The Book and Paper Group Annual

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AMY BAKER, JEAN ANN CROFT, JOSEPH TARANTO, AND JAMES WELSH

What Lies Beneath: Treatment of Canvas-backed Pennsylvania Coal Mining Maps for Digitization

ABSTRACT

An ongoing program to preserve approximately seven hundred oversized, canvas-backed, coal mining maps from the CONSOL Energy Mining Map Collection was initiated by the University of Pittsburgh (Pitt) in 2007, supported by funding from the United States Department of the Interior Office of Surface Mining and Reclamation (OSM) and the Pennsylvania Department of Environmental Protection (PA-DEP). The main goal of this project is to stabilize and clean the mining maps for digitization at the OSM National Mine Map Repository (NMMR) located in Pittsburgh, Pennsylvania. The digitized data of the underground mines will be incorporated into Geographical Information Systems relative to mine safety, land reclamation, current mining operations, and new development.

INTRODUCTION

The collection

CONSOL Energy Inc. first donated mining-related materials to the Archive Service Center at the University of Pittsburgh in 1991. The collection has grown with additional deposits of material including maps, survey books, photographs, and published works. Mining maps represent the largest component of the collection, with over eight thousand individual map sheets of various formats. The bulk of the collection dates from the 1890s through the first half of the twentieth century. The CONSOL Energy Mining Archives includes significant historical materials that document Pittsburgh's national industrial heritage. They include, for example, the records relating to Henry C. Frick Coal and Coke Company and materials that document the coal and coke mining industry in general.

This project focuses on approximately seven hundred oversized maps, the majority dating between 1850 and 1950, known as "hardbacks." The term "hardback," coined by the coal mining industry, refers to the map's construction of heavy-weight paper backed with canvas. The hardback maps were first drafted in graphite and later colored by hand using different media including inks, colored pastels, and watercolors (fig. 1). The large dimensions of the maps present challenges in use and preservation, as the average map is five feet in height, and varies from two to thirty feet in length (fig. 2). The hardbacks contain the most complete, if not only, diagram of underground mines owned and/or

LEFT TO RIGHT

Fig. 1. Detail of hardback mine map completed with watercolor and ink. The different colors and letters are date codes corresponding to the years that coal was mined out of the area

Fig. 2. A hardback map unrolled measuring five by fifteen feet (1.5 by 4.5 m)

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operated by Consolidated Coal Company and its constituents in the Pennsylvania counties of Allegheny, Westmoreland, Washington, Greene, Fayette, and Somerset.

Significance and use

The CONSOL Energy Mining Map Collection provides a wealth of information about the changing environment in Western Pennsylvania during much of its mining history. Increased access to this collection will allow fuller exploration by disciplines such as environmental studies, geology, and engineering, in addition to the mining industry. Beyond the typical use by researchers, the hardbacks are currently being consulted by the PA-DEP and OSM for the following projects:

- Access to the PA-DEP in support of the Pennsylvania Coal and Clay Mine Subsidence Insurance (MSI) program. These maps contain crucial data necessary to create better mapping and accurate information for the public to determine their risk of mine subsidence.
- Access and use by the California District Office of District Mining Operations to map mined area extents and determine approximate areas and extents of mine pools.

The maps are also an important source of information for municipal, economic, and transportation planners as they seek to develop new housing, commercial facilities, and highways, as well as deal with such issues as subsidence and mine water runoff. In recent years, these hardbacks have been consulted by a variety of people, including: a private citizens group undertaking a land reclamation project dealing with the underlying mines and mine drainage issues to convert 452 acres in the southwestern corner of Settler's Cabin Park in North Fayette and Collier Townships into the Botanic Garden of Western Pennsylvania; engineers planning the route of the Mon-Fayette Expressway, a key to future economic development in the Monongahela and Youghiogheny River valleys; and federal, state, and municipal officials dealing with the mine water breakthrough incident in McDonald, Pennsylvania, in 2005 (fig. 3). In these cases and others, the hardback maps held by the Archives Service Center provided vital information not available elsewhere and will continue to have a role in any new development or reclamation project.

Fig. 3. Mine water breakout in McDonald, Pennsylvania, in 2005

The large size and deterioration of the hardback maps render them cumbersome to handle and use. Stabilization and digitization of the maps will facilitate cataloging efforts and increase access. The Archives Service Center and the PA-DEP are collaborating to catalog the hardback maps and incorporate the inventory into the Pennsylvania Historical Mine Maps Inventory System (PHUMMIS). The PHUMMIS and the Pennsylvania Spatial Data Access (PASDA) system will provide for enhanced access to the data contained on the hardback maps. This project is one initiative fostering partnerships between the mining industry and educational institutions, but additional collaborations are needed to preserve these oversized materials and set cataloging agendas for underground mining maps to ensure that underground mining data is accessible for research, development, and safety in the future.

MAP PRESERVATION PROJECT

Workflow

The primary goals established by the Project Team were to design a treatment strategy and complete treatment on one hundred maps by June 2008. Conservation treatment is completed by the project conservator and student assistants at the University of Pittsburgh's Preservation Department. Once a month, a mining specialist from the PA-DEP transports a batch of treated maps from the preservation lab to the NMMR for scanning. The PA-DEP retains the digital files and returns the original maps to the University of Pittsburgh for archival storage (fig. 4).

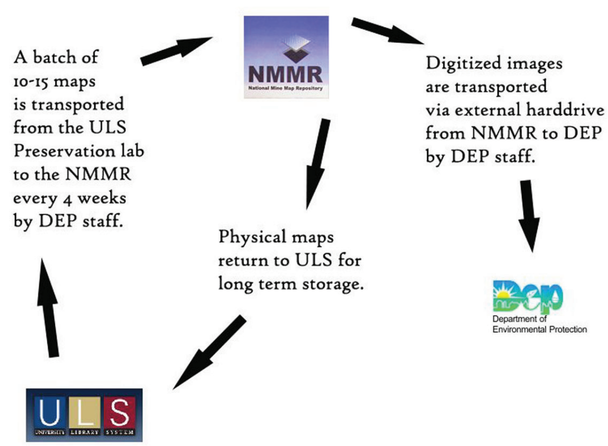


Fig. 4. Diagram showing the transportation of physical maps and digital images between the preservation lab, PA-DE,P and NMMR

Staffing

The conservation staff for this project consists of one full-time conservator working in the preservation lab, two paper conservators who serve as consultants, one student assistant who works for ten hours per week, and the head of preservation who provides overall supervision and guidance to the project. The consultants were required to work one hundred twenty hours, conduct training sessions relating to map preservation, submit detailed reports outlining their recommendations in achieving the project goals, and assist the project conservator in making decisions about materials, methods and treatments (fig. 5).

Database

In order to propose conservation treatment for the maps, an efficient tool was needed to conduct a detailed condition survey. The staff also required a system for recording treatment documentation, cataloging, and tracking maps. The project conservator designed a database building upon the Pennsylvania Historical Mine Maps Inventory System (PHUMMIS) template provided by the PA-DEP. The template contained fields relative to mining institutions, such as mine name and geographic location of a mine. Additional fields relating to condition, conservation treatment, and tracking were added to the template and this collaborative database was nicknamed "CONcat" (fig. 6).

CONSERVATION TREATMENT

Condition

In 2006 two interns from the School of Information Sciences at the University of Pittsburgh conducted an initial condition survey of one hundred hardback maps from the CONSOL collection. The survey revealed that forty-one percent of the maps assessed were in "good" condition, nineteen percent in "fair" condition, and forty percent in "poor" condition. Throughout the survey process, the interns also amended an item-level inventory provided by CONSOL Energy that accounted for just over six-hundred hardback maps. They discovered that multiple maps were rolled inside of other maps, increasing the original inventory. The staff continues to find additional hardbacks rolled together and the inventory has grown to 680 maps as of June 2008.

A detailed survey of the maps' condition also required identifying the types of damage that were common among the maps. It was found the main factors of deterioration were threefold: inherent vices in the materials used to construct the maps; the environment of the coal mines in which the maps were used; and the manner in which the maps were utilized, repaired, and stored. The combination of rolled storage and brittle paper resulted in a fragile map that users had to "crack" open in order to read, causing tears, regular patterns of creasing, and areas of loss (fig. 7). These damages were often

Fig. 5. The consultants and project conservator examine a map in the humidity chamber

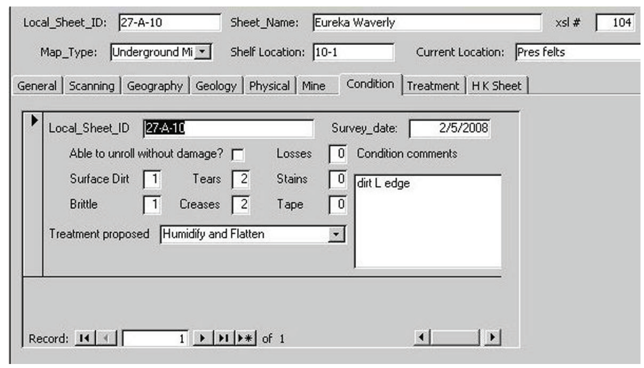


Fig. 6. Detail of the condition tab in the CONcat database

Fig. 7. A hardback map showing tears, losses, and a regular pattern of creases

repaired with pressure-sensitive tapes or patches of canvas. Because the maps were heavily used inside working mines, a considerable amount of coal dust has accumulated on the

maps. The most concentrated coal dust is usually found at the edges where the inner core of the rolled map was exposed to the storage environment.

The hardbacks depict different types of information relative to mining such as underground mine workings, property divisions, and coal town street plans. The archivist, PA-DEP, and project conservator determined that underground mine maps take treatment priority over other types of maps. After the maps are surveyed, depending on their priority and condition, they either return to the original shelf or enter the preservation lab for treatment. Treatments include dry cleaning, humidification and flattening, tape removal, and mending. For the first year of this project, maps requiring repair beyond the aforementioned treatments are returned to the original shelf for future assessment. As of June 2008 less than two percent of the 178 maps surveyed were returned to the original shelf for this reason.

Dry cleaning

The project conservator and consultants tested methods for dry cleaning including Absorbene putty, dust cloths, eraser crumbs, soot sponges, Wishab sponges, and Magic Rub erasers. Soot sponges and Wishab sponges removed the most soot and cleaned the largest areas on the front of the maps (fig. 8). The smaller 3 x 6 x ¾" soot sponges that are available in many archival products catalogs were originally used, but they proved difficult to grasp and the staff often had to fold these in half to get a better grip. It took two of these sponges to clean one map on average. Switching to larger 3 x 9 x 1¼" soot sponges and ordering them directly from the manufacturer made cleaning more efficient and reduced cost by ninety-five percent. The larger sponges are easier to hold and can be reused by trimming dirty areas with scissors. On average one large sponge will effectively surface clean up to three maps. Student assistants perform much of the dry cleaning on the maps; however, before any treatment begins the project conservator and students study the map together to identify areas that require extra attention, such as areas drawn in graphite that were never inked-in.

