Humidity Effects on Light Fastness Testing

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Abstract

In accelerated light fastness testing the display life environment is simulated by choosing defined constant humidity levels or by cycling between a dry/light and a humid/dark level. The humidity level is a factor that may cause dye diffusion effects on one hand and different degradation speed of the colorants on the other hand. The right choice of the humidity level is important for display life testing and display life predictions.

In a group of typical inkjet media/ink combinations some exhibited a strong influence on the humidity cycling conditions whereas others showed little effect. As different colorants have a different sensitivity to humidity their relative ranking change when the test parameters change. This changes the colour balance of faded prints and affects the display life predictions drastically. The first fading colour, as well as the colour shift in image degradation are shown to be a function of the sample humidity during the light exposure.

On the basis of light fastness measurements in humidity cycled system over several years the statistical variation for display life of a typical inkjet print has been determined which gives an indication about the experimental errors of a cycled system. A proposal for a dual humidity level test is made.

Introduction

As several hardcopy technologies have reached image quality similar to photography, end users want to know their archival stability and display life. The permanence of digital media, especially hardcopy media, has been a controversial topic recently.[1] As life expectancy of many hardcopy prints are well beyond several tens of years, direct real-life ageing is no longer an option. Accelerated tests have to be used to predict stability.[2] Predictions are difficult for several reasons.[11] There is concern that the print may exhibit reciprocity failure when exposed to a high dose of the environmental factor for example, light[10,12,13] or ozone. Secondly, at least 4 different environmental factors have to be investigated for an overall print life prediction, namely the effect of heat, humidity, environmental pollutants, and light exposure. The accelerated tests are preferentially done keeping 3 of those factors constant and varying the fourth until a pre-determined end point is reached. The results are then applied to the much lower exposure levels of the factor encountered in real-life. The predictions are only applicable to environments that match the environmental conditions of the test. For a light exposure test, for example, this may be 30°C as sample temperature and 50% r.h as sample humidity as well as an ozone level of < 5 ppb. However, most natural display environments do not exhibit such stable conditions and temperatures. There are also many natural indoor environments that are either more dry or more humid or exhibit higher level of pollutants than the standard environment assumes. Interaction and non-additivity between the environmental factors have been reported for light, ozone and humidity.[3] This papers extends an investigation of the effect of humidity on light fastness test of inkjet materials and the interaction of these two environmental factors.[4]

Experimental Setup

The sample set for the humidity cycling test comprised four different polymer IJ media printed with five different commercial aqueous dye based ink sets.

Long-term repeatability tests were done reference sample made up from a proprietary polymer IJ media printed on a typical four color inkjet printer with known and fixed composition of proprietary ink.

All samples were let to dry for several days in ambient conditions.

Table 1: Light Fastness Test Programs

		A		B	
		Cycled		Cycled	
cycle time	[h]	3.8	1	3.8	1
Xe lamp	[klux]	100	0	100	0
black panel	T [°C]	58	25	58	25
	Rh [%]	14	80	14	70
white panel	T [°C]	40	25	40	25
	Rh [%]	33	80	33	70
Chamber	T [°C]	36	25	36	25
	Rh [%]	40	80	40	70
sample *	T [°C]	50	25	50	25
	Rh [%]	20	80	20	70

* approximately

For light fastness exposure, we used an Atlas ci-4000 and an Atlas ci-35 weatherometer with 6 mm window glass filtered Xenon light. The two conditions for the cycled test programs are represented in table 1. In the humidity/light cycled programs the test chamber varies between a dry/light phase and a dark/humid phases. Sample humidity and temperature was assumed to correspond to chamber humidity in the dark phase. For the light phase, the sample temperature was assumed to be between the white and the black panel temperature. Sample humidity was approximated for the given environmental conditions.

Cycled environmental conditions re-moisture the exposed samples to simulate natural day/night cycles. Cycled test have been used for photographic materials for many years and have been correlated to real life fading.[5] Filtered xenon arc light has approximately the same spectral composition as average home light.[6] For indoor light with a very low UV light content, Mluxh can be used to define exposure condition, as long as the spectrum of the light source is constant.[7]

The test image was composed of full colour patches at 0.6 and about 1.5 density for all primary and secondary colours, as well as a grey wedge.

Results

Long-Term Experimental Variation of a Cycled Light Fastness Test

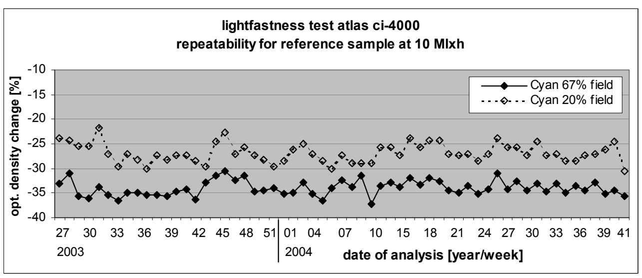

Figure 1. Light fastness testing– long-term repeatability

Over two years of light fastness testing, more than 50 IJ reference samples were exposed in the Atlas with the parameters listed in table 1 as program A. After 10 Mluxh of exposure, the density changes on the reference samples were recorded. Figure 1 shows the percentage change in cyan density that resulted from the repetitive test.

