Test Methods for the Water Sensitivity of Photobooks

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Abstract

Water sensitivity is one of the potential degradation routes of digitally printed images. ISO standards 2836 and 18935 are test methods for water fastness. These are shown to have limited application to some water fastness failure routes of printed images in books. As a result they only have limited applicability to the emerging photobook technologies.

ISO 18935 contains 3 test methods. These test the resilience of a print to water spill, wet wiping and total immersion. However, these water exposure routes are not always pertinent to images within books which often spend most of their lifetime closed. In this case the water exposure is commonly by percolation through the exposed edge, resulting in chromatography effects on the exposed image, a very different scenario than those covered in ISO 18935. This renders ISO 2836 less useful too.

The paper proposes a suitable test object and geometry for testing printed images within books. The strengths and weaknesses of this approach to in-book testing of images are also examined and the reasons for this choice of geometry are covered.

The work concentrates on various plain, uncoated papers to best illustrate the effects and examines ink / media interactions using a number of different ink sets. The effect of UV brighteners within the paper is also examined as a part of this work.

This work examines the issues around water sensitivity of inkjet prints within books and as such has direct relevance to photobook assemblies. As such it aims to form the basis for an extension to ISO 18935 to these increasingly important media for photographic hard copy.

Introduction

This paper first compares and contrasts the effect on a digital print of exposure to H_2O as humidity (gaseous phase) and water (liquid phase). The similarities and differences of the degradations is considered, as is the intermediate effect due to condensation.

There already exist 2 pertinent ISO standards for water sensitivity. These too are compared and contrasted and their pertinence to photobook testing examined, in the context of open and closed book exposure.

The effect of "water" exposure

The susceptibility of prints to water is influenced by the form in which the water exposure takes place. Degradation due to H_2O can take place either through exposure to humidity (gaseous phase) and water (liquid phase).

Water and humidity sensitivity are 2 degradation routes that involve the interaction between printed images and water in various forms. This work will first compare and contrast the effect of humidity (gaseous phase) and water (liquid phase) on inkjet prints. As such it will build on a paper in NIP27 on this topic. The comparison will also encompass the effect of condensation.

Water and humidity fastness – similarities

H_2O as humidity (gaseous phase) and water (liquid phase) can both have effects on digital prints. The illustration in shows a dye based inkjet print on a swellable gelatin coated substrate, before (left hand image) and after (right hand image) being subjected to elevated humidity.[1] The following general observations can be noted from this – these are not only pertinent to swellable coatings.

1. The humidity exposure has resulted in significant migration of some of the colorants that make up the image.
2. Some colorants are more subject to migration than others. In the case illustrated in it is the magenta colorant that is most affected.
3. The migration of colorant is uniform in both X and Y directions. This is because the ink receptive coating on the substrate is uniform along these axes as is the humidity exposure when conducted in free air.

Rather similar results can be seen in some cases from water exposure. However, this is something of a special case that results when the print is immersed unprotected in liquid water and there is no movement of the water. In some cases this can result in confusion as to the cause of the degradation – liquid water or high humidity exposure.

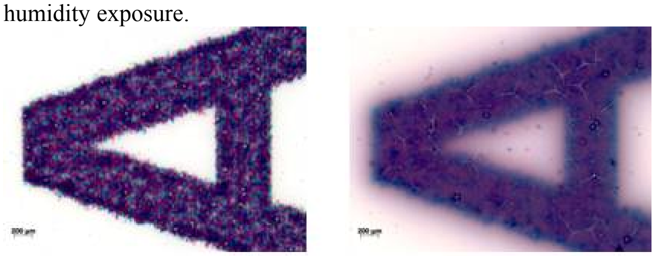

Figure 1 The effect of humid bleed

Lateral and vertical migration

The effect illustrated in and the associated text suggests that migration only takes place in the x and y directions, in other words parallel to the surface of the print. This is of course not the case and on a number of substrates diffusion in the z direction (into the depth of the substrate) can be an important consideration for a number of reasons.

