

# Selecting Suitable Enclosures for Digitally Printed Materials

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**Abstract.** It cannot be assumed that storage enclosures considered safe for traditionally printed images and documents are suitable for modern, digitally printed materials. In this project, a large variety of digital print types were tested using a modified version of the ISO 18916 *Imaging materials—Processed imaging materials—Photographic activity test for enclosure materials* standard to assess the risk to digital prints by paper enclosures known to be inert or reactive with traditional photographic prints. The types of enclosures tested included buffered and non-buffered cotton papers, and groundwood paper. In addition, qualitative filter paper that had been wetted and dried with either an acidic or basic solution was also tested to determine the effects of enclosure pH on digitally printed materials. It was determined that, in general, digital prints tended to be less reactive with various enclosure types than traditional prints. Digital prints were most sensitive to paper that contained groundwood. The enclosure reactivity test results were then integrated with previous published work on the tendencies of various enclosure types to abrade, ferrotype, or block to digital prints in order to create a comprehensive set of recommendations for digital print storage enclosures.

## Introduction

The purpose of this project was to determine if various common paper enclosures will be harmful to digital prints, both documents and photographs, during long-term storage. To date, it has been assumed that what is safe for traditional prints will also be safe for digital prints. This is because digital prints are known to be sensitive to some of the same deterioration forces as traditionally printed materials namely oxidation of the colorants (dyes or pigments) and yellowing of the paper or plastic supports. No previous experimental work is known to have validated or invalidated this assumption. Digital prints may or may not be more sensitive to these decay forces than traditional prints, or they may be sensitive to as yet unidentified reactants within paper enclosures. This project rectifies this problem by providing data that addresses the issues.

Note that this paper assumes that inert plastic enclosure types such as polyester and polypropylene would be chemically safe for use in storing digitally printed materials. As such they were not included in the experimental work. However, it could not be assumed that there would be no harmful physical interactions between plastics and digital prints such as blocking, ferrotyping, or abrasion. These properties have been previously examined by IPI and published elsewhere [1, 2]. Those results will be integrated with the results from the present project to provide a set of recommendations for selecting housing materials that takes both the potential chemical and physical interactions into consideration. Certain plastics known to be sensitive to deterioration themselves and/or to emit harmful agents such

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as plasticizers or acids should never be used. These have already been excluded for use with photographs by ISO 18902 *Imaging materials – Processed Imaging materials – Albums, Framing, and Storage Materials* [3].

The results will be useful to anyone working in cultural heritage institutions charged with housing digitally printed collections materials. The data will also be useful to the ISO working group on the physical properties and permanence of imaging materials in the further development of their standards related to print storage.

## Methods

The possibility of negative chemical interactions between traditional photographic prints and enclosure and display materials has been recognized for many years. For traditional photographic images, the Photographic Activity Test (PAT) was developed to screen for these potentially harmful enclosures. The method was subsequently standardized by the International Organization for Standardization (ISO) and is now designated as ISO 18916 *Imaging materials—Processed imaging materials—Photographic activity test for enclosure materials* [4]. This test involves the accelerated aging of special image interaction detectors and gelatin stain detectors against the enclosure materials being studied. The image interaction detector is a thin colloidal silver/gelatin layer on a polyester base that is used to screen for reactions that cause image fade. The gelatin stain detector is a photographic paper processed to minimum density (paper white) that is used to screen for reactions that cause print yellowing.

The current tests are based on that method but are modified from the original by the replacement of the image interaction and gelatin stain detectors with two new detectors made from the various digital printing materials. The image interaction detector is a uniform middle-grey (sRGB 128, 128, 128) print and the stain detector is unprinted paper (except dye sublimation which was printed to minimum density to include its overcoat and chromogenic silver-halide which was unexposed and processed to minimum density).

When printing, the “Best Photo” and “Photo Enhanced” printer settings were selected (when available) for photograph printing systems. Default settings were used for document printing systems. After printing, all samples were left to dry at 21°C and 50% RH in the dark for two weeks prior to testing.

