# Improved Dark Storage Test Method, part 2

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## Abstract

*Continuing research into last year's proposal for a new test method to improve the dark storage test of print images has led to further improvement in the sandwich method. Based on feedback, several additional test materials were investigated, with the most promising candidate being a clear polyester film. This material was most effective in preventing cross contamination between samples and in eliminating the influence of airflow. This research is part of ongoing work contributing to the development of standardized test methods for image permanence.*

## Introduction

Research conducted during the past few years has identified several noise variables which affect the consistency of thermal (i.e. dark storage) test results with respect to media yellowing, especially porous photo papers. Alternative testing methods have been investigated to explore ways to reduce or eliminate some of those noise variables. A promising method presented last year looked at sandwiching test samples with identical media in order to isolate the test sample from some of the environmental noise factors in testing, such as airflow and cross contamination from other test samples [1, 2]. This paper continues that research by investigating different sandwiching test materials.

## Experimental Results and Discussion

The sample preparation and test equipment for this research remained consistent with the prior study [1] except a new sample bracket holder was created to hold 4x6 inch samples. In a direct comparison between the original and new larger test brackets, using 5 different media with 2 replicates each, it was found that the rate of media yellowing of sandwiched test samples using the new larger bracket was equal to within several percent of the rate of media yellowing in the smaller Xenon sample bracket.

Based on feedback from the earlier study, several alternative sandwiching materials were investigated: plain paper only, Whatman Grade No. 1 Filter Paper only, and then a hybrid approach of placing the Whatman Grade No. 1 Filter Paper between sandwiched media (5 layers total instead of 3). Several commercially available porous photo media were selected in this preliminary study, and are designated by the letters N, U, and P. The samples were tested at 85C/50% RH and measured at 160 hour intervals. The test was conducted first without additional samples present in the chamber, and then a follow up test was conducted with additional contaminating samples.

Table 1 shows the relative sample yellowing between the 'contaminated' tests and the 'no contamination' tests of the media for each of the test methods at 3 measurement intervals. The standard free hanging method was included for reference. That data is then followed by 3 variations of the sandwich method. The first observation is that the 'contaminating' source selected for this study appears to be exhausting itself within the first test cycle. The diminishing percent deviation between the 'contaminated' tests and the 'no contamination' tests with test time can be understood as follows. If the media yellowed by 6 delta E with contamination vs. 5 delta E for no contamination at 160 hours, that is a 20% deviation between the two tests. But if at 480 hours the contaminated media had yellowed 11 delta E vs. 10 delta E for no contamination, then that is a 10% deviation for the same 1 delta E difference. The second observation is that both the plain paper and the Whatman Grade No. 1 Filter Paper proved to be ineffective in preventing cross contamination of samples. Moreover, inserting the filter paper in between the sandwiched media also rendered that method ineffective (labeled "Sandwiched + Whatman" in Table 1 and consisting of alternating layers of media and filter paper). The failure of the filter paper to prevent cross contamination was expected given the permeability of the filter paper to airflow.

**Table 1. Percent Deviation of test sample yellowing in 'contaminated' test vs. same test with 'no contamination' for each of the test methods listed.**

| | % Deviation (at X hours) | | |
|---|---|---|---|
| | 160 | 320 | 480 |
| **Media** | **Free Hanging** | | |
| N | 39.6% | 18.0% | 7.2% |
| U | 21.8% | 16.4% | 15.2% |
| P | 48.2% | 30.1% | 14.2% |
| **Media** | **Sandwiched w/ Plain Paper** | | |
| N | 27.7% | 12.0% | 6.9% |
| U | 15.4% | 12.6% | 9.1% |
| P | 40.2% | 30.1% | 21.8% |
| **Media** | **Sandwiched w/ Whatman** | | |
| N | 34.1% | 15.4% | 8.7% |
| U | 17.3% | 13.5% | 12.4% |
| P | 46.5% | 32.5% | 21.6% |
| **Media** | **Sandwiched + Whatman** | | |
| N | 14.2% | 6.2% | 1.9% |
| U | 6.3% | 4.7% | 4.1% |
| P | 41.1% | 32.1% | 27.5% |

Despite this initial failure there was still another recommended material that had not yet been tested—polyester film. Melinex® was purchased in a large roll and cut to match the sample size, then placed on both sides of the sample. This method was also compared to the previously proposed sandwich method which uses 3 layers of media, the outer layers being of the same material as the test sample. And once again the free hanging method was included as a reference.