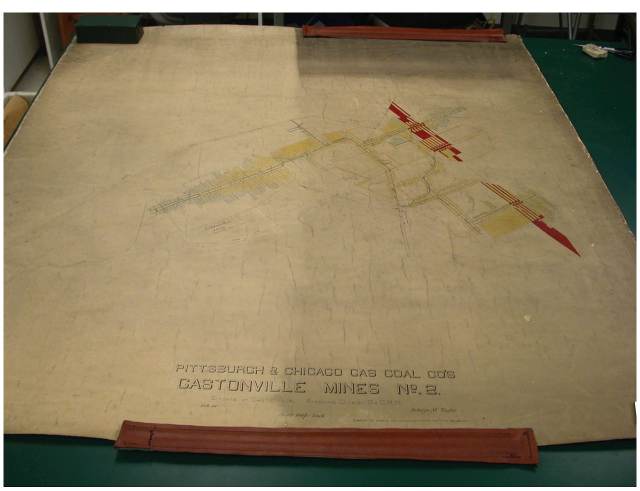


Fig. 8. The left side of this map was cleaned with soot sponges. The right half of the map shows the original amount of coal dust present

The staff cleans the canvas backing of maps using a Nilfisk back vacuum with hypo-allergenic dust brush attachment (fig. 9). A clothes brush attachment with short stiff bristles was tested for cleaning, but this attachment was not as effective at cleaning deep into the canvas weave as the soft long bristles of the dust brush. The vacuum is not used on the front of maps as the paper is too fragile to withstand even gentle suction and there is also friable media present on every map. A fellow conservator suggested holding the vacuum cone slightly above the paper, but this only removed a small amount of soot. The sponges are more effective at cleaning the front of the maps.

Fig. 9. A student assistant vacuums the back of a map with the Nilfisk back vacuum using the dust brush attachment

Tape removal

Approximately twenty-five percent of the maps surveyed were previously repaired with various kinds of pressure-sensitive tapes. The preservation lab at the University of Pittsburgh cannot accommodate the use of solvents for tape removal. Luckily, most adhesive softens with the application of a tacking iron through silicone-release paper or by humidification. The carrier can then be peeled away with a microspatula. In general, the plastic tapes are more difficult to remove than the cloth or paper tapes. After the carrier is removed, any remaining adhesive residue is left to dry, then reduced with a rubber cement pick-up eraser.

Humidification and flattening

Maps that cannot be unrolled without cracking are humidified in a dome constructed by Museum Services Corporation that measures five-by-eight feet. The dry- rolled map is placed

on top of mesh screening and blotter paper in the dome. A 1.7 gallon ultrasonic humidifier is connected to the dome with a black hose. Moisture build-up inside the hose tends to drip down the hose and leak out at the connection point to the dome. To catch the drip, a paper towel is placed between the black hose and the connection tube (fig. 10). Also, water builds up in the elbow-shaped plastic tube where humidity enters the dome. Every twenty minutes as someone regularly checks the map's progress in the dome, they also clean out the water build-up in the tube, and replace the paper towel. On average, maps take five hours to humidify this way. Larger maps take longer, and un-backed paper maps take a shorter amount of time.

Immediately following humidification the map is placed between polyester webbing and ¼" thick wool felts (fig. 11). Three-by-nine foot acrylic sheets are positioned on top of the felts, weighted with bricks, and the maps are left to dry in this stack a minimum of two days.

Mending

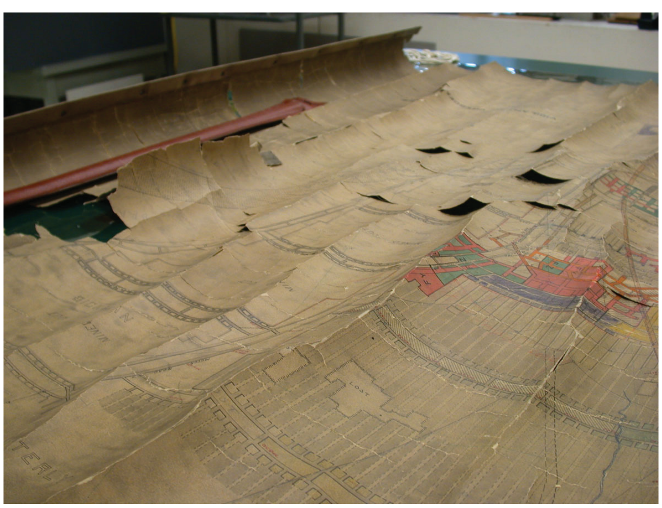
The treatment objective for mending maps is safe handling, making the technique more structural than aesthetic. Large tears are mended with Japanese tissue bridge mends and areas of loss are filled with muslin patches (figs. 12–13). The mends are adhered with Beva D-8, an ethylene vinyl acetate adhesive. The length of time to complete the mending process may vary from fifteen minutes to over twenty hours per map.

Housing

The project staff creates cores made of blotter as a temporary support to transport the maps around the lab. In order to protect the treated maps when they are sent to the scanning facility each month they are wrapped in a "raincoat" of four-millimeter polyester tubing. The tubing is cut down to the

Fig. 10. Map during humidification

Fig. 11. Map between polyester webbing and felt after humidification and flattening



Figs. 12–13. Front of map before mending (left). Front of map after mending showing white muslin patches (right)

length of the map, tucked in at both ends, and secured with Velcro. The proposal for long-term storage of the maps at the University of Pittsburgh is to wrap the maps in muslin and fasten with cotton ties.

IMAGE CAPTURE AND GEO-REFERENCING

The project staff determined that the maps had to be transported rolled to the scanning facility, but then be able to lay flat on the scanner bed. Maps that could not lay flat on their own had to be able to withstand the suction generated from the scanning bed in order to keep them even and level. A mining specialist from PA-DEP picks up an average of ten to fifteen maps each month to transport them to the NMMR for scanning and returns the original maps to the University of Pittsburgh for long-term storage. The various physical locations of the maps are tracked through the CONcat database.

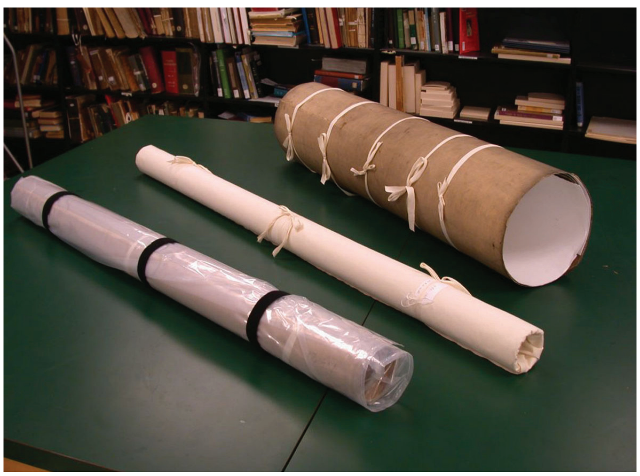


Fig. 14. From left to right: map wrapped in poly tubing, secured with Velcro for transportation to the scanning facility; map wrapped in muslin with cloth ties for final storage; and map wrapped on blotter core and secured with cloth ties for temporary support

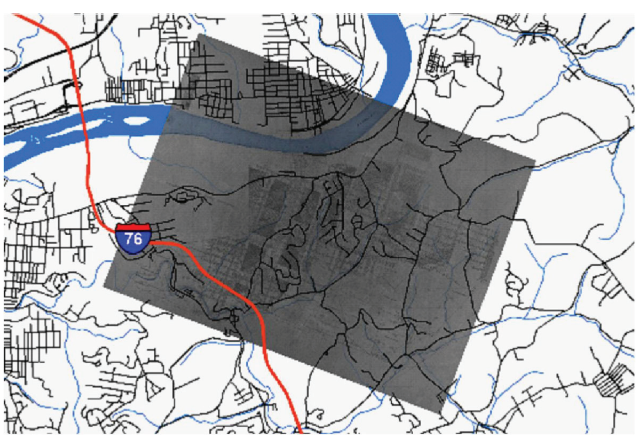


Fig. 15. Detail of a digitized hardback map geo-referenced to a road map also showing physical rivers and creeks

At the NMMR the maps are cataloged into their own database. The maps are digitized on a Cruse Table Scanner CS 285/1100 ST/FA. The scanner is equipped with a 58" x 90" vacuum table. The maps are scanned in 24-bit true color at 200–250 dots per inch, captured with an optical lens camera. The images are stored as uncompressed, tagged image file format (TIFF) files and the average size is 1.1 gigabytes per image. After the physical maps have been scanned the TIFF images are saved to an external hard drive and transported to the PA-DEP where the digital data is cataloged and geo-referenced by mining specialists.

CONCLUSION

The project goal of executing conservation treatment on one hundred maps within the first year has been exceeded. Figure 16 outlines the accomplishments as of June 2008.

CONSOL Mine Map Preservation Project Statistics	
# of maps	Activity completed
178	Surveyed
116	Dry cleaned
21	Humidified & flattened
15	Mended
89	Digitized

Fig. 16. Project statistics as of June 2008

The University of Pittsburgh has promoted this project in several ways. Jean Ann Croft, head of preservation, and Debbie Rougeux, archivist, collaborated on a short article that was published in *Archival Product News*. Colleagues from the PA-DEP, IUP, and the University of Pittsburgh collaborated on a presentation for the Mid Atlantic Regional Archives Conference held in Scranton, Pennsylvania, in April 2007. This session addressed the collaborative efforts in Pennsylvania to build an Internet-accessible database for the maps of underground coal mines in the state, to digitize vital maps, and to preserve the original maps.

Pitt is expecting additional funding from OSM and PA-DEP for the next year to continue this project. The cooperative preservation and scanning efforts of this project have increased the availability of mine mapping resources by providing mapping detail that was not previously accessible. The cataloging efforts and increased communication offer the coal mining industry the necessary tools to determine whether a desired map resides in the Pitt collection and a process by which to request and borrow the map

relatively quickly. This relationship benefits all parties concerned, especially the PA-DEP Mine Subsidence Insurance and Mine Safety Programs.

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National Mine Map Repository
Office of Surface Mining, Reclamation & Enforcement
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412–937–3001
http://arcc.osmre.gov/MMR_Intro.asp

University Library System
Preservation Department
7500 Thomas Boulevard
Pittsburgh, PA
412–244–7523
http://www.library.pitt.edu/

PROJECT WEBSITE

CONSOL Energy Mine Map Preservation Project Website
http://www.pitt.edu/~aeb59/index.html

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WHITNEY BAKER AND LIZ DUBE

A Preliminary Study of Current Book Conservation and Repair in Research Libraries: A Survey of the Landscape

ABSTRACT

The presentation reported preliminary results of a research project to evaluate the curent state of book conservation and repair in research libraries. Following a review of the literature, the authors administered an anonymous, web-based survey to practitioners of general and special collections book conservation and repair in research libraries. The survey requested basic demographic information about the respondents and their institutions, and gathered details about their book conservation and repair practices. The authors analyzed the results and identified which treatments the survey data showed to be standard practice. In addition, some relationships between the demographic characteristics of respondents and treatment practices were noted.

INTRODUCTION

The authors carried out a research project to evaluate the current state of book conservation and repair in research libraries. Following a review of the literature, the authors administered an anonymous, web-based survey in August and September of 2007 to practitioners of general and special collections book conservation and repair in research libraries. In addition to basic demographic information about respondents and their institutions, the survey instrument requested information about their treatment practices with respect to six categories of book treatments typical to research libraries: (1) protective enclosures and book jackets, (2) binding reinforcements, (3) minor paper treatments and textblock repairs, (4) board reattachment methods, (5) other binding repair and rebinding techniques, and (6) advanced paper treatments for bound materials. The authors analyzed the results and identified which treatments the survey data showed to be standard practice, which were employed less uniformly, and which were rarely employed. In addition, the authors identified some relationships between the demographic characteristics of respondents and reported treatment practices.

Presented at the Book and Paper Group session, AIC 36th Annual Meeting, April 21–24, 2008, Denver, Colorado.

