Image Permanence – Comparing the Technologies

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ABSTRACT

In today's market, the consumer has a wide array of technologies to choose from when making photo prints. The most prevalent of these include piezo inkjet, thermal inkjet, silver halide, color electrophotography and dye thermal imaging. Some of these are available as inexpensive printers for the home or business, and some through use of a kiosk or retail supplier. This presentation provides the results of testing of representative samples of each of the technologies that are readily available to consumers. Due to a growing awareness of image permanence, consumers are recognizing the value of using a technology that will provide a lasting image. Testing was performed using emerging methodologies for establishing performance in this important area. The tests include the effects of long-term UV exposure, gas fastness, dark keeping and humidity exposure. Test results are based on colorimetric values rather than densitometric values since the former are more likely to be useful to the consumer. A comparison of each technology and its image permanence performance is made and conclusions are drawn.

INTRODUCTION

The focus of most image permanence testing has been on silver halide and then inkjet. Over the years there has been a considerable improvement in the stability of both of these technologies, at least partially as a consequence of the publication of image permanence test information. Today's consumer has been encouraged to recognize that inkjet prints from some recent products will last for a lifetime. Market intelligence studies have shown that many consumers have a significant resistance to using a desktop printer to make photos and many continue to use photo processing minilabs employing traditional silver halide technologies.

At the same time, and perhaps in response to this issue, there has been a rise in the use of photo retail kiosks. Some of these kiosks use inkjet and some use thermal media to make photo prints. Finally, anyone observing the digital printing business for the past five years or so cannot fail to notice the proliferation of small color laser printers. These printers are accessible to the consumer either at home, or in many cases, at their place of work. When the first copiers were introduced many years ago, it was found that workers made a high proportion of copies for their own use rather than for business use. It is likely that the same phenomenon will occur with color laser printers.

The visual image quality performance of these technologies is not compared in this study. It can be argued that since some of the technologies are more capable than others of producing photographic images, then only those processes capable of producing the best images should be included This argument overlooks the fact that there is no universally accepted standard for photographic image quality and that for some digital photo applications, image quality is less important than cost and/or convenience.

METHODS

The methodologies and parameters for assessing image permanence are not yet embodied in industry standards, but the broad outlines and requirements have been published for some time[i] [ii] [iii]. The test methods used in developing this report are generally accepted and have been previously used by this company and others. The meaning of the results is perhaps less well accepted. In the past, we have used accelerated tests, allowing for reciprocity, to project print life in years.

Any projection of print life must assume constant conditions, or at least conditions that can be integrated to represent an equivalent of constant conditions. That set of constant conditions is the basis for all print life projections, and it is a good method for making scientific comparisons for the purpose of ink, media and technology development. The consumer however is very likely to assume that his or her photo will actually look the same for the stated print life. This would only be true of course, if that consumer used the exact exposure conditions specified in the extrapolation of the test results.

The light exposure conditions for a given photo print in a given home may average from less than 1 lux to 800 lux depending upon exactly where the photo was placed. The 1 lux condition might be true if the photo were kept in an album. The 800 lux average condition might prevail if the photo is on a wall opposite a very large window that allows direct sunlight for more than 8 hours per day, and the room includes skylights. To further complicate the situation, these prints could experience a combination of 'indoor' and 'outdoor' light exposure due to their position. This varies the amount and wavelength of the UV light that the prints receive, and since this is often the key component that affects the dyes or polymers in the ink, it can also affect the rate of fade[iv]. Finally, fade effects may also be affected by variations in temperature, humidity and industrial gas exposure.

The implications for this range of exposures on real print life are dramatic and the presentation of a single life projection to the consumer may be very misleading. It is obviously not the intention of TPR, other test labs, or printer suppliers to mislead consumers in that way. Therefore we will modify our interpretation of the results of this test to accommodate a less technical user.

In a departure from our previous reporting of these test data, we will be assessing changes based on colorimetric measurements rather than changes in density. Secondly, until a better solution is generally accepted, we have decided to make our independent projections of print life in comparative rather than absolute form.