1. If there is significant penetration into the depth of the substrate the overall optical density of the colorant measured on the printing surface can decrease. This can result in visible changes in colour, density and gamut.
2. In some usage cases the reverse side of the print is expected to remain uncoloured by the print on the front side. Examples of this may be the page in a book or a document. There are conditions in which the migration of colorant with humidity can be so significant that it is visible on the reverse side, as

illustrated in Figure 2. This illustrates a humidity test chart as used in our previous work before and after humidity exposure.[2] The left hand image shows the print before humidity exposure and it can be seen to be clear of any "strike through" of ink. The right hand image shows the appearance of a "ghost image" as the colorants migrate through the substrate, in this case an uncoated paper.

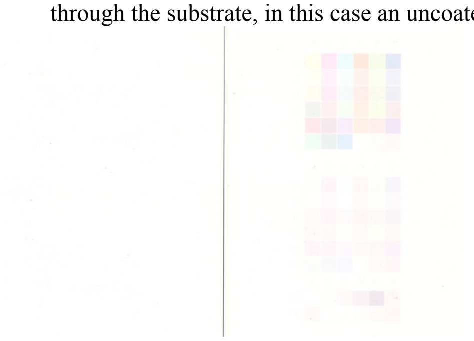

Figure 2 Z dimension colorant migration

Water and humidity fastness – differences

While the effects of liquid water and elevated humidity have many common features these are often overwhelmed by significant differences. One of the most important differences, particularly where books are concerned, is the fact that there is often a flow or concentration gradient of water across the printed image.

Consider the case where one area of a page gets wet. Water can then diffuse from areas of high concentration to low (wet to dry). If as part of this movement the water passes through a printed area containing printed images with water labile colorants part or all of the colorant contact will move with the water and also diffuse from high concentration areas to low.

As a result of these effects water damage to prints is often (although not always) anisotropic in nature. It can be considered in part to have chromatographic content –the effects are linked to the flow of the elutant (in this case water).

Another significant difference is one of degree of damage. The concentration of H_2O in a wet print is much higher than that of a humid one and the effects are commensurately larger. Added to this the effects linked to the flow of water and colorant with concentration gradients make water damage a potentially gross effect.

In summary, both humidity and water result in a bleed of colorant from high to low colorant concentration. The potentially more damaging effect with water is associated with flow that takes colorant along as the liquid moves from high to low water concentration.

The effect of condensation

Condensation is an interesting case that can combine both effects. It occurs when the local relative humidity rises above the level where it can be sustained in the vapour phase. If this happens in air a mist is formed containing droplets of water. If this happens on a surface the droplets form directly on that surface. In either case there may be damage through both high humidity on a macro scale plus water damage on the scale of the droplets.

Review of existing ISO standards

There are currently 2 ISO standards that may be considered to be pertinent to the testing of prints for water fastness. These are ISO 18935 and 2836.

ISO 18935

ISO 18935 "Imaging materials — Colour images on paper prints — Determination of indoor water resistance of printed colour images" was prepared by ISO TC42 (Photography) and contains 3 test methods.[3]

1. A test that models the effect of water spilt on an image and left to dry. Small drops of water are placed on the printed image and left to dry. The damage is then examined visually.
2. A test for the physical integrity of the colorant receptive layer. This can be an important if the print is softened by contact with water and can be damaged if touched before fully drying. The method is the same as with option 1 above but the sample is wiped with a tissue while still wet. This is particularly important for prints with swellable coatings such as those used to provide .
3. A test that indicates how images will behave under total immersion in water. They are then hung vertically to dry.