PROJECT GOALS

The research project, which is ongoing, aims to document the types of treatments currently employed in research libraries for the treatment of general and special collections materials. In addition, the authors are exploring the following related questions:

- How do current treatment practices compare with what is featured in the literature and presented at conferences?
- How consistent are book treatment practices among research libraries, from institution to institution?
- Has increased information exchange between general and special collections practitioners resulted in more similar treatment practices?
- Do "hybrid" practitioners—those with responsibility for both general and special collections—approach treatment differently than those focusing only on one type of collection?
- Do individuals in centralized facilities approach treatment differently than those in labs focused solely on general or special collections?
- How do training and education affect treatment practices?

This preliminary report describes the survey process and highlights major early findings from the survey.

THE SURVEY INSTRUMENT

The web-based survey consisted of six pages. The first welcomed the respondent and defined the survey audience as "the individual(s) with primary responsibility for book conservation and/or repair," adding that "institutions with multiple conservation/repair units may respond once for the entire institution or individually for each unit." An additional page requested basic demographic information about the

respondent and his or her institution, such as its scope, size, and age of the conservation laboratory, and requested information about the job duties and training of the practitioner completing the survey.

The main pages of the survey gathered information about conservation and repair practices with respect to fifty-five types of treatments (appendix A). To insure the survey's relevance to both general and special collections practitioners and to permit comparisons of their practices, the survey focused on treatments that could conceivably be employed in either a general or a special collections setting. Practitioners were asked to identify how frequently they employed each of the fifty-five treatments. In order to minimize bias or error, concise descriptions were provided in cases where treatment names were not self-explanatory. Three rounds of pre-testing helped the authors refine the list of treatments, treatment definitions, and response options.

Preliminary results

Only complete responses to the survey were included in the analysis. Seventy-nine individuals fully completed the questionnaire. Because the forty-eight "hybrid" practitioner respondents—those involved with both general and special collections treatment—were asked to fill out two treatment questionnaires, one for each type of collection, the seventy-nine respondents provided a total of 127 treatment cases. By coincidence, the responses were distributed nearly evenly between general collections and special collections, sixty-four and sixty-three, respectively.

The respondents were diverse in terms of the size of their libraries; they were divided nearly evenly among large libraries with over five million volumes, mid-size libraries ranging from two to five million volumes, and smaller libraries with less than two million volumes. In addition, the vast majority of respondents reported full- or near-full-time conservation responsibilities, with over sixty percent of the respondents working with both general and special collections.

From the survey results, the authors identified which treatments the respondents widely considered standard practice, which were employed less uniformly, and which were very rarely employed. In general, responses pertaining to general and special collections practices showed more similarity than might be expected, but differences were noted. Treatments in the categories of "binding reinforcements," "minor paper treatments," and "textblock repairs" were found overall to be more common to general collections than special collections. Conversely, treatments in the categories of "protective enclosures," "board reattachments," "additional binding techniques," and "paper treatments for bound materials" were found to be more common to special collections. Within the various categories, however, there were individual exceptions to these broader trends.

The data also pointed to some relationships between the demographic features of the respondents and the treatments they reported as standard practice. Most of these findings were not surprising but rather confirmed the authors' expectations. In the context of general collections treatment, "hybrid" practitioners—those with responsibility for both general and special collections treatments—were slightly more likely than their counterparts working solely on general collections to report treatments as standard practice, especially for more complex treatments. In other words, the "hybrid" practitioners tended to utilize a broader and more advanced range of techniques. In the context of special collections, however, the higher-end treatments were more commonly reported as standard practice by "special-collections-only" practitioners than by their "hybrid" counterparts.

The authors continue to analyze the data derived from the survey and plan to publish complete findings in the near future.

APPENDIX A: TREATMENTS INCLUDED IN THE SURVEY

Protective enclosures

- Polyester book jacket
- CoLibri polyethylene book jacket
- Pocket, envelope, or three- or four-flap folder in pamphlet binder
- Three- or four-flap "tuxedo" box (tongue & slot closure)
- Three- or four-flap "phase" box (rivet & string closure)
- Corrugated board box
- Cloth-covered clamshell box
- Leather-covered clamshell box
- Fitting books with custom sized boxes purchased from a vendor
- Polyester sleeves or encapsulation

Binding reinforcements

- Pamphlet binding, adhesive attachment
- Pamphlet binding, staple-through-the-fold
- Pamphlet binding, sew-through-the-fold
- Paperback stiffening

Minor paper treatments and textblock repairs

- Creating or inserting photocopy replacement pages
- Mending with "archival" tape (e.g., Filmoplast, Archival Aids)
- Mending with heat-set tissue
- Mending with Japanese paper and paste
- Guarding sections with Japanese paper and paste
- Resewing several sections
- Sewing or re-sewing an entire volume
- Barrier spine lining of Japanese paper and paste
- New tipped-on endsheets

- New hinged-on endsheets
- New sewn-through-the-fold endsheets

Board reattachment methods
- Joint tacketing
- Japanese paper board reattachment
- Toning Japanese paper with acrylics for board reattachment or binding repair
- Solvent-set tissue board reattachment
- Board slotting
- Partial cloth hinge
- New slips

Binding repair and rebinding techniques
- Recase
- New case
- Lapped case or Bradel binding
- New limp vellum and/or limp paper case binding
- Cloth reback
- Leather reback
- Japanese paper reback
- Reattaching detached spines with a hollow tube or v-hinge
- Lifting endsheets to save original pastedowns
- Dyeing cloth with acrylics for binding repairs
- Dyeing leather with leather dye for binding repairs
- Consolidating leather with Klucel-G
- Sewn boards binding
- Split board binding
- "Treatment 305"
- Double-fan adhesive binding

Advanced paper treatments performed on bound volumes
- Aqueous washing or alkalization
- Bookkeeper deacidification (in-house) Wei T'o deacidification
- Localized tape/adhesive removal using heat
- Localized tape/adhesive/stain removal using water (e.g., methyl cellulose)
- Localized tape/adhesive/stain removal using other solvents
- Dry cleaning with vinyl erasers or vinyl eraser crumbs

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Metadata for Conservators

ABSTRACT

Metadata is quickly becoming indispensable for anyone who creates and manages digital information. Conservators create digital images and text files for treatment documentation, and they are also often involved in preservation/access projects in which digital files are created in large numbers. Although the purpose of metadata is to make digital files more manageable and easier to access, it is often a source of confusion to non-specialists. While there are some standards under development, the lack of standards for conservation metadata was well as the lack of user-friendly metadata tools only contributes to these difficulties. This talk is a broad introduction to metadata, particularly as conservators may encounter it in the course of their work, and is intended to lay a framework and contribute to a fuller understanding of the metadata related aspects of the EMG/BPG joint session talks.

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CLAIRE DEKLE AND MARY ELIZABETH HAUDE

Iron-gall Ink Treatment at the Library of Congress: Old Manuscripts—New Tools

ABSTRACT

Following the scientific research of the Library of Congress' Iron-Gall Ink Corrosion Group (2002–2005), the Conservation Division's Protocols for Iron-Gall Ink Treatment Group (PIT) has worked to incorporate recent findings into treatment practice and to develop a unified approach to the conservation of paper-based collections containing iron-gall ink.

The paper will illustrate how the methodology and tools produced by PIT are used in the treatment of iron-gall ink-inscribed manuscripts. The tools include an examination form for recording the information specific to iron-gall ink that leads directly to treatment choices. Flow charts, called *Treatment Trees*, guide treatment based on visual, chemical, and solubility characteristics of the ink and address options for washing, alkaline, and complexing treatments. Additional documents on treatment methods work in conjunction with the flow charts to further refine and optimize treatments.

For the past two years Library conservators have used the methodology and tools to guide treatment of collection materials of various formats and containing iron-gall ink at various stages of deterioration. The paper will directly demonstrate the use of the PIT tools in guiding conservation treatments of eighteenth-century American manuscripts undertaken jointly by a paper and a book conservator at the Library of Congress.

INTRODUCTION

The problems associated with historical iron-gall ink are well-known to conservators. The Library of Congress Conservation Division has focused on addressing these problems during the last eight years through two initiatives. The first, the Iron-gall Ink Corrosion Group, scientifically evaluated various papers treated with eight combinations of pH neutral and alkaline solutions following accelerated aging. The second initiative was more practical in focus. The Protocols for Iron-gall Ink Treatment Group, or PIT Group, had a two-year mandate to develop a consistent approach for treatment of iron-gall ink-inscribed materials in the Library's collections.

Many of the special collections in the Library's custodial divisions contain iron-gall ink. The Manuscript Division alone currently has over fifty million items in eleven thousand collections, and thus holds the majority of the Library's iron-gall ink-inscribed materials. Some of the United States' written historical treasures reside there, including Thomas Jefferson's rough draft of the Declaration of Independence, Abraham Lincoln's Gettysburg Address, and the manuscripts presented in this paper.

PROTOCOLS FOR IRON-GALL INK TREATMENT TOOLS

The first part of this paper briefly describes the "toolkit" of documents devised by the PIT Group. The tools are an examination form specific to iron-gall ink with an accompanying *Glossary*, treatment decision-making flow charts, and a series of explanatory notes to support examination and treatment. PIT developed these tools tailored to practice at the Library of Congress (LC). In LC's specific, institutional context, several factors were key in shaping the PIT Group protocols: anticipated research or exhibit use for individual items, environmental conditions in storage areas and reading rooms, and the resources available to Division conservators—equipment, materials, and the cumulative conservation experience of the staff. The PIT documents are shown in the final paper of this publication, "Developing Guidelines for Iron-Gall Ink Treatment at the Library of Congress" on p. 129.

As the PIT Group began its work, it recognized that careful examination and testing were the basis of treatment decisions for iron-gall ink-inscribed materials. Although the Conservation Division had developed several examination and treatment forms for various types of paper and book

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treatments, none of them specifically addressed iron-gall ink. PIT developed a new form, the *Record of Examination for Iron-Gall Ink on Paper* (See pp. 131–133) to guide close examination, beginning with the appearance of the ink. Characteristics such as the intensity of the ink, the quantity and quality of application, and the degree to which the ink penetrates the paper are noted. The condition of the ink—cracks, losses, and delamination of the inked paper; discoloration surrounding and resulting from contact with the ink; the friability and overall adhesion and cohesion of the ink; the degree of burn-through; and the absorption or fluorescence of an inked area in both visible and long-wave UV light—is also noted.

Some of the *Examination* terms are familiar, others perhaps are not so well known. The Group developed a *Glossary*, a common vocabulary, to describe the characteristics and damage associated with iron-gall ink. The examination form provides space to record characteristics of the paper support, but focuses on qualities, such as opacity, surface texture, and degree of sizing, that relate closely to reactions with an iron-gall ink medium.

"Testing" is a large section of the *Record of Examination*. Here, the conservator can note the rate at which the paper absorbs water, the pH of the paper surface, and the results of the iron (II) ion and solubility tests before, during, and after treatment.

The iron (II) ion test is paper impregnated with bathophenanthroline, (4, 7-diphenyl-1, 10-phenanthroline), a chemical indicator used to signal the presence of iron (II) ions (fig. 1). These iron ions are not part of the ink complex, but exist as water-soluble salts. In this chemical form the ions act as catalysts for cellulose oxidation, the most destructive reaction caused by iron-gall ink corrosion. Although the test is qualitative rather than quantitative, the presence of iron (II) ions provides an indication of ink stability and is a valuable tool in assessing the condition of the ink.