In the past, we and other test centers have based our image stability results upon densitometry measurements. In particular, we have generally used the variation of Status A densities of primary colors from one or two starting points. Consumer photos do not often include primary color density areas but do include wide tonal scales. It has been found[v] that for such images, colorimetric measurements can provide a reliable measure that correlates well to densitometry. The superiority of colorimetry in the analysis of the full tonal scale and ranking comparative results has been pointed out and a colorimetric standard has been proposed[vi]. This method, though comprehensive, has not yet become generally accepted.

Modern reflection spectrophotometers that are used to make color measurements of photo prints provide a very large data set. This data set includes at least Status A and L* a* b* values for each measured area. In order to assess image stability it is necessary to measure a large number of areas that can represent the full tonal range of the system. Interpretation by a consumer of the resulting massive data set is practically impossible without some further reduction. The first reduction that we have used is to calculate the ΔE values for each measured area of the print at each test condition.

In the initial CIE definition, a ΔE of 1 was intended to define the smallest perceptible change in a color that could be detected by a human observer. In practice, and especially for untrained observers, it is more likely that the average consumer would not detect any differences less than a ΔE_{max} value of 5. The casual observer would need a basis for comparison to see even this difference. That is, unless an 'original' was compared with a test print, the casual observer viewing the test print might find nothing wrong with a print that had even greater variance from an 'original'. In the analysis of our results, we have identified the color area that changed the most and used that as the endpoint. So, for some samples that may have been the 100% magenta, whereas for others it may have been the 40% cyan.

The other criterion that has been used in evaluating the data from this test is an 'endpoint'. An endpoint is generally understood to mean a point where the print has changed an unacceptable amount. In this study we have used ΔE_{max} of 15 as the endpoint. This endpoint was based on guidance from endpoint illustrations in the recently issued ISO standard 18909:2006[vii]. We recognize that for certain tonal areas, lower endpoints may be preferred, but a ΔE of 15 serves well for comparison purposes for the complete range. Again, we have identified the color patch that changed the most.

MATERIALS

For this study printers were selected that are representative of the various technologies available to consumers for making photo prints. In each case, where possible the manufacturer recommended supplies were used and the system settings were selected based on the supplies used.

TYPE	Printer	Media
Desktop Inkjet	Kodak EK5300	EK Ultra Premium Photo
	Epson RX580	Epson Ultra Premium Glossy
	HP Photosmart C5180	HP Premium Plus Photo
	Canon MP600	Canon Photo Paper Pro
	Lexmark X9450	Lexmark Perfect Finish Photo
	Epson CX7800	Epson Premium Photo Glossy
Photo Kiosk	HP Kiosk	Inkjet
	Kodak Kiosk	Thermal
	Sony Kiosk	ZUPC-R154H Thermal
	Pixel Magic Print Rush	Altech CW-01 Thermal
	Mitsubishi CP-9550	Thermal
Photo Lab	Kodak	Kodak Royal
	Fuji	Fuji Crystal Archive
	Kodak	Kodak Professional Super Endura
Desktop Laser	HP Color Laserjet 2600	HP Photo Paper Laser Glossy
	Konica Minolta 2500W	HP Photo Paper Laser Glossy
	Dell 3010cn	HP Photo Paper Laser Glossy

Where possible and appropriate we purchased the printer and supplies at retail and made the prints ourselves. Otherwise the prints were made in the normal retail process. Nine copies of each print were made, one for reference and the others for exposure in the four stability tests. Each stability test exposed two identical prints for each printer/media set.

EXPERIMENTAL

Four stability tests were performed as follows:

Light Fade

Light stability was assessed using a custom fixture that exposes the print samples to filtered radiation from high output daylight fluorescent tubes. The environment at the sample plane is maintained at 24 ºC ± 1.5ºC and 50% ±5% RH. Uniformity of exposure was maintained by relative motion between the samples and the lamps, and by using only the central section of the exposure plane. In addition, the samples were re-arranged every three days to avoid any potential hotspots.

The two light fade tests were carried out using 50 kLux exposure through polycarbonate filters and 35 kLux exposure through glass filters.

