Wilhelm Imaging Research & Heritage Science for Conservation

Johns Hopkins University

Building Bridges with Science & Industry for Heritage Collections

The role of temperature on the loss of physical and optical properties of newsprint: An assessment of deacidification and subzero freezer storage for the long-term preservation of newspapers in their original form

Henry Wilhelm[a], John Baty[b], and Andrew Han[c]

[a] Co-founder and Director of Research, Wilhelm Imaging Research, Inc. (WIR); Co-Founder, the Center for the Image. [b] Assistant Research Professor and Heritage Science for Conservation (HSC) Scientist, Departments of Conservation and Preservation – Sheridan Libraries and University Museums, and Materials Science and Engineering – Whiting School of Engineering, Johns Hopkins University. [c] Undergraduate Student, Department of Materials Science and Engineering – Whiting School of Engineering, Johns Hopkins University.

Introduction & Motivation

Traditional newspapers contain many of the elements we value in artifacts. Printed as history unfolds, they are primary sources and often the best witnesses we have to historical events. In addition to their inherent value as historical artifacts, much of what an original newspaper contains has *not* been—and in many cases still cannot be—retained in analog or digital reformatting. These features include the color and halftoning (see Fig. 1) of the images, the advertisements, and the feel and texture of the pages.


200,000 MARCH FOR CIVIL RIGHTS IN ORDERLY WASHINGTON RALLY; PRESIDENT SEES GAIN FOR NEGRO

Fig. 1. August 29, 1963 issue of *The New York Times* downloaded from nytimes.com exhibiting poor halftone reproduction

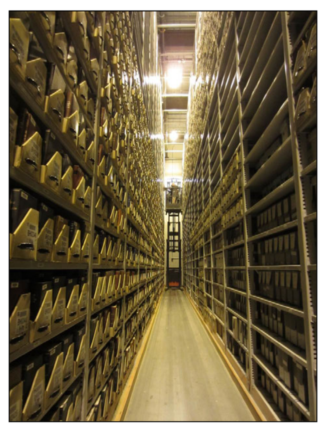


Fig. 2. Duke University Libraries Service Center. Location of American Newspaper Repository

With the advent of the Internet and the widespread adoption of computers and mobile smartphones and tablets, the worldwide distribution of news has rapidly shifted away from the traditional newspaper. The newspaper industry is in a state of precipitous decline, the more than 500-year history of this decisively important form of communication is coming to an end, and the physical artifact that we know as an unbound, folded paper newspaper is vanishing. It is therefore important that representative selections of newspapers in every country in the world be preserved in their original form.

This study uses accelerated aging of deacidified and untreated newspapers at multiple temperatures to determine the temperature dependence of newsprint aging and assess the efficacy of deacidification and sub-zero cold storage to preserve newspapers in their original form.

Materials & Methods

Materials acquisition

Fig. 3. H. Wilhelm purchasing 175 copies of the 31 March 2014 issue of *The New York Times* from the Grinnell College (IA) Bookstore

We determined there were two ways to obtain newsprint for our study. We could (1) commission a pilot run of newsprint formulated according to our specifications with all variables documented. Thereafter, we would have the paper printed on a web press with printing similarly controlled. Alternatively, we could (2) obtain printed newsprint that we determined constituted a "lot," meaning every specimen was formulated and printed under similar conditions. We would then need to analyze this newsprint for criteria we could not obtain from the vendor. We opted for the latter approach, acquiring 175 copies of the 31 March 2014 issue of the New York Times. We further elected only to use Section A, because the subsequent sections may have been from another lot of paper.

Treatments

Rather than single-item treatment, this research explores technologies to preserve collections of newspapers in their original form. These technologies include (1) the Bookkeeper method of mass deacidification, which deposits magnesium oxide in the paper, leaving an alkaline reserve[1], and (2) sub-zero cold storage (-20 °C) of the newspapers in a humidity-controlled vault[2].

Fig. 4. C. Brower Wilhelm (l) and H. Wilhelm (r) at the Wilhelm Imaging Research/Smithsonian newspaper preservation collection storage facility in Grinnell, Iowa, USA

Mechanical testing

Mechanical testing in this project centers around two primary criteria: MIT Folding Endurance[3] and Elmendorf Tear Resistance[4]. Folding endurance (in principle) has been identified by HSC conservators as a key criterion for the preservation of collections in which pages are turned by the user.