The results of examination of the ink and paper lead the conservator to decision–making strategies presented in flow charts. The two types of flow charts or "trees" that PIT includes in its toolkit are *Washing Treatment Trees* and *Alkaline & Complexing Treatment Trees* (See pp. 139–140). These *Trees* are the result of PIT Group member Julie Biggs's idea for flow charts containing various options for conservators to draw from when treating iron-gall ink-inscribed materials. For the 2006 ICON conference, Julie and fellow PIT Group member Yasmeen Khan wrote *Treatment Trees for Iron-Gall Ink on Paper: Using Flow Charts to Develop Treatment Protocols.*

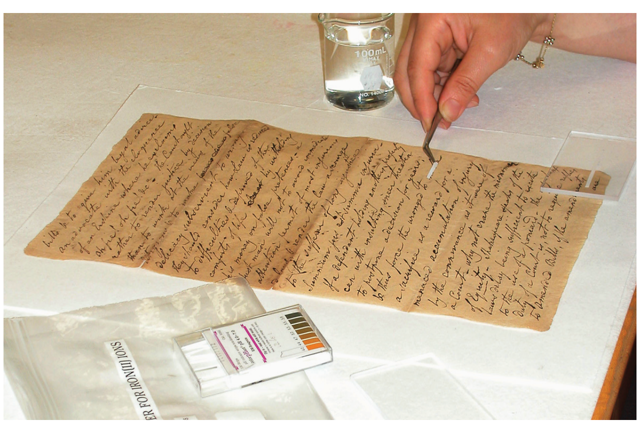


Fig. 1. Testing for presence of iron (II) ions

At the top of the *Washing Trees* there are three Guide Boxes with four criteria from examination. The four criteria or "Guiding Factors," are: a) the condition of the paper, based on evaluation of several factors, including visual examination and surface pH; b) iron (II) ion test results; c) visible presence of ink corrosion; and d) presence of UV fluorescent haloes surrounding the ink. The results of the iron (II) test and corrosion of the ink are the key differences between the two Guide Boxes that branch to treatment steps. For example, in the box on the left the iron (II) test results are positive and the ink is corroded, while in the box at center the iron (II) test is negative or very slightly positive and the ink is not visibly corroded. Below the Guide Boxes the *Trees* guide the conservator in washing decisions based on the solubility of the ink in water and ethanol. After obtaining results from examination and testing, the conservator can choose the appropriate tree and recommended steps. The steps differ based on the examination and testing results.

In the usual sequence of treatment activities, alkaline treatment follows washing. To use the *Alkaline & Complexing Treatment Trees*, the conservator considers the criteria appearing in the Guide Boxes. These criteria are best obtained by testing following washing, as an object will have changed in response to the washing treatment. Like the *Washing Trees*, the branches diverge from the two Guide Boxes, based on the solubility of the ink in water, then divide again, depending on the solubility of the ink in ethanol.

The *Alkaline & Complexing Treatment Trees* include alkaline treatment via fully aqueous, solvent-modified, and non-aqueous methods, and complexing treatment with calcium phytate and calcium bicarbonate via fully aqueous and solvent-modified methods. The *Alkaline & Complexing Trees* also recommend re-evaluation of the criteria in the Guide Boxes when phases of treatment are completed. It is important to emphasize that the *Trees* present a range of treatment possibilities, rather than a prescription for treatment or a substitute for the conservator's experience.

The *Washing* and *Alkaline & Complexing Trees* are summaries of treatment options. Since the primary goal of the PIT Group was to establish a package of examination and treatment guidelines for the LC conservation lab, the Group also created a series of technical notes. The *Notes* provide a more nuanced view of treatment methods populating the *Trees*. Subjects of PIT *Notes* include instructions for examining iron-gall ink using the Library's imaging equipment;

procedures for spot testing for ink solubility; and procedures for washing, alkaline and complexing treatments, as well as advantages and disadvantages of those procedures.

TREATMENTS DEMONSTRATING THE USE OF PIT TOOLS

[Diary] [Detailed proceedings of the Continental Congress, as observed by Richard Smith, member of the Committee on Claims], (1775 Sept. 12–Oct. 1; 1775 Dec. 12–1776 Mar. 30)

The second part of this paper demonstrates the use of PIT tools for treatment of several late eighteenth-century objects from the Library's Manuscript Division: the *[Diary]* of Richard Smith, the *Petition of the Continental Congress to the King,* and James Madison's *Notes on Debates in the Federal Convention of 1787*. These were just a few of the many iron-gall ink-inscribed items selected for the Library's recently opened exhibit "Creating the United States." The following conventions apply to all of the treatments that will be described: a) ethanol, with a few drops of deionized water added, was used for conditioning before washing; b) for the washing solutions, the percentage of solvent to water and the pH of the wash bath is stated; c) all of the treatment baths were solutions of deionized water, adjusted with a saturated calcium hydroxide solution to the desired pH, and ethanol; d) ColorpHast (EM Science / Merck) strips were used to indicate the pH of solutions and the surface pH of paper; and e) drying after all phases of treatment included blotting and placing leaves between dry polyester web and lightly weighted felts.

The first treatment concerns a diary kept by New Jersey delegate Richard Smith during the Continental Congress from 1775–1776 (fig. 2). The diary is Smith's personal record of the proceedings of the Congress, and includes details of property losses and government expenditures during the Revolutionary War. One large pamphlet-sewn gathering of more than 50 bifolia dominated the two-gathering binding structure. The size of that first gathering required the leaves to round around the spine and the paper to flex considerably as pages were turned (fig. 3). Cotton cord wrapped around the gathering held it together. The cord sawed into the edges of the leaves, causing them to break away at the spine folds (figs. 3–4). Some pages had been lost and in some instances only fragments of others remained. Many pages showed evidence of water damage. The 15 x 9 cm pages contained closely spaced lines of text on both

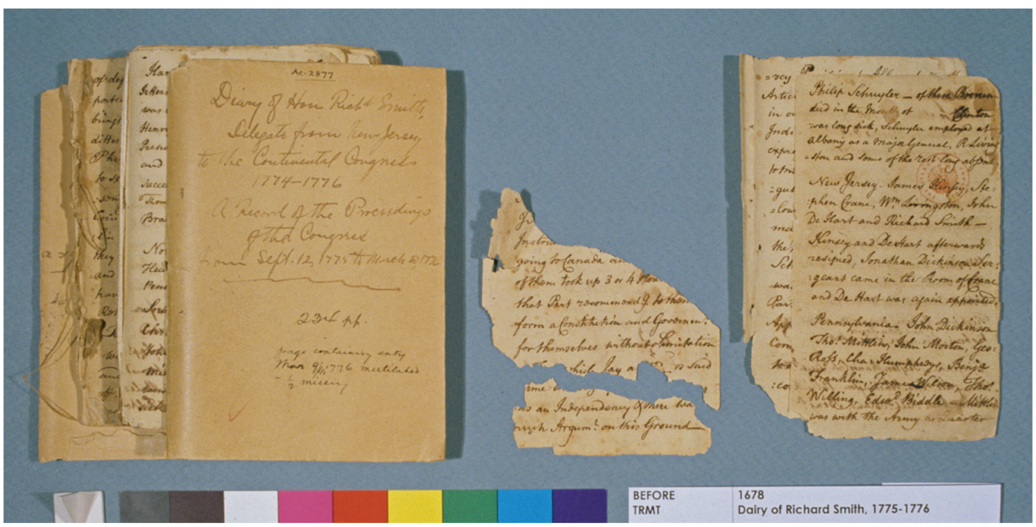
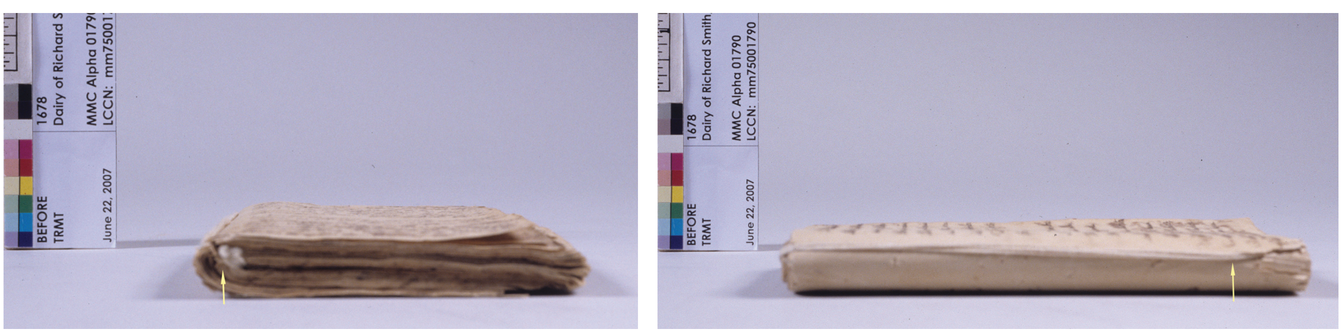


Fig. 2. Richard Smith, [Diary] [Detailed proceedings of the Continental Congress, as observed by Smith, member of the Committee on Claims], (1775 Sept. 12–Oct. 1; 1775 Dec. 12–1776 Mar. 30), iron-gall ink on paper, approx. 15 x 9 cm, Manuscript Division, The Library of Congress (MMC, Ac. 2877, LC Control No. mm75001790). Before treatment, overall



Figs. 3–4. Richard Smith, [Diary]. Before treatment, tail (left) and spine (right)

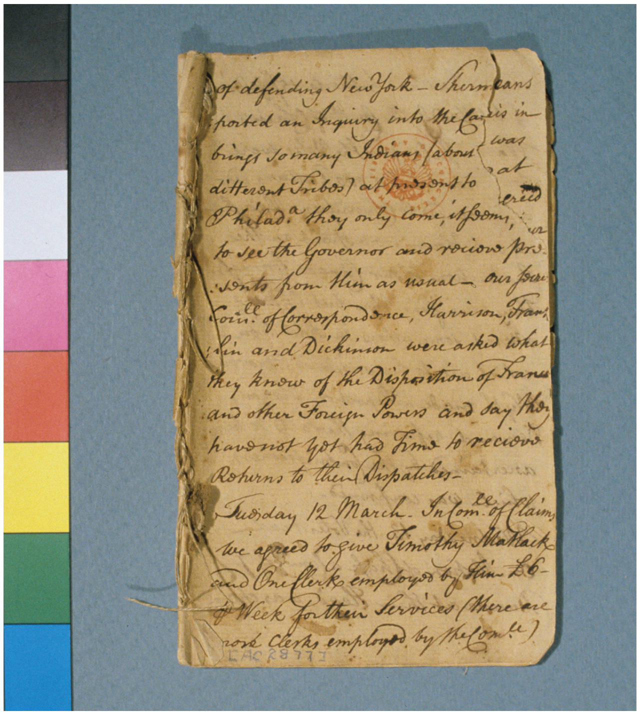

of defending New York – Shermans
ported an Inquiry into the
bring so many Indians (about
different Tribes) at present to
Philada. they only come, it seems,
to see the Governor and receive pre-
sents from Him as usual –
Comm. of Correspondence, Harrison, Frank-
lin and Dickinson were asked what
they know of the Disposition of France
and other Foreign Powers and say they
have not yet had time to receive
Returns to their Dispatches –
Tuesday 12 March. In Com. of Claims
we agreed to give Timothy Matlack
and One Clerk employed by Him £6
p Week for their Services (There are
Clerks employed by the Comm.)

Fig. 5. Richard Smith, [Diary]. Before treatment, [f. 53] recto

sides, thus the ratio of iron-gall ink relative to the surface area of the paper was high (fig. 5).