The light fade tests used images that consisted of a series of 57 color patches at various tones ranging from 0 ink (media background) to 100% ink for each color and for tonal ink combinations. Each patch on each of these samples was measured at intervals of 0, 14, 28, 56 and 112 days using a Gretag Macbeth Spectralino spectrophotometer.

Gas Exposure

Gas exposure was assessed using an Orec ozone chamber with an 03DM-100 ozone monitor and environmental controls. The system exposed the samples to 1 part per million ozone at 24 ºC ± 1.5ºC and 50% ±5% RH. Light was excluded from the chamber during the exposure test.

The ozone test used the same image as the light fade tests. Each patch on each of these samples was measured at intervals of 0, 14, 28, 56 and 112 days.

Humidity Exposure

Humidity exposure was assessed using a Tenney Benchmaster environmental chamber with Tenn Trol II controller and a Honeywell data recorder. The system exposed the samples to 24 ºC ± 1.5ºC and 80% ±5% RH. Light was excluded from the chamber during the exposure test.

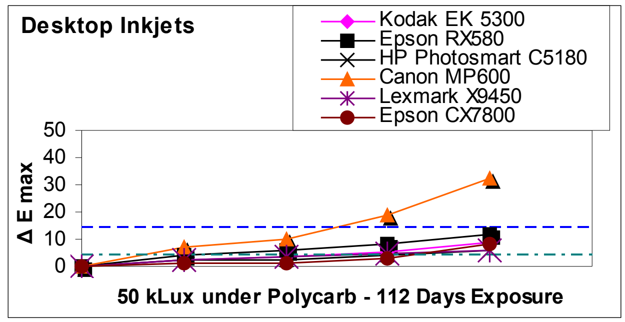
The humidity test used the same image as the light fade tests. Each patch on each of these samples was measured at intervals of 0, 14, 28, 56 and 112 days.

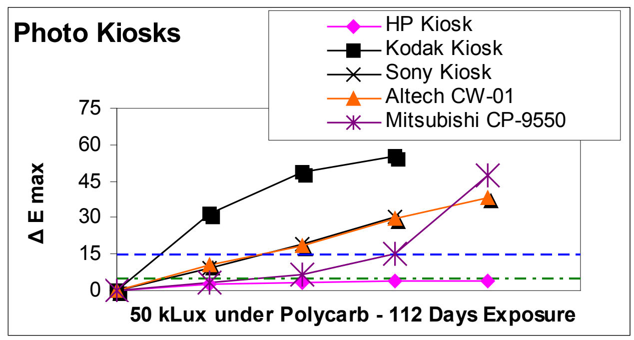
In addition to the basic test image, an additional image was exposed in the humidity test. This image included a photo together with some test color patches with contrasting lines overlaid. The purpose of this image was to make a visual assessment of color change and also to assess color bleed. These images were examined visually in a Gretag Judge II Light bench and scored from 0-3.