The cyan density changes shown are based on two density levels of pure cyan patches, which are printed by the same ink but with different dot percentage, one to about 1.5 density, the other to 0.6. This relation between dot coverage, density and density change upon exposure known form half-tone printing, was described in [8,9] and is given by equation 1.

$$D = -\log\left[c\,10^{-D_{max}} + (1-c)\right] \qquad (1)$$

c = relative covered area by the dots [-]
Dmax = Optical density at 100% coverage [-]

For the same exposure, two patches with different dot coverage will show different percentage density losses. The more of the area is covered by dots, the more of the colorant is exposed to light and the bigger is the relative loss in density of the printed patch, as is confirmed in figure 1.

Hypothetical display life predictions and its error were calculated for the two cyan patches using the following assumptions and equation (2):

- 450 lux indoor indirect daylight over 12 h daily
- calculation of light exposure to end point by linear interpolation
- end point at the optical density change of -25%
- +/- 2s represents 95% of all results in normal distribution

$$Lt = L\exp \cdot \frac{1000}{450 \cdot \frac{12}{24} \cdot 365 \cdot 24} \qquad (2)$$

Lt = life time [years]
Lexp = light exposure to end pointe [klxh]

The hypothetical display life predictions and their standard deviation based on the long-term test of figure 1 are shown in figure 2 and numerical data are given in table 2. Based on only one colour and only taking long-term repeatibilty into consideration, display life can vary by around 10%.

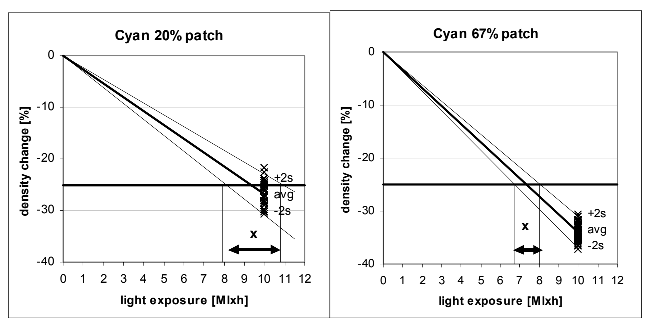

Figure 2. Interpolation for display life calculation

Table 2: Variation in Display Life Prediction

		OD change [%]	light exposure to failure [Mlxh]	life time [years]
Cyan 67% patch	Average	-34.0	7.4	3.8
	stdev	1.5	0.3	0.17
	2s abs.	3.0	0.7	0.34
	2s rel.	9.0	-	(9.0%)
Cyan 20% patch	average	-26.9	9.4	4.8
	stdev	2.0	0.7	0.37
	2s abs.	3.9	1.4	0.73
	2s rel.	15.3	-	(15.3%)

Experiments at Different Environmental Conditions

Variations Dependent on Extent of Humidity Cycling

The influence of humidity in cycled testing was studied using the Atlas exposure unit and program A and B on an experimental print set with 5 printers and 4 media. The chamber changed its humidity in case A between 20% (light phase) to 80%rh (dark phase) and in case B from 20% (light phase) to 70%rh (dark phase). All other parameter were kept constant.

Figure 3 and 4 show the results of the tests from the two exposure conditions. Figure 3 is the plot of the pure cyan and the pure magenta patch density change after 10 Mluxh exposure for the 4 media on one particular printer. The change in humidity during exposure leads to differences in light stability for the different ink/media combinations. In most media, the density change of cyan is higher in the test with higher humidity cycling. The density changes in media 4 are too small to be significant for both test conditions. Contrary to cyan, the density changes on the magenta patch are lower with higher humidity in cycling. The colorants react in the opposite way to a change of humidity in the test.

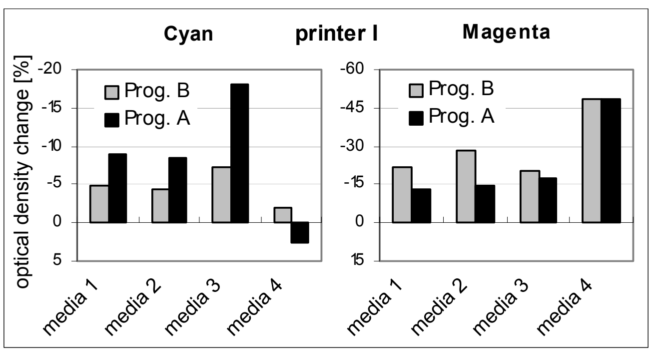

Figure 3. Density changes after 10 Mluxh light exposure for condition A and B for two colorants.