Essential elements of the information observed and recorded on the examination record are highlighted in the four criteria in the Guide Boxes of the *Washing Treatment Trees:* a) the iron (II) test was strongly positive; b) the pH of the paper was acidic, between 4.0 and 4.4; c) there was strong visible evidence of ink corrosion—cracks appeared in areas where ink was heavily applied, slight to moderate localized discoloration surrounded the ink, and ink burn-through ranged from moderate to severe—and d) no haloes or fluorescence were observed in UV light. The examination and testing results pertaining to the four criteria guide the treatment to the left of the *Washing Treatment Tre*es. The solubility of the ink in water but not in ethanol directs the user down the first branch where the *Trees* suggest ethanol-modified washing immediately followed by pre-drying with ethanol, then final drying (fig. 6).

Before washing, each bifolium was conditioned by spraying with ethanol, with special attention given to the spine folds. This additional step was to facilitate more even wetting-out in the wash bath. Most of the bifolia were washed by immersion in batches for 40 minutes total, in four baths at pH 7.5. The goal was to wash the manuscript leaves with as much water in the bath as possible, to remove most of the residual iron. To be cautious with the water-soluble ink, a higher proportion of ethanol to water was used in initial baths; the proportion of water was gradually increased as washing progressed. The first 10-minute bath was 75% ethanol, 25% water, followed by two 10-minute baths of 50% ethanol, 50% water. The last 10-minute bath contained 25% ethanol, 75% water. Leaves that were too fragile for immersion were supported on screens during washing. Bifolia were removed from the last bath, then immersed in 100% ethanol for five minutes to drive out as much water as possible and thereby reduce tensions in the inked paper as it dried. On the *Trees*, this step is "Pre-dry with ethanol." The bifolia were removed from the ethanol bath, blotted, and dried.

Returning to the progress of the treatment on the *Trees*, following washing, test results were: a) slightly positive to positive iron (II); b) paper pH acidic, 5.0; c) ink corroded; d) no haloes. These results guide the treatment to the left side of the *Alkaline Treatment Trees* (fig. 7). The solubility of the ink was re-tested. It was insoluble in both ethanol and water. With this change in solubility, the treatment was guided along the second branch. Although the ink was not severely corroded, the paper pH and the flexing that will occur as the

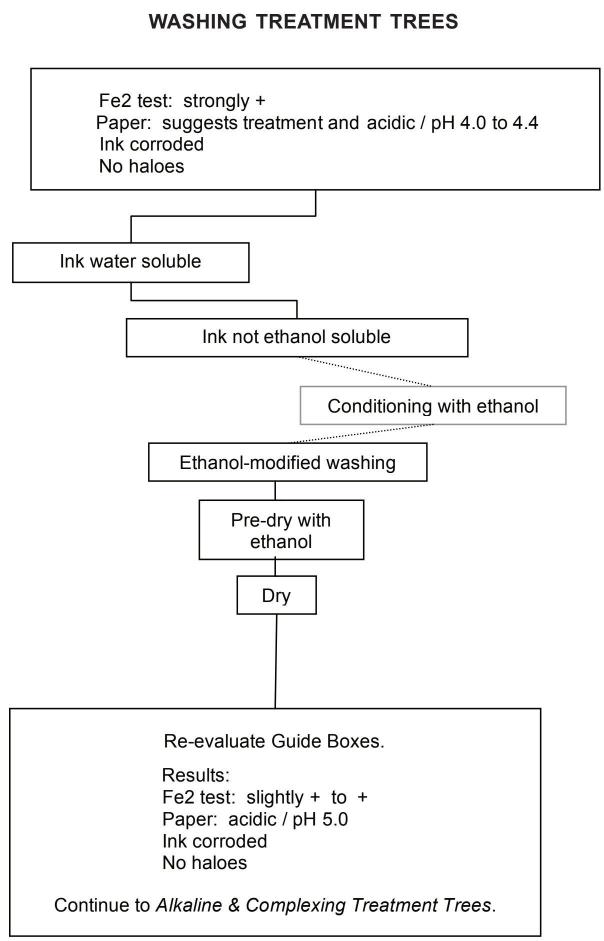


Fig. 6. Richard Smith, [Diary]. Sequence of treatment steps on *Washing Treatment Trees*. Note additional step

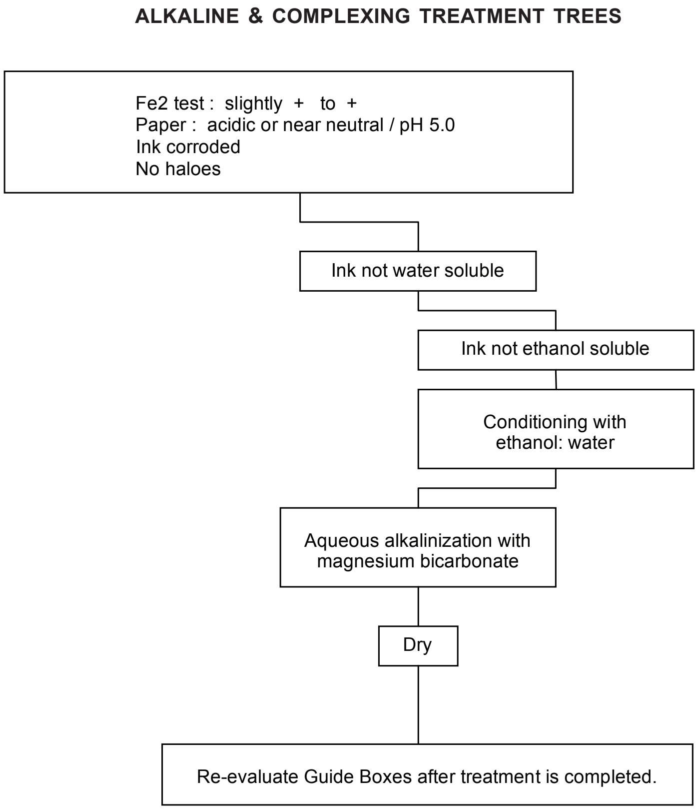


Fig. 7. Richard Smith, [Diary]. Sequence of treatment steps on *Alkaline & Complexing Treatment Trees*

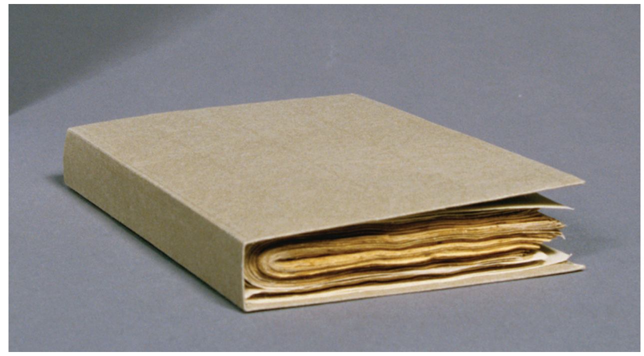


Fig. 8. Richard Smith, [Diary]. After treatment, front cover, spine, and tail

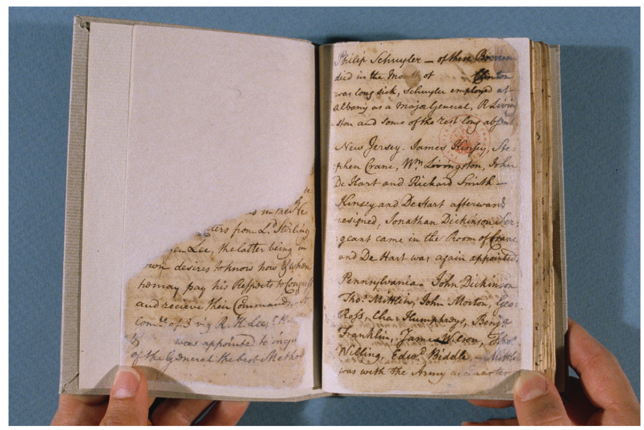


Fig. 9. Richard Smith, [Diary]. After treatment, [f. 1] verso - [f. 2] recto

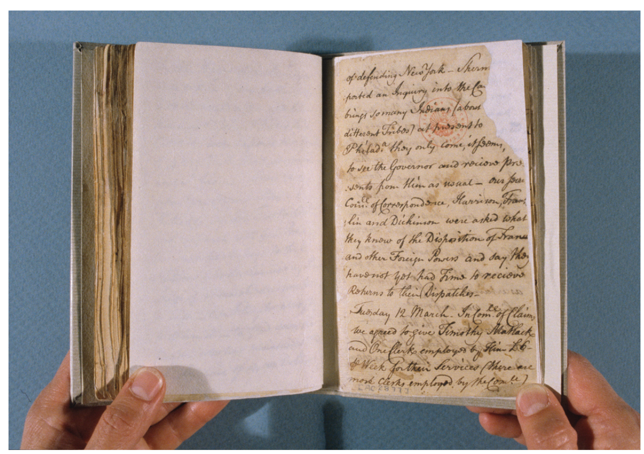
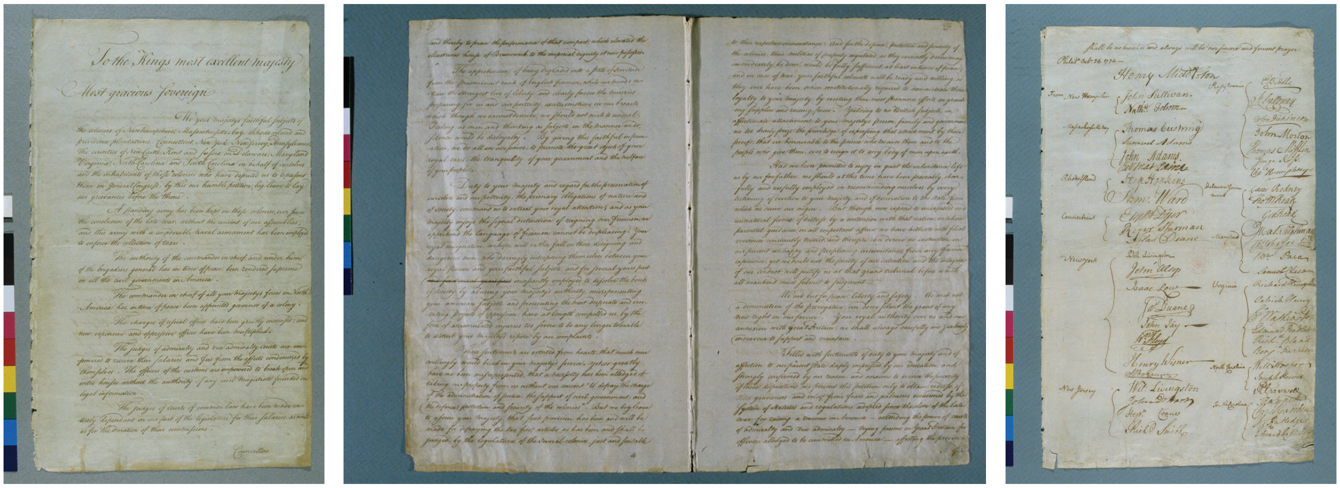


Fig. 10. Richard Smith, [Diary]. After treatment, [f. 53] recto

book is read were considered carefully. Based on the favorable results for magnesium bicarbonate reported by the Library's Iron-gall Ink-Corrosion Group, the conservators chose that solution for alkaline treatment of the acidic paper. No color change of the ink was observed during a 20-minute test with 20% magnesium bicarbonate, 80% water. The bifolia were conditioned by spraying with ethanol and then immersed in the magnesium bicarbonate bath for 20 minutes. Fragile leaves were supported on screens. Following alkaline treatment, the iron (II) test was negative and the surface pH of the paper was slightly alkaline at 7.5.