Materials & Methods (continued)

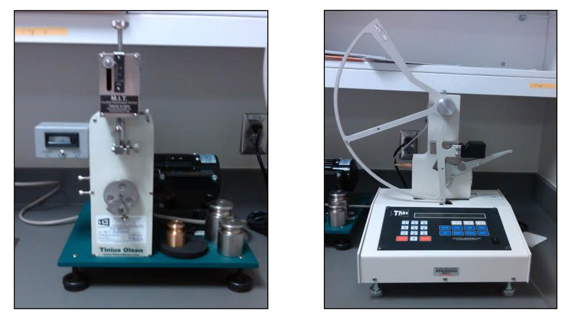


Fig. 5. Elmendorf Tear Tester (l) and MIT Fold Endurance Tester (r) at HSC

Tearing resistance is similarly relevant to newsprint, and is specified in the ANSI/NISO Z.39.48 permanent paper standard. A downside is the great quantity of paper required to perform this test.

Chemical testing

Fig. 6. A. Han operating the GPC Workstation

There are several chemical criteria for monitoring paper degradation such as pH, alkaline reserve, concentration of degradation products, etc. In this study, we focused on the determination of polysaccharide (cellulose, hemicellulose) molecular weight because a loss of molecular weight means that irreversible disintegration has within the fiber structure.

Specifically, we followed a procedure at HSC published by Stol and coworkers[5] to determine polysaccharide molecular weight via Gel Permeation Chromatography (GPC).

Optical testing

Because newspapers contain both text and monochrome and color images, it is appropriate to evaluate them using an imaging standard. Accordingly, we use "ISO 18936:2012, Imaging Materials – Processed Colour Photographs – Methods for Measuring Thermal Stability[6]." Specified spectrophotometric criteria include CIELAB (illuminant D50, 2° standard observer), available at HSC and WIR. Also at WIR are optical density and near-UV (relevant to yellowing).

Fig. 7. Handheld spectrophotometer at HSC

Arrhenius aging

Also specified in ISO 18936:2012 is that at least 4 temperatures be used for a rigorous calculation of temperature dependence. Because of the importance of this to imaging, WIR has several humid ovens maintaining these conditions continuously. Rigorous calculation of temperature dependence is a contribution to paper aging generally, and is especially useful in our case to forecast behavior down beyond ambient to subzero freezer conditions.

Fig.8. WIR staff member Barbara Stahl with the Arrhenius ovens maintained at 57, 64, 71, and 78°C—all at 50% RH

Results & Discussion

Mechanical testing

Table 1. MIT Folding Endurance, Initial Condition (*t*=0), machine direction (MD)

Applied tension	Average MIT double folds	Sample standard deviation (σ)	% uncertainty
1 kgf *	9.5	1.8	19
500 gf	378.5	129.9	34

* 1 kgf is the default loading for MIT Folding Endurance.

Table 2. MIT Folding Endurance, Initial Condition (*t*=0), cross direction (CD)

Applied tension	Average MIT double folds	Sample standard deviation (σ)	% uncertainty
1 kgf	-- Fail -- *(This paper fractures at 1 kgf loading in this direction.)*		
500 gf	5.8	1.2	21
295 gf	65.9	40.6	62
200 gf	1299.3	774.9	60

Fig. 9. MIT Folding Endurance (MD, 1 kgf) vs. aging (80°C, 51% RH)

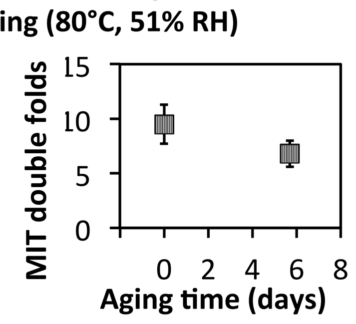
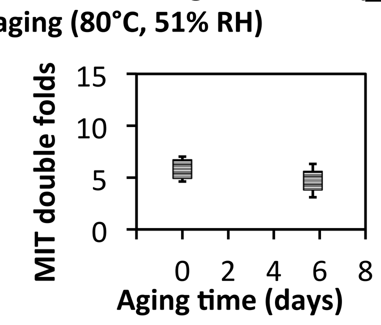


Fig. 10. MIT Folding Endurance (CD, 500 gf) vs. aging (80°C, 51% RH)



Tables 1 & 2 show efforts to employ MIT Folding Endurance in this study, selecting an applied tension that does not cause fracture but enables sufficient precision. The recommended 1 kgf offers the best precision in the MD but fractures in the CD.

Results & Discussion (continued)

Figs. 9 & 10 show the number of MIT double folds for the initial condition and the results of aging at 80°C, 51% RH for the MD and CD with the optimum tensions, 1 kgf and 500 gf, respectively. As shown by the error bars, no significant difference is observed, suggesting that, at best, MIT Folding Endurance will only reveal qualitative differences in this study.

In contrast to folding endurance, we readily optimized Elmendorf Tear Resistance conditions for this newsprint. While material fracture is inherently inconsistent, Elmendorf Tear involves the tearing of several plies at once. (In this case 16 plies X ten replicates = 160 small sheets per test unit) Fig. 11 shows the tearing force per ply for both the MD and CD for the initial condition. Higher tearing force in the CD is attributable to tearing cross-grain. An uncertainty of ~ 3% enables us to resolve the initial condition from the aged samples (5.7 days, 50°C – orange stripes , 80°C – red stripes) and the aged samples from each other.