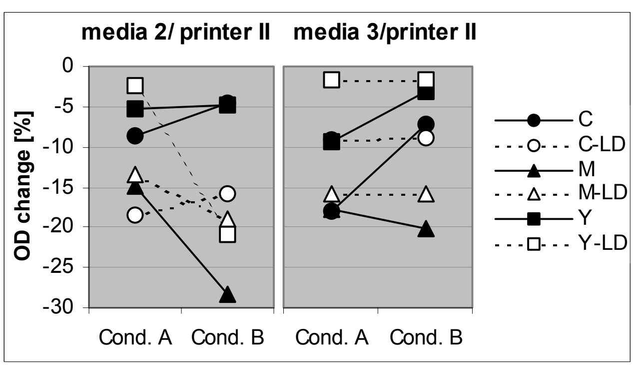

Figure 4. Density changes after 10 Mluxh light exposure for media 2 and 3 on printer II under condition A and B.

Density changes of the 4 media were determined for the colours light cyan, dark cyan, light magenta, dark magenta, light yellow, dark yellow. In figure 4, the changes in all colours are plotted for one printer and two media. This graph shows that each colour reacts differently to the change of test conditions and that the two media behave differently as well. The colour balance of the faded prints would be very different depending on the conditions used for the test. Media 2 would fade to a greenish yellow under high humidity and to a cyanish colour under lower humidity.

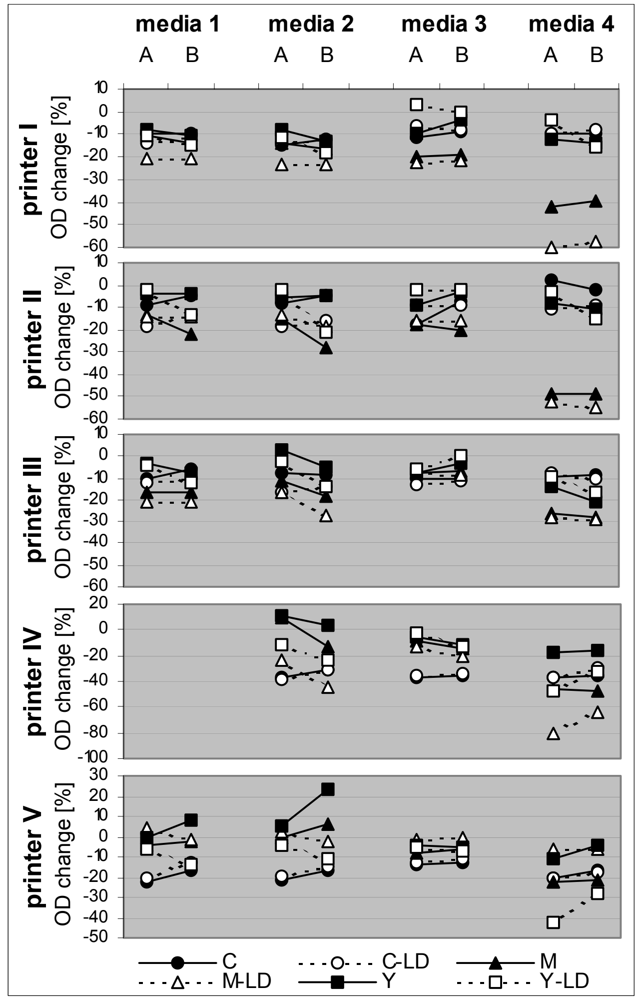

Figure 5. Density changes after 10 Mluxh light exposure for condition A and B for all colorants and all printers.

Results on all printers and all colours are shown in figure 5. Some general trends can be recognized, but there is no clear rule on how the density will change on a print patch in response to higher humidity during the test. Media and colorant both have a considerable influence.

Conclusion

Long-term tests showed that display-life predictions can be made with about 10% of repeatability if all other parameters are closely controlled.

However, when changing the humidity cycling condition in light exposure tests, dye diffusion and the sensitivity of dye degradation to humidity play a role and much larger variations are encountered.

The variation of only 10% of cycled humidity conditions in accelerated test resulted in drastic changes for some sensitive colorants. No general trend could be found that all investigated samples would follow. The density change would be positive for certain ink/media combinations and negative on others. The effects of humidity changes in light exposure are not easily predictable and attempts to correlate them with dye diffusion tests failed. There is a strong dependence on the ink/media interaction as well. The colour balance and final colour shift of prints will vary depending on the humidity that prevailed during the exposure. This can lead to very different results in overall display life prediction made in different labs or using different experimental equipment.

One problem with the cycled test is that the sample humidity during exposure is not well defined. The sample is re-moistured during the dark phase while cooling down, then dries out again when light phase starts. This leads to varying levels of moisture in the sample. Uncycled test have the advantage to have a better defined sample humidity. Bearing in mind the strong dependence on sample humidity, fixed humidity test are preferable.

The experimental results show that display life predictions are only valid if the sample humidity during exposure equals the real-life condition. This will be difficult to achieve for all the various humidity conditions encountered in the real world. A feasible approximation maybe to test at least at two very different and fixed humidity levels, for example 50% and 70% r.h. This would ensure that sample having a very strong light degradation with humidity could be identified.

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J. Reber studied chemistry at Burgdorf engineering school in Switzerland. He worked for several years in analytical chemistry as test engineer and group leader in a private service laboratory. In 2003 he joined ILFORD and works in the field of image science and performance in research and development. The focus of his activities is in test methods and result characterization for inkjet media.