The test results are shown in Table 2 using the same commercial media as in the previous experiment. Once again, the free hanging samples show much more yellowing when in the presence of the contaminating samples. The sandwich method using the same media was more effective in isolating the sample than was demonstrated in the previous experiment using different materials. However, media P showed significant signs of cross contamination, thus revealing a known deficiency of this method: that is, some media are not effective at preventing cross contamination. Fortunately, this is not an issue with the Melinex®, which is not gas permeable and therefore prevented any cross contamination from occurring. The sandwich method using Melinex® was effective even with the susceptible media P.

**Table 2. Percent Deviation of test sample yellowing in 'contaminated' test vs. same test with 'no contamination' for each of the test methods listed.**

| | % Deviation (at X hours) | | |
|---|---|---|---|
| | 160 | 320 | 480 |
| **Media** | **Free Hanging** | | |
| N | 26% | 17% | 11% |
| U | 13% | 18% | 20% |
| P | 39% | 40% | 37% |
| **Media** | **Sandwiched** | | |
| N | 1% | -1% | -2% |
| U | 0% | 2% | 3% |
| P | 15% | 21% | 25% |
| **Media** | **Sandwiched w/ Melinex** | | |
| N | 0% | -2% | -2% |
| U | -2% | 0% | 1% |
| P | 1% | 2% | 4% |

During the course of running the various experiments for this study it was found that the media itself may not be consistent and consequently may contribute to some of the variation seen in testing. For the prior experiments the media samples were always tested newly removed from the same package. Table 3 illustrates the consequence of testing the 'same' media from different packages. This table shows the delta E values of media N and media O in a thermal stability test. These are from the same manufacturer and the package description is identical, but media N was purchased more recently than media O. Based on these test results for both free hanging and sandwich test methods, it may be concluded that there was an adjustment in manufacturing which did not warrant a change in packaging. The free hanging test of these two versions of the same media also demonstrates how two samples can reach the same failure point in different ways. If failure is set at 10 delta E, then media N and O will both reach failure near 450 hours at 85C/50% RH. However, the older version, media O, yellows more linearly; starting slower, but then continuing to yellow at a steadier rate compared to the newer version which yellows aggressively in the beginning then slows down dramatically later in the test. The customer will notice that the newer version is poorer in this respect even though the test protocol will evaluate them as being similar. When comparing this media in a test using the sandwich method, the results suggest that a new additive may have been included which is promoting self-contamination, since media N yellows more when sandwiched with itself than when free hanging. As shown in the earlier study, the sandwich method reduces media yellowing with a wide range of media since it prevents airflow on the sample. From a customer perspective, there is added value in having the sandwich method reveal those media that have a propensity to self-contamination—as it models the typical consumer behavior of storing prints in an album, scrapbook, or shoebox more closely than the free hanging method.

**Table 3. Delta E of same media from two different packages in a thermal stability test at 85C/50%.**

| | Delta E (at X hours) | | |
|---|---|---|---|
| | 160 | 320 | 480 |
| **Media** | **Free Hanging** | | |
| N | 5.01 | 8.01 | 10.64 |
| O | 3.68 | 6.81 | 10.62 |
| **Media** | **Sandwiched** | | |
| N | 5.86 | 9.25 | 11.60 |
| O | 3.09 | 4.75 | 6.11 |

Another question about using the sandwich method is whether it is necessary to restrict airflow on both sides of the sample. Another test was run to investigate this: in the first instance, Melinex® was only applied to the front side of the sample, and for the second test case Melinex® was applied on both sides of the sample. The results are shown in Table 4 as a function of the amount of yellowing as measured in delta E. For media N and U there was almost no difference between one-sided and two-sided sandwiching, keeping in mind that it was the sample's front side that was covered. With media P there was less yellowing with the one-sided sandwiching and this is consistent with previous observations. Referring back to Table 2, media P demonstrated more gas permeability than media N or U. It is suspected that media P contributes to its own yellowing by self-contamination, thus when only the front side is covered, its permeability allows the self-contaminating influence to be vented through to the back side, thus yellowing less than when both sides are covered.