The following enclosure materials were tested against the digital print samples:

- Non-buffered cotton paper
- Buffered cotton paper
- Groundwood paper
- Whatman No. 1 filter paper
- Whatman No. 1 filter paper soaked in 0.1N HCl
- Whatman No. 1 filter paper soaked in 0.1N NaOH

The hydrochloric acid (HCl) and sodium hydroxide (NaOH) samples consisted of Whatman No. 1 filter paper strips (the test control stipulated in ISO 18916) soaked in solution for one hour, and then left to air dry for 24 hours before testing. The papers were then tested to determine their pH using TAPPI T 509 *Hydrogen ion concentration (pH) of paper extracts (cold extraction method)* [5]. The HCl soaked filter paper had a pH of 3.9 and the NaOH soaked filter paper had a pH of 10.1.

Table 1 lists the printed digital materials that were used in the test as image interaction detectors. Multiple examples of each printer technology were tested when possible.

**Table 1.** Printed digital materials used as image interaction detectors.

Printer	Paper
Inkjet - Pigment – Photo 1	Fine Art 1
Inkjet - Pigment – Photo 2	Fine Art 2
Inkjet - Pigment – Photo 3	Fine Art 3
Inkjet - Pigment – Document 1	Plain Office
Inkjet - Pigment – Document 2	Plain Office
Inkjet - Pigment – Document 3	Plain Office
Inkjet – Dye – Photo 1	Porous Photo 1
Inkjet – Dye – Photo 2	Porous Photo 2
Inkjet – Dye – Photo 3	Polymer Photo 1
Inkjet – Dye – Photo 3	Polymer Photo 2
Inkjet – Dye – Document 1	Plain Office
Inkjet – Dye – Document 2	Plain Office
Inkjet – Dye – Document 3	Plain Office
Colour Electrophotographic 1	Plain Office
Colour Electrophotographic 2	Plain Office
Colour Electrophotographic 3	Plain Office
B&W Electrophotographic 1	Plain Office
B&W Electrophotographic 2	Plain Office
B&W Electrophotographic 3	Plain Office
Dye Sublimation 1	Dye Sublimation 1
Dye Sublimation 2	Dye Sublimation 2
Silver-halide – Colour	Chromogenic photo paper
Digital Press – Liquid Toner	Coated Glossy
Digital Press – Dry Toner 1	Coated Glossy
Digital Press – Dry Toner 2	Coated Glossy
Offset Lithography	Coated Glossy

Table 2 lists the unprinted digital papers used in the test as stain detectors. Note that many of the samples in table 1 used the same paper but were printed on different printers (i.e. the plain office paper). These papers were tested for stain only once. Again several examples of each paper type were tested when possible.

**Table 2.** Unprinted digital papers used in the test as stain detectors.

Paper
Inkjet Fine Art 1
Inkjet Fine Art 2
Inkjet Fine Art 3
Inkjet Photo – Porous 1
Inkjet Photo – Porous 2
Inkjet Photo – Polymer 1
Inkjet Photo – Polymer 2

Dye Sublimation 1  
Dye Sublimation 2  
Chromogenic photo paper  
B&W photo paper  
Plain Office  
Digital Press - Coated Glossy  
Offset Lithographic - Coated Glossy

The image interaction and stain detectors were cut into 2cm x 4cm strips in accordance with ISO 18916: 2007. All strips were read before and after incubation using a Gretag Spectrolino/Spectroscan (no UV filter, 2° observer, D50 illuminant) for CIELAB L\*a\*b\*. The test was performed in duplicate. Each enclosure paper was incubated with four detectors, two image interaction and two stain. They were stacked into a specimen jig for incubation in the following configuration.