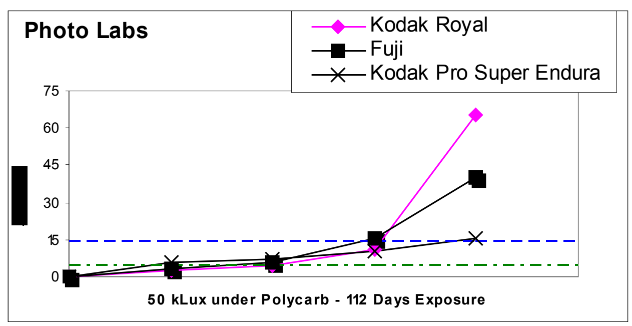
RESULTS

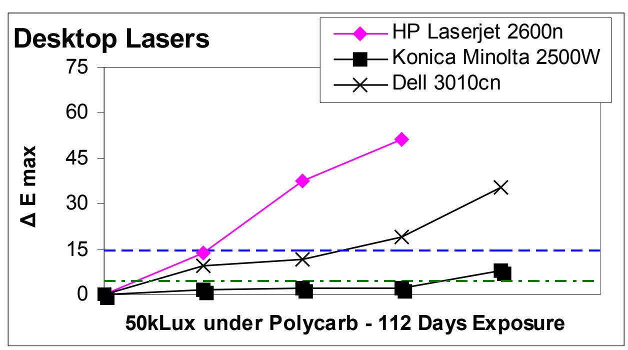
Light Fade

The results for the light exposure through polycarbonate filters are summarized in the first set of graphs below. It can be seen that only the HP kiosk using inkjet technology meets the first criterion of ΔE_{max} less than 5. Some examples of each technology are capable of meeting the second endpoint, but many fail before that point. Desktop inkjet printers provided the best results as a group.

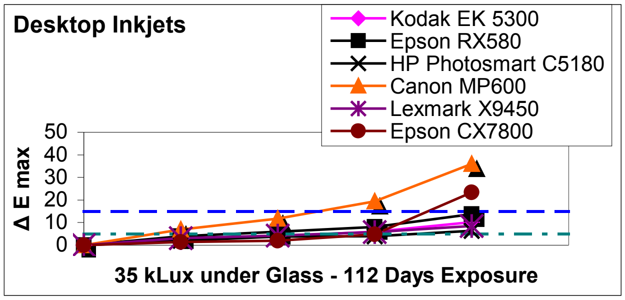


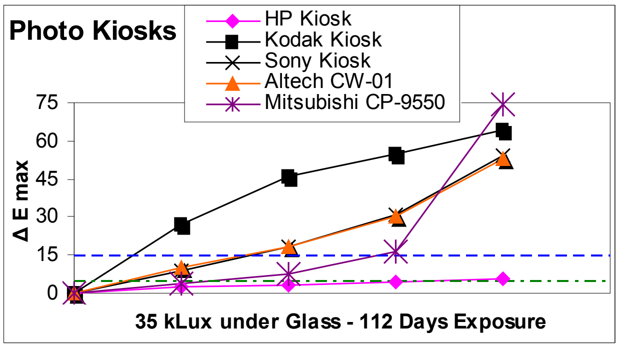


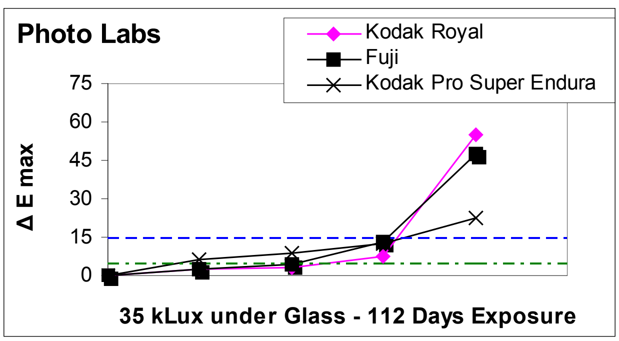


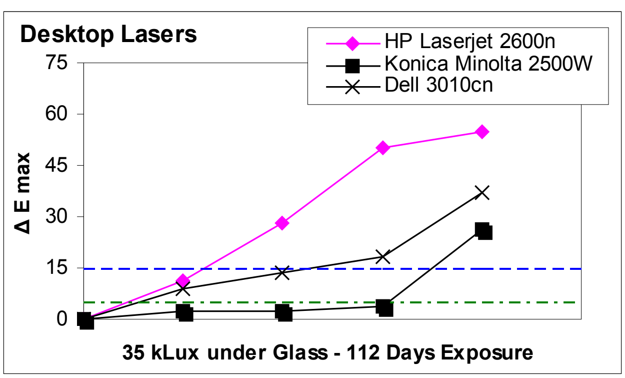


The results for the second light exposure test at 35 kLux through glass filters are as follows:





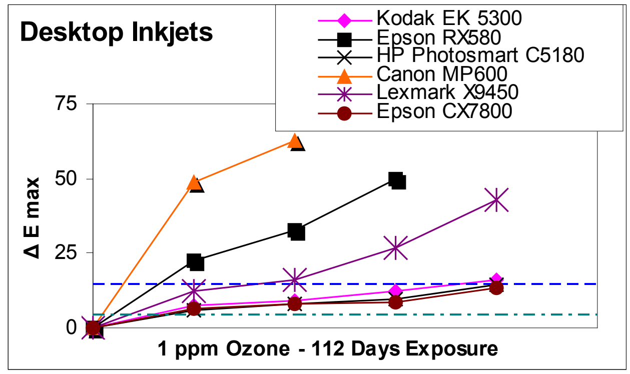


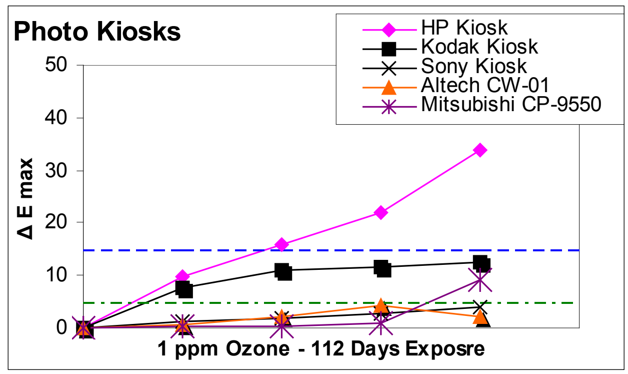


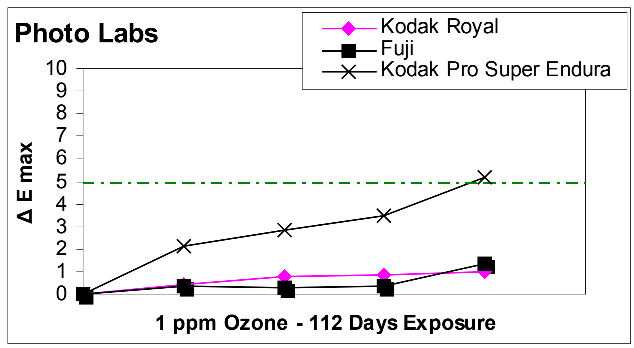
From these results it can be seen that few systems are able to meet the final endpoint where most observers would find the color change unacceptable. Those that did meet this requirement were all inkjet systems.

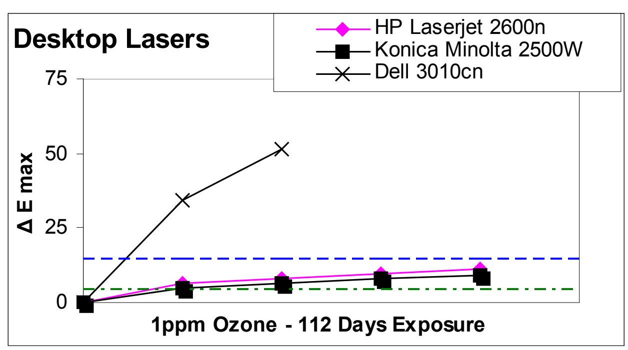
Gas Exposure

The results for gas exposure are summarized in the following graphs:





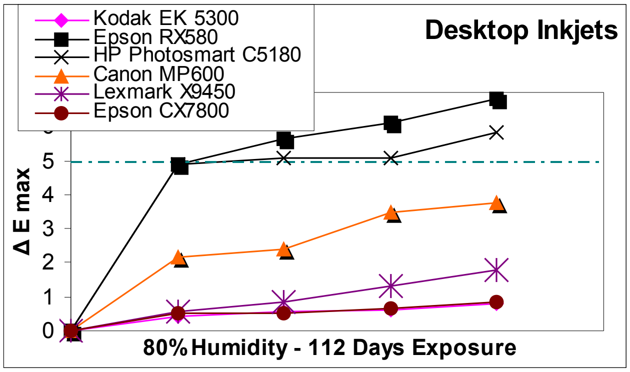


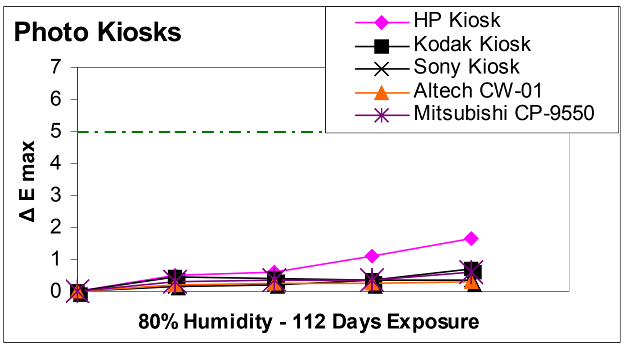


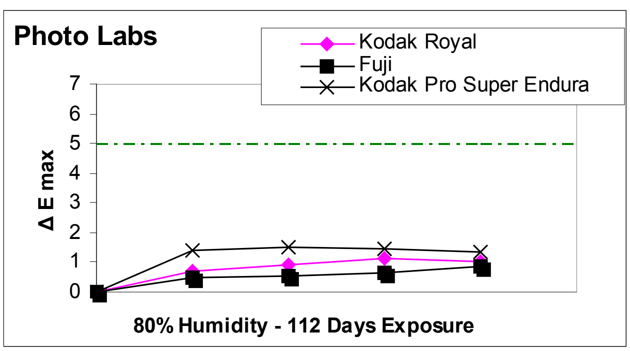
Only the silver halide samples from photo labs were able to meet the entry endpoint. That is, for all other technologies, most observers would be able to detect color changes when comparing the exposed samples to an original print. In addition, some print samples from each group except the photo labs would exhibit unacceptable change after this gas exposure test.

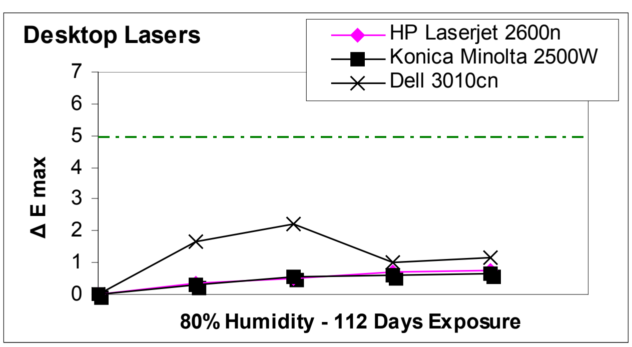
Humidity Exposure

The results for ΔE_{max} change due to exposure to 80% humidity at 24 °C are as follows:









For this exposure, only two of the desktop inkjet samples exceeded the threshold endpoint. That is, for all except two desktop inkjet samples, most observers would be unable to detect any color change when compared to the original print made using any of the tested combinations.

In addition to the ΔE measurements, we also assessed color bleed on a different test image exposed to the same humidity profile as the color change test strips. The image included color lines printed in contrasting color solid blocks. These results are summarized below:

TYPE	Printer	Bleed Score	Line	Solid	Other
Desktop Inkjet	Kodak EK5300	0			
	Epson RX580	0			
	HP Photosmart C5180	0			
	Canon MP600	0-1	C	M	
	Lexmark X9450	0-1	C	M	
	Epson CX7800	0			
Photo Kiosk	HP Kiosk	0			
	Kodak Kiosk	0			
	Sony Kiosk	0			Overlaps
	Pixel Magic Kiosk	0-1	C	M	Overlaps
	Mitsubishi	0			Overlaps
Photo Lab	Kodak Royal	0			
	Fuji Crystal Archive	1	C	M	
	Kodak Super Endura	0			
Desktop Laser	HP Color Laserjet 2600	0			Jaggies
	Konica Minolta 2500	0			Jaggies
	Dell 3010cn	2	C	M	Jaggies

The visual assessment was rated using the following guide:

0 – No Bleed
1 – Slight Bleed
2 – Moderate Bleed
3 – Heavy Bleed

Very few of the prints showed any problem. Where there was a very slight bleed, it was between the cyan and magenta colors and was not likely to be unacceptable to most observers.