ISO 18935 also gives examples of potential test targets for water fastness, as illustrated in Figure 3. It suggests the use of a CMYKRGB line chart to monitor inter-colour bleed plus a checkerboard target for colorant migration of the type specified for humidity testing.[4]

ISO 2836

ISO 2836 "Graphic technology — Prints and printing inks — Assessment of resistance to various agents" was prepared by ISO TC130 and has as scope "…printing on all substrates by all of the traditional printing processes and digital imaging processes such as ink-jet, electrophotography, etc…".[5] It is pertinent to the effect of many liquid and solid agents on a uniform density print area. It measures water fastness visually when left in contact with wet filter paper under user defined conditions.

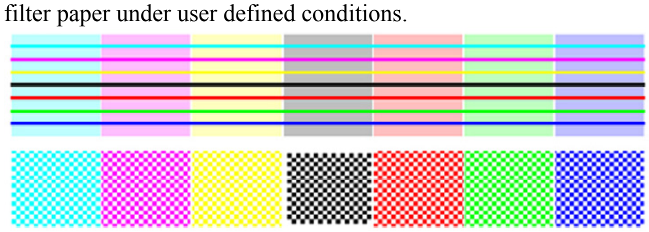

Figure 3 Water fastness test chart from ISO 18935

Relevance for photobook testing

Both these standards have something to offer for the testing of photobooks.

Although the title of ISO 18935 stipulates "paper prints" the scope covers "…the relative indoor water resistance of printed colour images…both digital and analogue prints." As such it seems to be relevant to photobook products, although in some cases we may need to invoke a rather loose definition of "paper". However, the test methods themselves (droplets with or without wiping, immersion without contact) are really only pertinent to open book testing.

ISO 2836 comes closer to closed book testing in that it covers contact with wet paper. However, the stipulation that filter paper is used reduces relevance. For photobooks it would be better to test contact with wet samples of paper identical to that used in the book construction. It also allows the testing of liquid and solid agents other than deionised or distilled water.

In summary, both these standards have something to offer in terms of testing of open photobooks. However, they do not appear to be pertinent to the testing of closed photobooks.

Photobook water fastness exposure modes

The premise of this work is that both open and closed book testing of photobooks is pertinent in the real world. Open book is certainly pertinent in use but closed book is important in display and storage. For books subjected to full immersion for a protracted period whilst closed some slight modification of ISO 2836 would probably be pertinent. However, a more likely scenario and one seen by the authors in practice is where a closed book is immersed only on one edge and the water soaks up into the pages, taking the colorants with it.

In theory this would be easy to test. A closed book would be placed with the plane of the pages in a vertical plane in a shallow puddle of water. During some predetermined time the water would be absorbed by the paper and a wet edge would propagate upward through the book and a printed test pattern. The book would then be dried while still closed and the result examined.

In practice this is a protracted process and leads to variable results for the following reasons.

1. The pages of the closed book are often subject to edge cockling – a random waviness that results in uneven contact. This induces further variation in the depth of penetration of the water and hence of the results.
2. Drying a closed book in a reproducible and pertinent manner is a long process, making for extended testing times.
3. Opening the book after drying and testing tends to result in both water fastness and adhesion issues. Philosophically these are different tests and methods should be able to distinguish these.

As a result of these issues a new test method for the water fastness of printed images in closed books has been devised that seems to be more pertinent in that it gives results more indicative of those seen in real circumstances.

The proposed test method

The test method uses a test chart utilising the same components as that shown in Figure 3. However, these are placed in a horizontal line as illustrated in Figure 4, towards the lower edge of a page. This is then placed in a clamp consisting of 2 "U" shaped portions of rigid plastic, holding the lower and 2 side edges flat. The system was engineered such that the plastic clamps were at least 5mm away from any areas of the printed test chart.

A thick glass chromatography tank was prepared containing a small depth of deionised water. It was left covered for at least 24 hours in ambient conditions to allow the temperature of the whole system to stabilise and the air in the tank to become saturated with water vapour. This latter stipulation ensured that any evaporation of the water wicking up the paper was kept to a minimum. As the results are likely to show some variation with temperature this should be recorded – it was 23°C in this work. Chromatography tanks have internal ridges which facilitate clamped systems such as those described above to be slid in and retained in a vertical orientation.