----- Weight to provide 500 Pa (including top glass)  
----- Glass  
----- Filter paper separator  
----- Image interaction detector (face down)  
----- Filter paper separator  
----- Enclosure material  
----- Uncoated polyester  
----- Stain detector (face down)  
----- Filter paper separator  
----- Enclosure material  
----- Glass

Filter paper separators between the enclosure material and the print samples are required by the ISO standard. This filter paper separator was not used in the untreated Whatman No. 1 filter papers tests. Another strip of filter paper was placed between the top image interaction detector and the glass to prevent sticking between the two.

Once the jigs were prepared, they were placed in an incubation chamber on racks with sufficient space in between to allow for air circulation. The tests (sample sandwiches in jigs) were incubated at 70°C and 86% RH for 15 days in an ESPEC ESL-3CA Humidity Cabinet. At the end of the incubation, the sample jigs were disassembled and the detectors were removed and remeasured. Delta E was then calculated.

It was understood that the high temperature and relative humidity test conditions required in ISO 18916 will likely cause colorant bleed for some of the digital print processes under investigation. However, it was believed that the inclusion of known, nonreactive materials (non-buffered cotton paper and Whatman No. 1 qualitative filter paper) in the experiments should still allow useful conclusions to be drawn. This project should be seen as a preliminary investigation.

## Results

Table 3 shows the delta E values for the printed samples in contact with the cotton, cotton buffered, and groundwood papers.

**Table 3.** Delta E values for printed samples in contact with cotton, cotton buffered, and groundwood papers.

Printer	Paper	Cotton Non-buffered	Cotton Buffered	Ground- wood
Inkjet - Pigment – Photo 1	Fine Art 1	4	3	4
Inkjet - Pigment – Photo 2	Fine Art 2	0	0	1
Inkjet - Pigment – Photo 3	Fine Art 3	1	1	2
Inkjet - Pigment – Document 1	Plain Office	1	1	2
Inkjet - Pigment – Document 2	Plain Office	1	0	2
Inkjet - Pigment – Document 3	Plain Office	1	1	2
Inkjet – Dye – Photo 1	Porous Photo 1	2	1	2
Inkjet – Dye – Photo 2	Porous Photo 2	4	3	5
Inkjet – Dye – Photo 3	Polymer Photo 1	10	10	17
Inkjet – Dye – Photo 3	Polymer Photo 2	17	17	20
Inkjet – Dye – Document 1	Plain Office	3	3	4
Inkjet – Dye – Document 2	Plain Office	11	11	11
Inkjet – Dye – Document 3	Plain Office	9	9	10
Colour Electrophotographic 1	Plain Office	3	3	2
Colour Electrophotographic 2	Plain Office	2	2	3
Colour Electrophotographic 3	Plain Office	6	6	7
B&W Electrophotographic 1	Plain Office	1	1	5
B&W Electrophotographic 2	Plain Office	3	2	6
B&W Electrophotographic 3	Plain Office	3	4	4
Dye Sublimation 1	Dye Sublimation 1	2	2	1
Dye Sublimation 2	Dye Sublimation 2	4	4	4
Silver-halide – Colour	Chromogenic photo paper	1	1	1
Digital Press – Liquid Toner	Coated Glossy	1	1	2
Digital Press – Dry Toner 1	Coated Glossy	2	1	3
Digital Press – Dry Toner 2	Coated Glossy	4	4	4
Offset Lithography	Coated Glossy	3	3	4
	<i>Total</i>	<i>119</i>	<i>117</i>	<i>149</i>

Adding the delta E values for each enclosure paper type shows that, in general, there was little difference between buffered and non-buffered cotton papers with respect to image interaction of printed materials (see bottom row of table 3). The groundwood papers tended to be slightly more reactive which matches actual experience of traditional photos that have been stored in groundwood containing envelopes and boxes.

Table 4 shows the delta E values for the printed samples in contact with the acidic, basic, and untreated Whatman No. 1 filter papers.

**Table 4.** Delta E values for printed samples in contact with acidic, basic, and untreated Whatman No. 1 filter papers.