The next consideration for treatment was assessment and application of a sizing agent to the paper. Although some of the original sizing remained in the paper after the washing and alkaline treatment steps, it was not sufficient for anticipated use of the *[Diary]*. The leaves that had been washed in batches were sized in a vat containing a low percentage gelatin solution, 0.25%. More fragile leaves were sized by brushing the gelatin onto them through polyester web. After treatment, the paper is flexible and the ink appears stable, with no observable changes in color.

Four bifolia were re-established by leaf-casting with the fragments. Pages were repaired with toned *kozo* tissue adhered with wheat starch paste. After brief humidification, the gatherings were re-assembled and sewn onto handmade paper that acts as endleaves and spine support. Loose guards of Japanese tissue were used to separate the sewing thread from original material. A limp paper case was made to protect the text block. With careful handling and proper support, research use of the *[Diary]* is now possible (figs. 8–10).



Figs. 11–13. Petition of the Continental Congress to the King, Philadelphia, Pa., Oct. 26, 1774, iron-gall ink on paper, 38.2 x 23.9 cm, Manuscript Division, The Library of Congress (Papers of Benjamin Franklin, Series 1, vol. 10, LC Control No. mm73021451). During treatment, pg. B (left), pp. E–F (center), pg. H (right)

Petition of the Continental Congress to the King, Philadelphia, Pa., Oct. 26, 1774

The next treatment, guided by referring to the *Treatment Trees*, was performed on the *Petition of the Continental Congress …* [to George III of England], *Oct. 26, 1774* (figs. 11–13). Through the *Petition,* representatives of the American colonies sought to negotiate solutions to injustices by laying their "grievances before the throne." The King's rejection of this and other diplomatic efforts by the colonies fueled the colonial movement for independence. Although only five leaves comprise the manuscript, numerous hands and inks appear in the document and accompanying letter. The principle hand is that of engrosser Timothy Matlack, who later engrossed the Declaration of Independence. This copy, signed by the delegates to the Congress, was Benjamin Franklin's. Prior to treatment the manuscript was in a tightback, full leather, presentation binding—the signature binding for the Franklin Collection of Henry Stevens, an American book dealer active in London in the mid-nineteenth century (fig. 14). To produce the highly finished ideal binding of that time, the manuscript was incorporated into a text block and then heavily rounded (fig. 15). The rounding brought the corroded ink text dangerously close to the flexing area near the gutter. Numerous contracted repairs on the pages also threatened the manuscript (fig. 16).

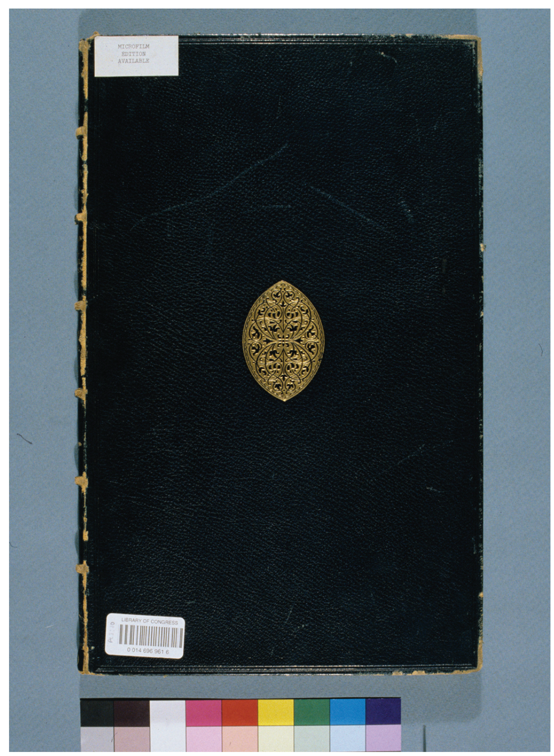


Fig. 14. Petition of the Continental Congress… Oct. 26, 1774, goatskin binding, Francis Bedford, 39.1 x 24.9 x 2 cm. Before treatment, overall front

Since so many different inks were used in the document, test results varied widely. The iron (II) tests ranged from faintly to strongly positive. Even uninked paper adjacent to iron-gall ink tested positive for the presence of iron (II). The surface pH of the paper ranged from 4.2 to 4.7. The ink was corroded, as evidenced by cracks, flaking, and losses in areas of heavy application, such as the signatures. Discoloration and moderate burn-through were also present in heavily inked areas, and, in UV light, faint, green-yellow fluorescence appeared on the verso. Using the *Trees*, a treatment plan was developed to address the worst conditions observed. Solubility testing guided the treatment to "Ethanol-modified washing" (fig. 17).

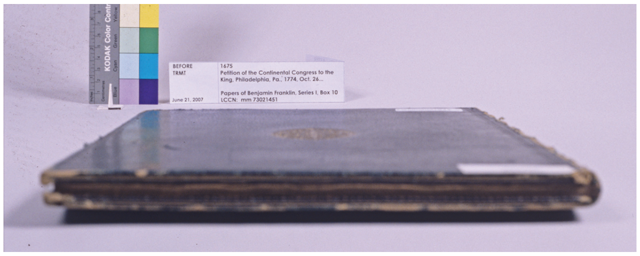


Fig. 15. Petition of the Continental Congress… Oct. 26, 1774. Before treatment, head

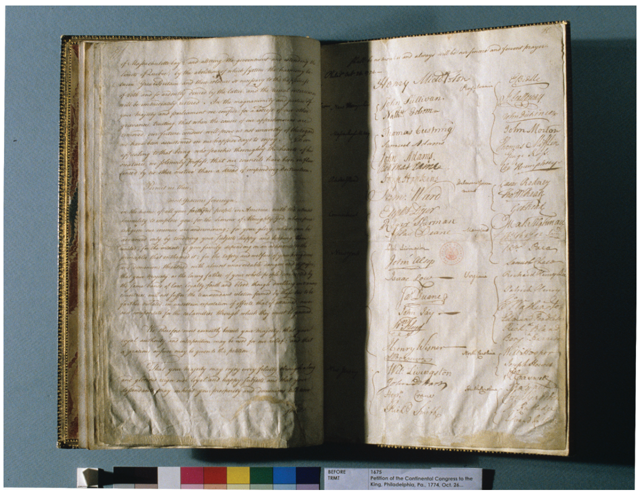


Fig. 16. Petition of the Continental Congress… Oct. 26, 1774. Before treatment, pp. G–H

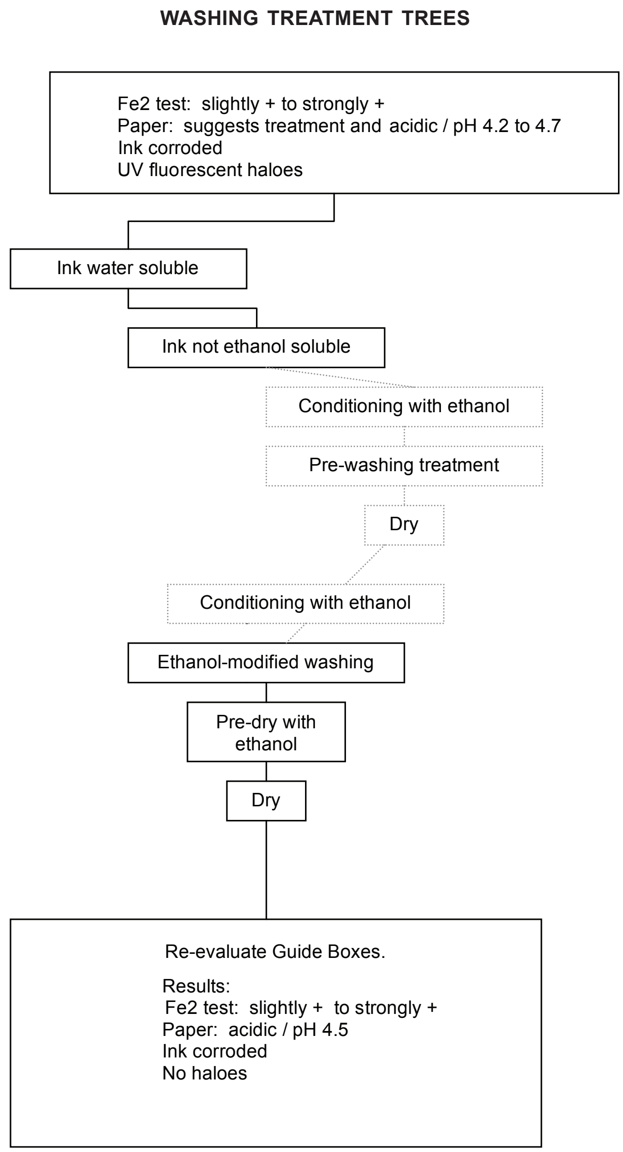


Fig. 17. Petition of the Continental Congress… Oct. 26, 1774. Sequence of treatment steps on *Washing Treatment Trees*, first washing cycle. Note additional steps

The leaves were conditioned before immersion in a bath of 80% ethanol, 20% water and then dried completely. The conditioning was to facilitate more even wetting out of the paper; the bath of 80% ethanol, 20% water, followed by complete drying, was to stabilize the varied inks before washing. Prior repairs were removed from the leaves before washing in three 15-minute baths of 50% ethanol, 50% water at pH 8.0. During washing, the baths were agitated by gently rocking the trays every few minutes and the areas of adhesive residue were tamped with soft brushes. Leaves were then immersed in 100% ethanol for five minutes. This step was especially important in areas where the ink had cracked or dropped out. When the leaves were dry, areas of ingrained dirt and adhesive residue were cleaned with dilute methyl cellulose.

After washing, iron (II) tests were faintly to strongly positive; the paper pH was about 4.5, not much improved; the ink was corroded; and no haloes around the ink were visible in UV light. In consideration of the iron (II) and pH test results, the inks were tested for solubility using a higher percentage of water. Then all leaves were spray-conditioned with ethanol; washed in 25% ethanol, 75% water at pH 8 for 15 minutes; pre-dried; blotted; and dried (fig. 18). The additional immersion in a bath with a proportionately larger amount of water removed more discoloration from the paper and improved the flexibility of the leaves. Immersion in a larger amount of water also removed more “free” iron from the iron-gall ink. Tests for most areas yielded faintly positive results for the presence of iron (II). In a few areas of very heavy application, the test results were improved, but still sufficiently colored to indicate iron (II). The paper pH of 5.0, the sensitivity of the inks to water and, unlike the previous treatment, a concern for possible color shift in the warm-toned inks strongly suggested complexing and

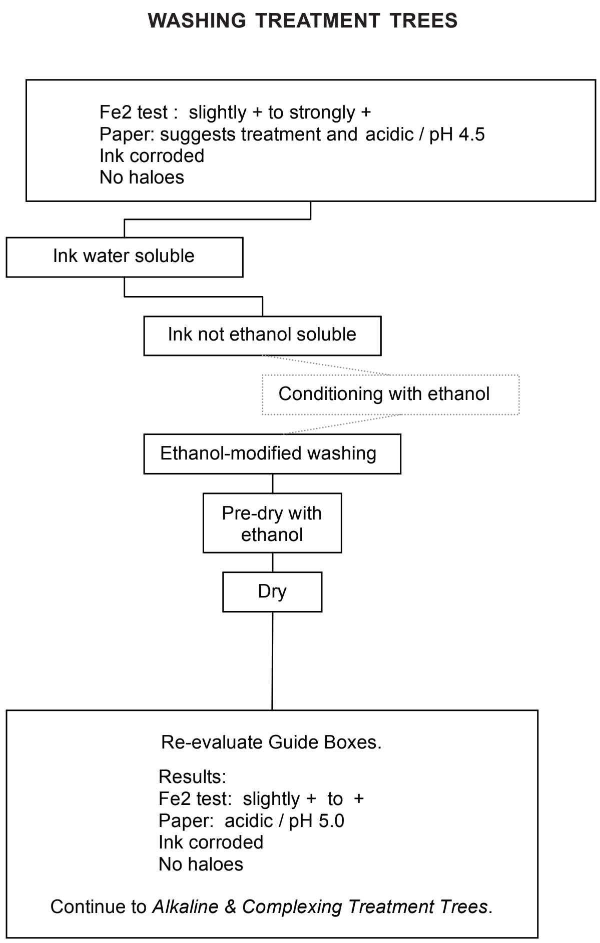


Fig. 18. Petition of the Continental Congress… Oct. 26, 1774. Sequence of treatment steps on *Washing Treatment Trees*, second washing cycle. Note additional step