**Table 4. Delta E of test sample yellowing in 'contaminating' thermal stability test at 85C/50%.**

| | Delta E (at X hours) | | |
|---|---|---|---|
| | 160 | 320 | 480 |
| **Media** | **Sandwiched w/ Melinex front side only** | | |
| N | 4.28 | 6.97 | 9.34 |
| U | 4.47 | 6.34 | 7.89 |
| P | 4.43 | 5.87 | 6.81 |
| **Media** | **Sandwiched w/ Melinex both sides** | | |
| N | 4.30 | 6.88 | 9.19 |
| U | 4.58 | 6.40 | 8.01 |
| P | 4.43 | 6.15 | 7.43 |

## Conclusion

Earlier research had found that the sandwich test method helped reduce the influence of airflow and cross contamination from other media in thermal stability tests as compared to the standard free hanging method. This study continued to explore the sandwich test method and whether other materials may be suitable alternatives as a sandwiching material to cover the test sample. After eliminating several material choices, it was found that polyester film is extremely effective in preventing cross contamination of samples.

The goal of the thermal stability test is to achieve consistent results which accurately represent actual customer usage. The use of a polyester film is a good comparison to the practice of storing print images in photo albums and in frames. Last year's proposed test method of sandwiching media with media more closely represents the practice of storing stacks of print images together, such as in shoe boxes or scrapbooks. However, within the high airflow environment of a thermal test chamber, the permeability of some media compromises the effectiveness of the sandwich method utilizing the same material as the test sample. Therefore, the use of polyester film is the overall recommended approach.

In other testing of printed samples covered with polyester film, it was found that some inks stick to the polyester film. The experiments described in this paper only evaluated unprinted test samples, because media yellowing has been observed to be the most common first failure mode in dark storage testing. There are potential solutions to the problem of sticking inkjet samples. Foremost would be to test full printed test targets using the free hanging method in parallel with a test of unprinted media sandwiched with a polyester film such as Melinex®. Figure 1 shows the test target used for this study. The locating marks printed on the target are outside the measurement area and would not affect the results if the ink stuck to the film in those areas. Another advantage of this test target is that it allows multiple measurements over a large area which can then be averaged together so as to improve repeatability and reproducibility of the test.

Finally, the authors acknowledge that there may be hesitation to adopt a new test method without widespread experience using it. However, data presented these past few years has demonstrated that the free hanging method is not effective in consistently quantifying media yellowing for the commercially available porous photo papers on the market today.

## References


[1] M. Comstock, A. McCarthy, "Improved Dark Storage Test Method", Final Program and Proceedings of IS&T's NIP25: International Conference on Digital Printing Technologies, Louisville, Kentucky, pp.114-117 (2009).

[2] M. Comstock, A. McCarthy, P. Sacoto, R. Silveston-Keith, "Effect of Airflow on Rate of Paper Yellowing in Dark Storage Test Conditions", Final Program and Proceedings of IS&T's NIP23: International Conference on Digital Printing Technologies, Anchorage, Alaska, pp. 716-720 (2007).


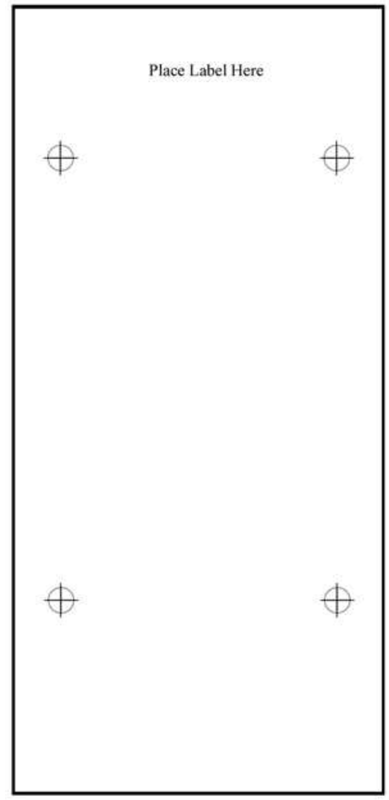


*Figure 1. Example of unprinted test sample for evaluating media yellowing. Locating marks are outside the measurement area.*

## Author Biographies


*Matthew Comstock received his B.S and M.S. degrees from Purdue University in Mechanical Engineering specializing in heat transfer and thermodynamics. He joined Lexmark International, Inc. in 1999 as a development engineer for color laser products. Since 2005 he has been responsible for the Lexmark Image Permanence Lab in Lexington, KY. His work is primarily focused on image permanence test method development and image permanence testing.*

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