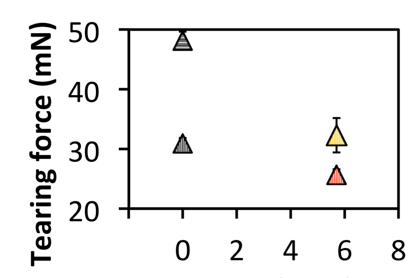


Fig. 11. Tearing force (Elmendorf Method) vs. Aging time (days) for the initial condition (MD-vertical stripes CD-horizontal stripes) and aged samples (5.7 days, 50°C – orange stripes, 80°C – red stripes)

Chemical testing

The method we selected to analyze our paper for molecular weight was unsuccessful in getting the fibers to drop into solution. As lignin content increases, GPC becomes increasingly difficult, and newsprint (composed of groundwood) is evidently on the frontier of current capabilities.

A research group active in this area was able to obtain molecular weight criteria for us using a yet-unpublished method. We look forward to learning more.

Optical testing

Table 3. CIELAB (illuminant D50, 2° standard observer, specular component included)

Aging conditions	L*	σ	a*	σ	b*	σ
Initial condition	81.30	0.87	1.81	0.18	6.56	0.54
5.7 days, 80°C, 51% RH	77.82	1.32	2.38	0.34	8.83	0.61
5.7 days, 50°C, 51% RH	77.94	2.45	1.65	0.40	6.65	0.34

In our spectral reflectance measurements, we have been able to detect significant changes in all three CIELAB criteria between the initial condition and the 5.7 days, 80°C, 51% RH aging condition. Namely, the aged paper is significantly darker, yellower and, if only subtly, redder.

Conclusions & Future Work

1. MIT Folding Endurance testing of our newsprint is only precise enough for, at best, *qualitative* comparisons between aging conditions. HSC is particularly interested to identify an alternative measure for this key preservation criterion for newspapers.
2. Molecular weight analysis of polysaccharides in newsprint via Gel Permeation Chromatography is not yet fully developed and reported. We will partner with, or closely follow, leading developers of this technology to incorporate GPC analysis into this study because of its rigor measuring chemical degradation.
3. Elmendorf Tear Resistance and visible spectroscopy (CIELAB criteria) offer very precise measurements of mechanical and optical/chemical properties of this paper while targeting key preservation criteria. We have demonstrated that this low uncertainty, for both the un-aged and aged paper, enables quantitative analysis of paper aging in our study.
4. Currently at Wilhelm Imaging Research and Heritage Science for Conservation we have 92 test units under test (deacidified/undeacidified, 4 different temperatures, 11 incubation times). Each of these units is further subjected to a gamut of 7 mechanical, chemical, and optical tests, providing a rigorous assessment of sub-zero cold storage and/or deacidification to preserve newspapers long-term in their original form.

References

[1] Pauk, S., and van de Watering, J. (1993). "Deacidification with Bookkeeper [deacidification spray]," Abbey Newsletter 17(6), 1-2.

[2] McCormick-Goodhart, M., and Wilhelm, H. (2004). "The design and operation of a passive humidity-controlled cold storage vault using conventional freezer technology and moisture-sealed cabinets," IS&T Archiving Conference, Final Program and Proceedings, sponsored by The Society for Imaging Science and Technology, San Antonio, Texas, April 20-23.

[3] TAPPI (Technical Association of the Pulp and Paper Industry). T 511 om-02: "Folding endurance of paper (MIT tester)," 2002-2003 TAPPI Test Methods [CD-ROM]; TAPPI Press: Atlanta, Georgia, USA, 2002.

[4] TAPPI (Technical Association of the Pulp and Paper Industry). T 414 om-99: "Internal tearing resistance of paper (Elmendorf-type method)," 2002-2003 TAPPI Test Methods [CD-ROM]; TAPPI Press: Atlanta, Georgia, USA, 2002.

[5] Stol et al. (2002). Anal. Chem. 74, 2314-2320

[6] ISO/DIS, (2012). ISO/DIS 18936:2012, Imaging Materials – Processed Colour Photographs – Methods for Measuring Thermal Stability Geneva, Switzerland: ISO/DIS.

The Center for the Image | WIR | HSC | Johns Hopkins Sheridan Libraries & University Museums

Funded by The Andrew W. Mellon Foundation

100 YEARS Johns Hopkins Engineering

Presented at the 42nd Annual Conference of the American Institute for Conservation of Historic and Artistic Works (AIC) on May 29, 2014. The conference took place at the Hyatt Regency Embarcadero Hotel in San Francisco, California USA. Poster size: 44 x 51 inches (112 x 130 cm).