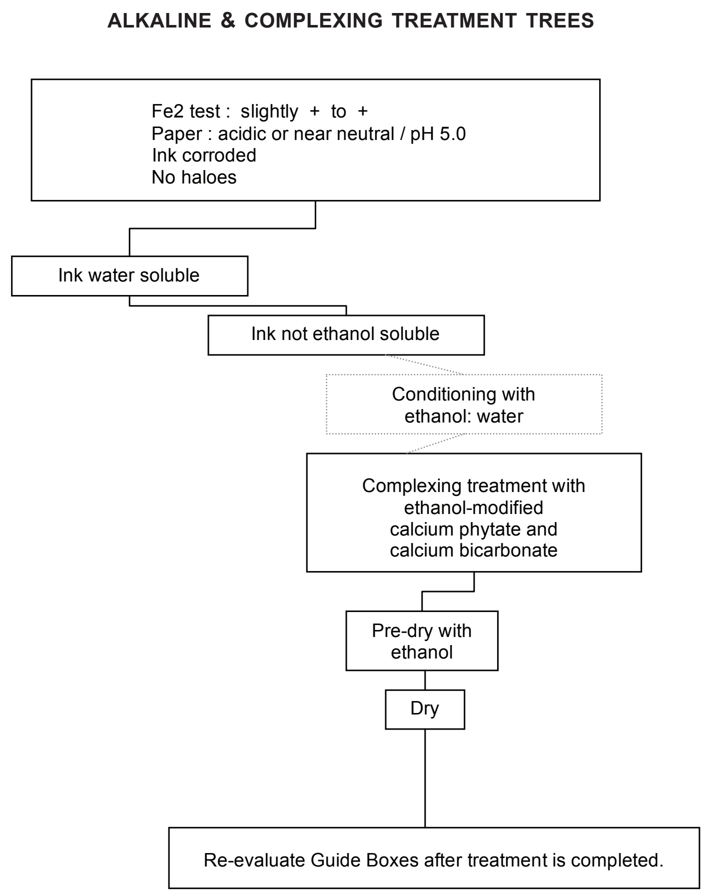


Fig. 19. Petition of the Continental Congress… Oct. 26, 1774. Sequence of treatment steps on *Alkaline & Complexing Treatment Trees*. Note additional step

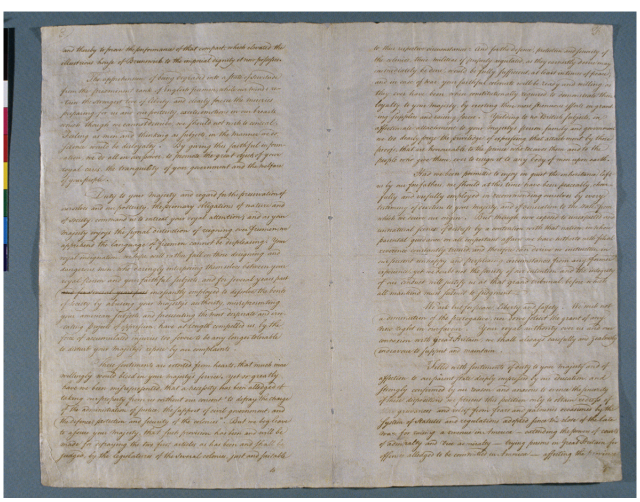


Fig. 20. Petition of the Continental Congress… Oct. 26, 1774. After treatment, pp. E–F

alkaline treatment with ethanol-modified calcium phytate/calcium bicarbonate (fig. 19).

Post-complexing and alkaline treatment test results for iron (II) ions were barely perceptible as positive, and the paper pH ranged from 6.5 to 7.0. The paper was slightly lighter in color overall and the contrast between media and support enhanced. As observed for the *[Diary]* of Richard Smith, the *Petition* leaves retained some original sizing throughout treatment, but not enough for future handling. Dilute gelatin (0.25%) was brushed onto the leaves through polyester web. Japanese tissues adhered with wheat starch paste were used to repair tears and compensate for losses (fig. 20). After exhibition, Asian tissue and starch paste will also be used to re-unite pages B and H as a folio. Although the *Petition* will not be returned to the Stevens Collection binding, the binding will be housed with it in an enclosure compatible with the other volumes of Franklin materials collected by Stevens and now held by the Manuscript Division.

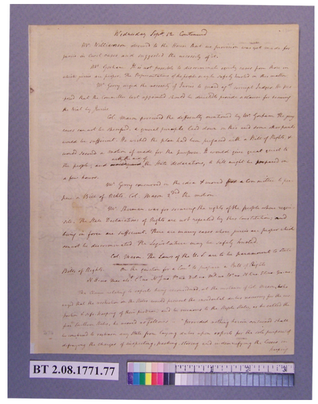
Notes on Debates in the Federal Convention of 1787
Sept. 12–13, 1787

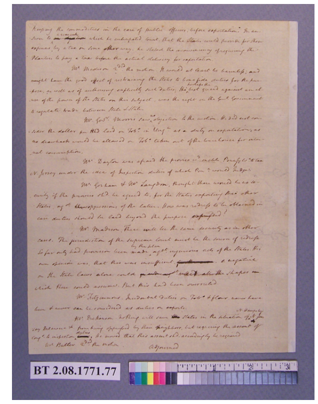
The last treatment regards an entry from Virginia delegate James Madison's journal, in which he recorded the debates at the Federal Convention at Independence Hall in Philadelphia from May 25 to September 17, 1787. It was an important convention—the U.S. Constitution was drafted. Three entries from Madison's journal were treated so that they could be safely exhibited. The paper was similar for all three entries and thus it was decided to attempt to treat all three consistently. Seen here is the September 12th to 13th entry that records the delegates' debates about preparing the Bill of Rights (figs. 21–26).

The results obtained during the examination of the Madison document before treatment included: a) strongly positive iron (II) tests; b) acidic paper with a pH of 4.0; c) visible evidence of corrosion in areas of heavily applied ink, with moderate localized discoloration surrounding the ink, and moderate to severe burn-through; and d) UV fluorescent haloes around the ink. As with the earlier example, these criteria guided to the left of the *Washing Treatment Trees* (fig. 27). Since the heavily applied inks were soluble in water but not in ethanol, the treatment moved toward "Ethanol-modified washing." The Madison document was conditioned by spraying with ethanol, pre-treated for 10 minutes in 80% ethanol, 20% water, and dried completely. The conditioning spray facilitated even wetting-out of the paper. The high ethanol content pre-treatment was used to stabilize the variety of inks before washing.

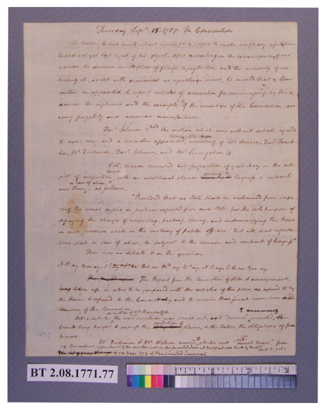
After conditioning the document for washing, it was immersed for 30 minutes total in three baths at pH 7.5. As in the *Richard Smith* treatment, progressively lower proportions of ethanol were used in the baths as the inks demonstrated less solubility in water. The first 10-minute bath was 75% ethanol, 25% water, followed by two 10-minute baths of 50% ethanol, 50% water. Before drying, the water content in the document was reduced by immersing it in 100% ethanol for five minutes. However after washing, the inks still tested strongly positive for iron (II) and the paper pH rose only slightly to 4.5. Another washing cycle in baths with a larger proportion of water would be necessary to remove more of the residual iron and degradation products in the paper. This experience underscores the importance of testing inks after treatment to determine the efficacy of the treatment.

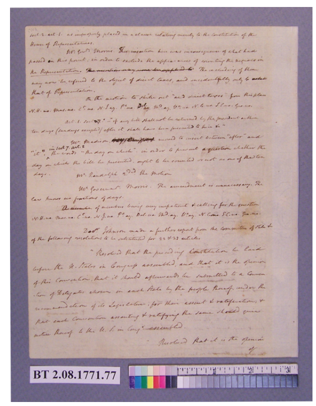
The second washing cycle proceeded with conditioning by spraying, followed by immersion for 25 minutes (fig. 28). The first bath was 50% ethanol, 50% water for ten minutes. The second bath was 25% ethanol, 75% water for 15 minutes. Again the document was immersed in 100% ethanol for five minutes before drying it. Following the second washing cycle, areas of heavily applied ink tested positive for iron (II) and the pH of the paper was raised to 5.0. While residual



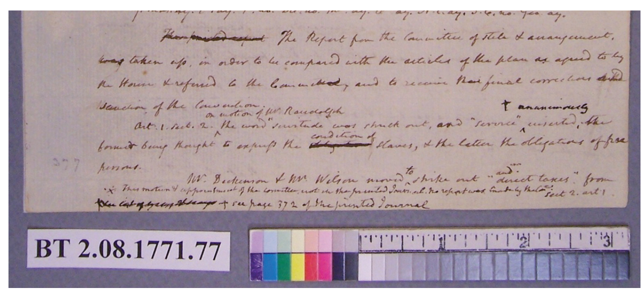


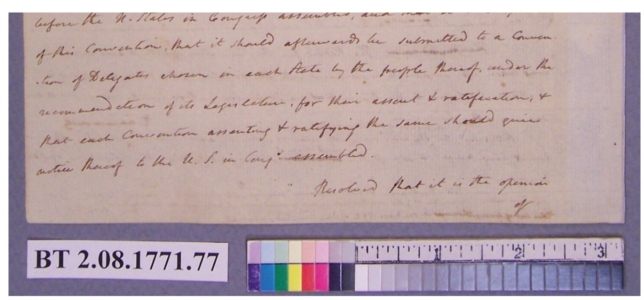
Figs. 21–22. James Madison, Notes on Debates in the Federal Convention of 1787, Sept. 12, 1787, iron-gall ink on paper, 23.1 x 18.7 cm, Manuscript Division, The Library of Congress. Before treatment, recto (left), verso (right)





Figs. 23–24. James Madison, Notes on Debates… Sept. 13, 1787. Before treatment, recto (left), verso (right)





Figs. 25–26. James Madison, Notes on Debates… Sept. 13, 1787. Before treatment, detail, recto (top), verso (bottom)