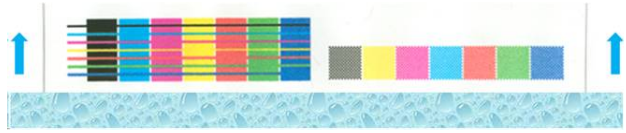

Figure 4 Modified in book water fastness test geometry

As illustrated in Figure 4 the water level in the tank was set to a few millimetres below the lower level of the printed test image. Although the exact distance was not found to be significant for the purposes of this test the volume of the enclosed water was much greater than the volume absorbed by the sample and so the change in level was effectively constant throughout the test.

Depending on the substrate type the samples were left for 4-24 hours to allow the water front to advance up the paper and through the printed image, as illustrated by the arrows in Figure 4.

Results

The test method described above is very effective at separating the performance of different inkjet ink/paper combinations and provides results that appear to correlate with real world in-book performance.

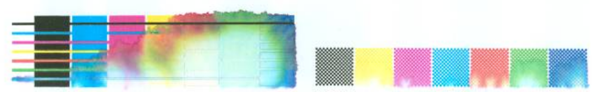

Figure 5 Results from dye based ink on copy paper

Figure 5 illustrates a test on a 4 colour dye based inkjet print onto standard commercial copy paper that illustrates some interesting effects. It shows how the moving waterfront has gone through the printed image and taken the colorants with it. It is also interesting to note that the rate of progress of the waterfront appears to be a function of the ink level with the RGB sections showing faster progress. The inked areas themselves appear to make the paper more hydrophilic.

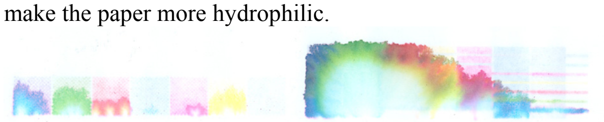

Figure 6 Reverse face of the dye based ink on copy paper

The water also encourages the colorants to penetrate through the paper. The image of the reverse side, shown above as Figure 6 also better illustrates the progression of the waterfront.

It was also instructive to repeat this test on another brand of copy paper.

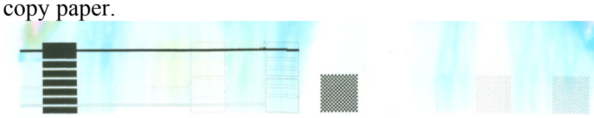

Figure 7 Water fastness test on an alternative copy paper

The results from this test, using the same ink set and water exposure time are shown in Figure 7. In this case the waterfront has progressed many times further through the paper, taking almost all the dye based colorant with it. The more substantive nature of the cyan ink can be seen in this illustration.

Although it is not visible in these images the test method is also good at revealing the migration of optical brightening agents in the paper samples. In the copy paper samples illustrated above the optical brightening agents were found to be highly mobile when viewed using a UV lamp.

High quality UV dull papers

Higher quality papers without UV brightening agents are much used in the art, photographic and security markets. This test is also capable of separating the performance of dye based inks on this type of product.

Figure 8 illustrates a water fastness test on this type of product. The same dye based inkset was used as in the previous illustrations and once again the magenta dyes are seen as the most fugitive.

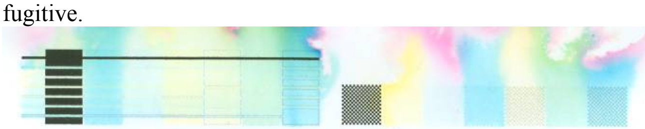

Figure 8 Same dye based inkset on a high quality UV dull paper

However, once again the performance of this system is highly dependent on the selection of the paper type. This is illustrated in Figure 9 where the only change made was to select an alternative paper used for the same application. This was almost completely unaffected with very little absorption of water.