These patterns did incidentally highlight two image quality problems that that would be fairly easily observable. The dither pattern used in the laser printers tended to create jagged edges on the color lines and these edges were easily observable. Some of the thermal prints from the kiosks seemed to not be printed exactly orthogonally and this resulted in a slight overlap where a new print line begins. This was also observable, though less so than the jagged lines on the laser prints.

Color Change Summary

Each of the lines on the graphs above represents the ΔE_{max} change for a given process and media combination and in each test. It is useful for color scientists and supplies development personnel to know which colors were most affected by a given test factor.

The table below lists the colors that were most changed for each combination and test.

TYPE	Printer	35kLux PC	50kLux Glass	1 ppm Ozone	80% Hum.
Desktop Inkjet	Kodak EK5300	M	M	MC	M
	Epson RX580	Y	Y	M	Y
	HP Photosmart C5180	Y	Y	YC	C
	Canon MP600	Y	Y	Y	Y
	Lexmark X9450	M	MC	KC	C
	Epson CX7800	MY	MY	MC	Y
Photo Kiosk	HP Kiosk	M	MC	C	KY
	Kodak Kiosk	K	K	C	KY
	Sony Kiosk	K	K	C	CK
	Pixel Magic	CK	CKY	MK	MY
	Mitsubishi CP-9550	M	MY	YCK	KM
Photo Lab	Kodak	YC	Y	K	K
	Fuji	MY	MY	CMK	YMK
	Kodak	Y	Y	C	YK
Desktop Laser	HP Color Laserjet 2600	M	M	M	M
	Konica Minolta 2500W	MCY	KMY	C	C
	Dell 3010cn	Y	Y	K	YK

In most but not all cases the problem was most obvious in the 100% patch for a primary color. In some instances more than one color was affected and this might then result in the worst-case measurement occurring on a secondary color. In those instances we have listed the primaries that made up the secondary.

The same primary color problem was not found in all examples of a given technology. For example, in the inkjet group there were examples where magenta and cyan failed, but there were other inkjet systems where yellow failed most.

CONCLUSIONS

Any print that failed the upper ΔE_{max} within the 112 day period of exposure of any of the tests described herein would show obvious color changes to most observers.

Due to the tremendous variability in exposure conditions in the consumer environment we have not attempted to assess actual print longevity under these conditions. Suffice to say that the tests used in this paper are very similar to those used by TPR and others to project print life in the 50 to 100 year range under normal exposure conditions.

What the results do show as far as expected image stability or longevity is concerned, is that the consumer is currently presented with a mixed bag. Even within a technology group, under the same conditions of exposure, image stability results vary widely and the consumer cannot choose a winning technology or process.

Technically, what that means is that in the image permanence realm, all of the technologies and all of the implementations still have a long way to go in order to provide long term stability for the consumer.

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[i] E. Zinn, E. Nishimura, and J. Reilly, "Effects of Pollutant Vapors on Image Permanence." PICS 1998 274-281.

[ii] E. Zinn, E. Nishimura, and J. Reilly, "High-Intensity Fluorescent Light Fading Tests for Digital Output Materials' Proc. NIP 15, pp. 416–20 (1999).

[iii] E. Baumann and R. Hoffmann, "The Characterization of Humidity Sensitivity of Ink-jet Prints', Proc. NIP 19, pp 402-405 (2003).

[iv] G. v Ackere, H. Kanora, M. Graindourze, H. Friedel, and S. Lingier, "Interpretation of Life-of-Display Prediction Calculated from Accelerated Light Fading Tests" Proc. NIP 17, pp. 213-217 (2001).

[v] R. Hoffman, E. Baumann, and R. Hagen, "Densitomety vs Colorimetry for Permanence Investigations" Proc. NIP 17, pp 209-212 (2001).

[vi] H. Wilhelm and M. McCormick-Goodhart, "A New Test Method Based on CIELAB Colorimetry for Evaluating the Permanence of Pictorial Images", Wilhelm Imaging Research July 2003.

[vii] International Organization for Standardization, TC 42-Photography – 18909:2006 Processed photographic colour films and paper prints - Methods for measuring image stability.