsion, making the image somewhat impervious to further deterioration. That discovery made photography possible. But other matters contributed to the keeping problems with photographs—the tarnishing of silver, the fading of dyes used in creating color, the poor base support materials, and the increasing effects of pollution, which attack both paper and image layers in the print. Indeed, even high temperature and humidity became a storage issue, as did the album pages and containers in which photographs were held, which could emit harmful gases.

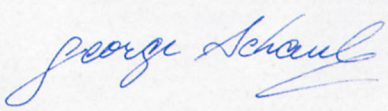
While some black and white photographs have withstood the test of time, color has its own particular issues. Anyone who used color film in the 1950s, '60s, and even the '70s knows what this is about. Of all the color slide films only Kodachromes seem to have done well, given they were stored properly. My father made photographs of my older brother in the early '50s on Kodachrome 4x5, and they still hold color and density as if they just came out of the lab. The same goes for black and white prints on fiber paper I made in the early '70s. I was a stickler then (and now) about archival processing procedures, and those extra steps have paid off.

Now nothing lasts forever, but at least I'd like photographs I have made in my lifetime to last as long as I do, whatever the good Lord figures that out to be. But sadly, that's not the case. We have seen some major improvements and awareness about archival quality materials from manufacturers, and that's good and has resulted in some amazingly durable films and papers. The same goes for storage materials, and today we have a number of firms offering nothing but archival quality albums, pages, boxes, and slide storage pages. But the fact remains that many of the images made in the not too distant past will fade and disappear, many before we even have a chance to relive those memories in our old age.

Along comes digital and a whole new set of problems...and solutions. On the good side, digital can help us rescue old photos with ease. Get yourself a scanner, some Applied Science Fiction (now Kodak) software in the scanner for removing minor cracks and surface defects and restoring color, and you can get all those old photos out and spend a few weekends making the old photos new again. In the old days you'd have to set up a copy stand or send the work out to an expensive studio for copy and restoration work.

On the bad side, the archival side of digital is a still an open question. How long do CDs last? What about DVDs? Are all digital printers and ink and paper combinations equal? Will your back-up systems be able to be read 20 years from now? These are issues we'll be exploring in the months ahead.

Which brings us to what I consider a very important article in this month's issue, our interview with Henry Wilhelm on digital print archival quality. Wilhelm is considered one of the top people in the field of archival and conservation research. His efforts have opened many eyes into what has to be done to ensure that our precious memories are available for those who come after us. He is a true friend to photographers and everyone who values the image. I encourage you to read the article and to visit Wilhelm's website at www.wilhelm-research.com.



Printed in the U.S.A.
 For information on display rates or media kits, please write: ***SHUTTERBUG***, 5211 S. Washington Ave, Titusville, FL 32780, (321) 269-3212. Subscriptions: US—One Year (12 issues) $22.95 (Periodicals), $75 (First Class), Canadian/Foreign $36 (Periodicals), $165.00 (Air Mail). Single Copies $3.99 (US), $4.99 (Canada). (800) 829-3340.
Canada Post International Publications Mail Product (Canada Distribution) Sales Agreement No. 1022849

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CONTENTS

November 2003 • Volume 33 • Number 1 • Issue 398

Features

Page 102

Page 64

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Test Reports

Page 72

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columns, departments & reader services on page 6

Shutterbug (ISSN0895-321X) is published monthly for $22.95 per year by PRIMEDIA Consumer Media & Magazine Group, 200 Madison Ave., New York, NY 10016. Periodicals postage paid at New York, NY and additional mailing offices. POSTMASTER Send address changes to SHUTTERBUG, PO Box 421190 Palm Coast, Florida 32142.

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