Process	Paper	Untreated Paper	Acidic Paper	Basic Paper
Inkjet - Pigment – Photo 1	Fine Art 1	4	4	4
Inkjet - Pigment – Photo 2	Fine Art 2	1	0	1
Inkjet - Pigment – Photo 3	Fine Art 3	1	1	1
Inkjet - Pigment – Document 1	Plain Office	1	1	1
Inkjet - Pigment – Document 2	Plain Office	1	1	0
Inkjet - Pigment – Document 3	Plain Office	1	1	1
Inkjet – Dye – Photo 1	Porous Photo 1	2	2	1
Inkjet – Dye – Photo 2	Porous Photo 2	3	4	3
Inkjet – Dye – Photo 3	Polymer Photo 1	10	10	14
Inkjet – Dye – Photo 3	Polymer Photo 2	16	13	16
Inkjet – Dye – Document 1	Plain Office	3	3	3
Inkjet – Dye – Document 2	Plain Office	11	12	11
Inkjet – Dye – Document 3	Plain Office	8	9	8
Colour Electrophotographic 1	Plain Office	2	3	4
Colour Electrophotographic 2	Plain Office	1	3	2
Colour Electrophotographic 3	Plain Office	6	7	6
B&W Electrophotographic 1	Plain Office	1	2	1
B&W Electrophotographic 2	Plain Office	3	3	2
B&W Electrophotographic 3	Plain Office	3	4	3
Dye Sublimation 1	Dye Sublimation 1	1	1	2
Dye Sublimation 2	Dye Sublimation 2	3	4	4
Silver-halide – Colour	Chromogenic photo paper	2	3	2
Digital Press – Liquid Toner	Coated Glossy	1	2	1
Digital Press – Dry Toner 1	Coated Glossy	2	2	2
Digital Press – Dry Toner 2	Coated Glossy	4	5	5
Offset Lithography	Coated Glossy	4	3	3
<i>Total</i>		<i>115</i>	<i>121</i>	<i>119</i>

The acidic and basic papers behaved very similar to the untreated Whatman filter paper. The pH of enclosures at these levels (3.9 and 10.1) seems to have had no effect on the stability of the image. This is not to say that acidic or basic enclosures should be allowable for storing prints, as the pH of paper has long been correlated with longevity. Therefore, while the image may remain intact, the support may still deteriorate over time. This experiment was performed only to determine the effects of enclosure pH on fade or yellowing and not other parameters such as coating integrity or paper durability. For that reason, paper enclosures should still meet the pH requirements of ISO 18902 of 7.0 to  $9.5 \pm 0.2$ .

Table 5 shows the delta E values for the unprinted papers in contact with the cotton, cotton buffered, and groundwood papers.

**Table 5.** Delta E values for unprinted papers in contact with cotton, cotton buffered, and groundwood papers.

Paper	Cotton Non-buffered	Cotton Buffered	Ground- wood
Inkjet Fine Art 1	10	9	11
Inkjet Fine Art 2	1	1	5
Inkjet Fine Art 3	3	3	7
Inkjet Photo – Porous 1	2	2	4
Inkjet Photo – Porous 2	2	2	5
Inkjet Photo – Polymer 1	6	5	14
Inkjet Photo – Polymer 2	7	7	14
Dye Sublimation 1	1	1	1
Dye Sublimation 2	1	1	1
Chromogenic photo paper	6	5	12
B&W photo paper	11	10	21
Plain Office	1	1	5
Digital Press - Coated Glossy	6	5	7
Offset Lithographic - Coated Glossy	5	5	8
<i>Total</i>	<i>62</i>	<i>58</i>	<i>117</i>

Again the non-buffered and buffered cotton papers were similar to each other in terms of their potential for staining or yellowing digital printing papers. Most of the prints yellowed somewhat just as a result of the incubation, but the groundwood paper was considerably more reactive than the cotton papers and caused additional yellowing of most of the prints.

Table 6 shows the delta E values for the unprinted papers in contact with the acidic, basic, and untreated Whatman No. 1 filter paper.