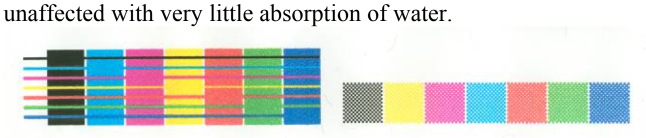

Figure 9 Same dye based inkset on an alternative UV dull paper

Pigmented inks

All the work cited above uses dye based inkjet inks. Although these tend to show the largest effects it should not be considered that pigmented inks are without issue.

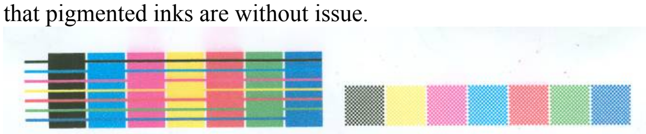

Figure 10 Pigmented inkset on a high quality UV dull paper

The test illustrated in Figure 10 shows a pigmented inkset printed onto the same paper as used to produce Figure 8. Careful examination of the water damage shows a small amount of magenta bleed with water exposure but otherwise the print is hardly affected.

However, if the reverse side of the paper is examined it can be seen that a potentially more serious effect has occurred – the magenta colorant has penetrated through the paper as illustrated in Figure 11.

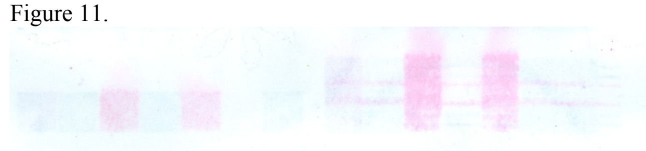

Figure 11 Reverse side of the print showing colorant penetration

Conclusions

None of these test methods produces an objective result in terms of a numeric value. Given the variability illustrated in some of the images above the suggestion is that objective results are likely to be very difficult to achieve in a reproducible manner.

It should be noted that the results achieved above are for ink/substrate systems in isolation. In practice there are covers and adhesives in real photobook construction. Although these were out of scope for the experiments described here the method could be adapted to these systems, for example by testing a print with a cover assembly sandwiched to the back of the sheet or in close proximity. It could also be adapted to cover page to page image transfer. This work may therefore form the basis for a test method for the water fastness of photobooks.

References

[1] A. L. Fricker, A Hodgson, J. H. Townsend, C Woods, " Humidity Sensitivity of Inkjet Prints", Indoor Air Quality 2012, 10th International Conference, "Indoor Air Quality in Heritage and Historic Environments - Standards and Guidelines", UCL Centre for Sustainable Heritage, London, UK, 17- 20 June 2012.

[2] A.L. Fricker, A. Hodgson, P. Green, "An Evaluation of the Humidity Test Method ISO 18946", NIP 27, pp. 267-270 (2011).

[3] ISO 18935:2005 "Imaging materials — Colour images on paper prints — Determination of indoor water resistance of printed colour images".

[4] ISO 18946:2011. "Imaging materials — Reflection colour photographic prints — Method for testing humidity fastness".

[5] ISO 2836:2004 "Graphic technology — Prints and printing inks — Assessment of resistance of prints to various agents".

Author Biography

Alan has 30 years experience in printed hard copy and a background in photography and image science. Alan previously managed R&D and Technical Services groups active in inkjet application development. For the next 4 years he worked on printing and optics consultancy projects, including some in Image Permanence. He now works for 3M in the UK and continues to be a regular conference speaker and tutor.

Alan has a BSc in colorant chemistry and a PhD in instrumentation, both from the Department of Chemistry at the University of Manchester. He is a Fellow of the Royal Photographic Society as an Accredited Senior Imaging Scientist. In addition to the IS&T Alan is active in the Royal Photographic Society and Institute of Physics as a speaker and session chair. He is currently IS&T Executive President and the proud recipient of the 2012 HP Image Permanence Award. He is also Head of UK Delegation to ISO TC42.