**Table 6.** Delta E values for unprinted papers in contact with acidic, basic, and untreated Whatman No. 1 filter paper.

Paper	Untreated Paper	Acidic Paper	Basic Paper
Inkjet Fine Art 1	10	10	9
Inkjet Fine Art 2	1	1	0
Inkjet Fine Art 3	4	5	3
Inkjet Photo – Porous 1	2	2	2
Inkjet Photo – Porous 2	2	2	2
Inkjet Photo – Polymer 1	5	7	5
Inkjet Photo – Polymer 2	7	8	7
Dye Sublimation 1	1	1	1
Dye Sublimation 2	1	1	1
Chromogenic photo paper	5	6	6
B&W photo paper	11	13	10
Plain Office	1	2	1

Digital Press - Coated Glossy	5	6	5
Offset Lithographic - Coated Glossy	5	5	4
<i>Total</i>	<i>61</i>	<i>70</i>	<i>55</i>

As with image interaction, the pH of the enclosure paper had little effect on the yellowing of the print papers.

### Conclusions

The following conclusions were reached regarding the potential for enclosure-induced image fading or paper yellowing:

- Digital prints are as sensitive to groundwood containing paper enclosures as traditional prints.
- The pH of paper enclosures has little effect on the fading or staining of digital prints.
- Digital prints should be housed in paper enclosures that meet the requirements outlined in ISO 18902 *Imaging materials – Processed Imaging materials – Albums, Framing, and Storage Materials*.

IPI has previously performed and published research on three other aspects of enclosure suitability for digital prints: ferrotyping, blocking, and abrasion [1]. While the above project assumed that plastics which meet ISO 18902 should be chemically safe for both traditional and digital photos, there is the possibility of physical interactions which may be harmful. Certain elevated temperature and humidity combinations can soften the gelatin coating on traditional photos resulting in conforming (ferrotyping) or bonding (blocking) of the photo to adjacent smooth surfaces such as plastic films or glass. Experimental work at IPI showed that all digital print types (inkjet, electrophotographic, and dye sublimation) were less likely to ferrotype or block than traditional photos. As such, plastic sheeting should be safe in terms of ferrotyping or blocking when used as an enclosure for digital prints, though recommended storage conditions (temperature and relative humidity) should always be maintained [6].

IPI has also performed research into the abrasion resistance of digital prints [2]. It was determined that abrading digital prints with common enclosures results in various types of damage including change to surface gloss, loss of colorant from the darker areas of the prints, and smearing of colorant into the light areas of the prints. While some print types were nearly impervious to abrasion such as color electrophotographic, others abraded very easily especially pigment inkjet prints on all types of papers. Some pigment inkjet prints may be so sensitive that no surface should ever be placed in contact with the face of the print. Polyester sheeting was the least abrasive enclosure material and is recommended for sensitive print types.

Given the above, it is recommended that all paper and plastic enclosures for digital prints meet the ISO 18902 standard. Additionally prints that are sensitive to abrasion should be housed in polyester sleeving as opposed to paper, and the most sensitive and valuable pigment inkjet prints should be housed in such a way that no surface comes in contact with the print's face. This can be achieved through the use of window mats or spacers when prints are stored stacked in boxes.

This project did not examine the potentially harmful effects of other materials used in housing digital photographs and documents, such as the adhesives used for constructing enclosures and writing instruments used for labeling. No recommendations on the use of these materials can be given at this time.

### References

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### **Primary Author Biography**

*Daniel M. Burge, Senior Research Scientist*, has been a full-time member of the Image Permanence Institute (IPI) staff for the last 19 years. He received his B.S. degree in Imaging and Photographic Technology from the Rochester Institute of Technology in 1991. He managed IPI's enclosure testing services from 1991 to 2004. In 2004, he took over responsibility for all of IPI's corporate-sponsored research projects. Currently he is investigating digital image stability and storage issues.