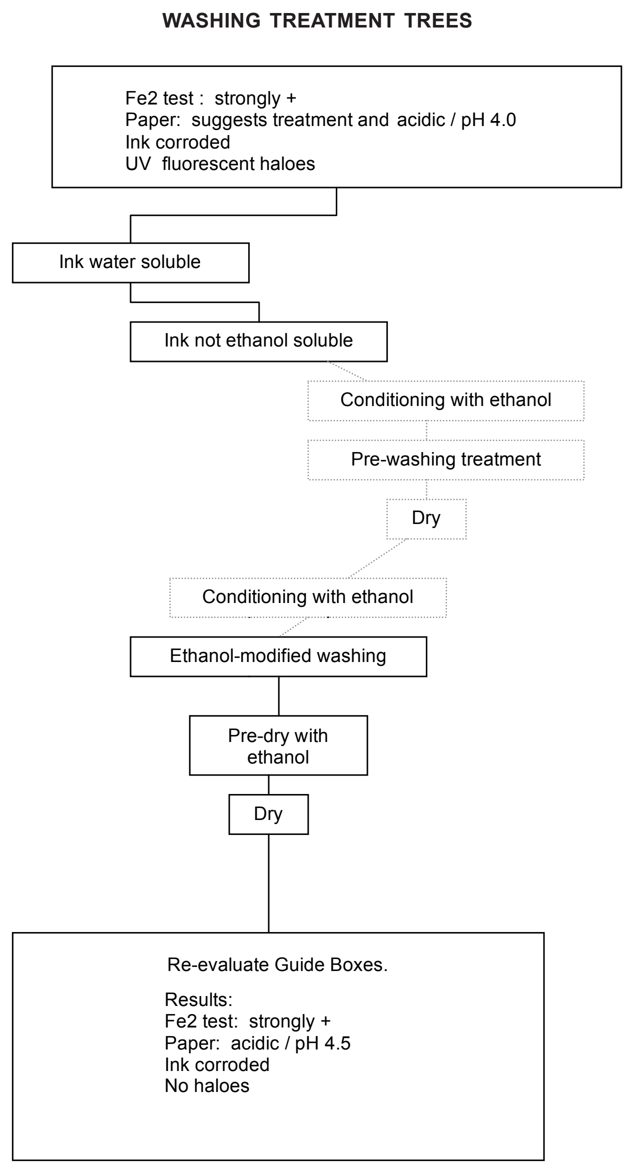


Fig. 27. James Madison, Notes on Debates… Sequence of treatment steps on *Washing Treatment Trees*, first washing cycle. Note additional steps

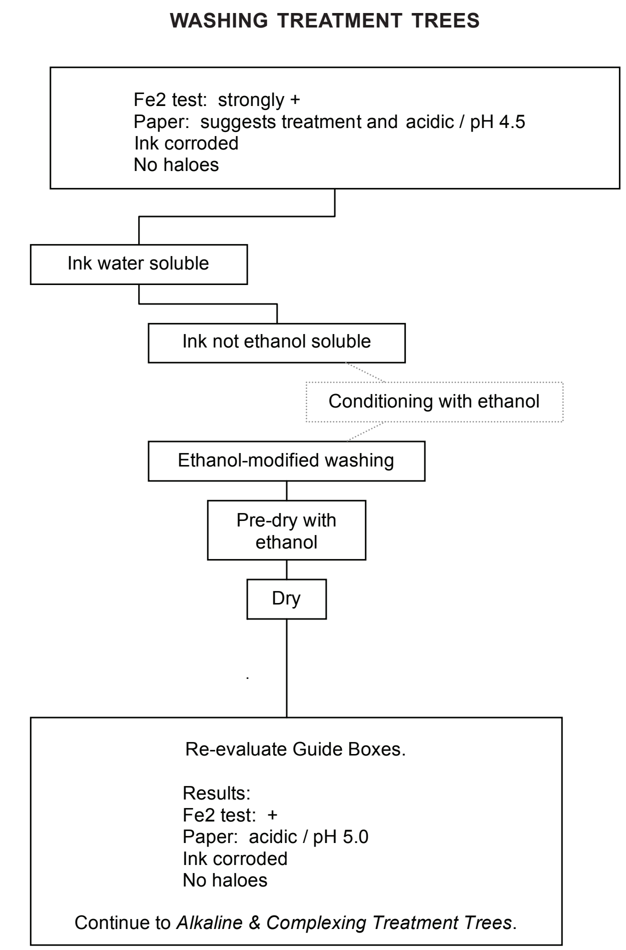


Fig. 28. James Madison, Notes on Debates… Sequence of treatment steps on *Washing Treatment Trees*, second washing cycle. Note additional step

iron remained in some inked areas, it was decided to move to the next phase of treatment rather than to subjecting the document's inks and paper to further washing.

Post-washing test results and the solubility of the inks directed treatment to the first branch of the *Alkaline & Complexing Treatment Trees* (fig. 29). Several entries from Madison's journal, dated July 16th to 17th, 1787 exhibited severe ink corrosion and cracking in heavily inked areas. To stabilize the ink on those pages, alkaline and complexing treatment with ethanol-modified calcium phytate and calcium bicarbonate was appropriate. The positive iron (II) test and low pH for the September 12th to 13th leaves also pointed to calcium phytate and calcium bicarbonate treatment.

The cracks in the inked areas of the two other leaves required that all three documents be supported on a screen during treatment, and that they be conditioned prior to immersion by spraying with ethanol. The documents were immersed in 50% calcium phytate, 50% ethanol for 20 minutes. After draining and blotting them briefly, they were immersed in a 50% calcium bicarbonate, 50% ethanol solution for 20 minutes. After drying, none of the inks tested positive for iron (II) and the pH of the paper rose to 7.5. The final steps of the treatment included sizing with a 0.5% gelatin solution applied by brushing through polyester web, mending with Korean tissue and wheat starch paste, and humidifying and flattening overall (figs. 30–35).

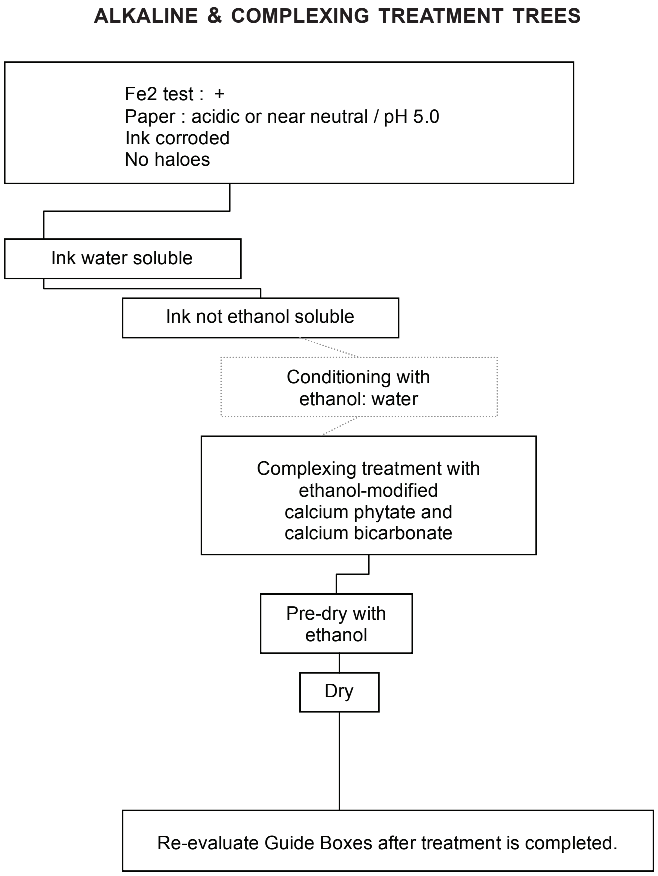
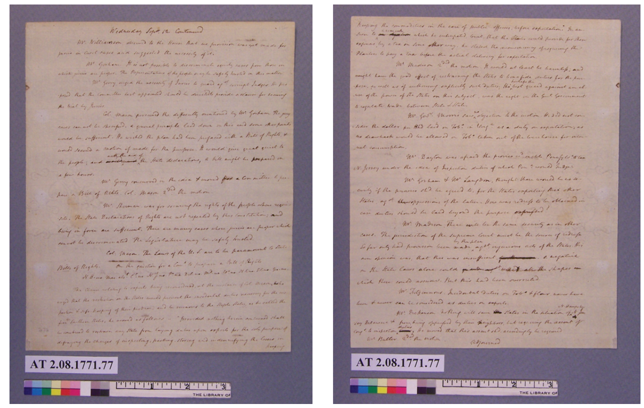
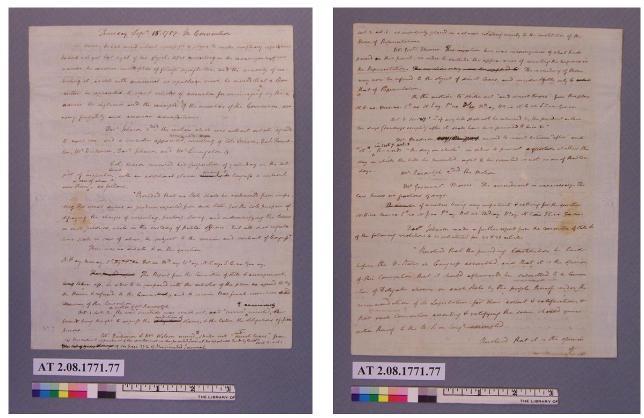


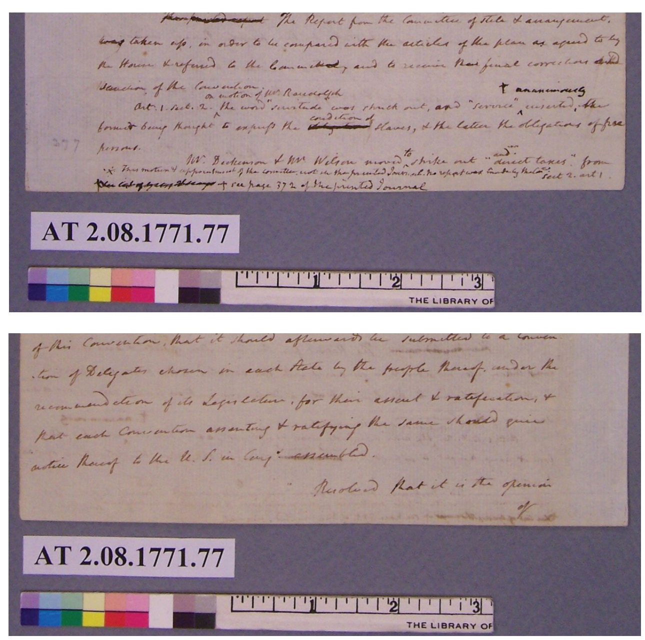
Fig. 29. James Madison, Notes on Debates… Sequence of treatment steps on *Alkaline & Complexing Treatment Trees*. Note additional step



Figs. 30–31. James Madison, Notes on Debates… Sept. 12, 1787. After treatment, recto (left), verso (right)



Figs. 32–33. James Madison, Notes on Debates… Sept. 13, 1787. After treatment, recto (left), verso (right)



Figs. 34–35. James Madison, Notes on Debates… Sept. 13, 1787. After treatment, detail, recto (top) verso (bottom)

CONCLUSION

PIT concepts and tools were successfully used to support the examination and decision-making for the three treatments described. Two years after being introduced to Conservation Division staff, PIT protocols have also been applied to many other iron-gall ink-inscribed materials, including nineteenth-century American correspondence, a sixteenth-century letter to the Archbishop of Mexico from Philip II of Spain, and the documents and journals of the founders of the United States. None of the tools is intended to replace the judgment of the conservator. Rather, the tools distill and focus the body of conservation literature and practice related to various aspects of iron-gall ink treatment. In particular, the *Washing Trees* and the *Alkaline & Complexing Treatment Trees* display decision-making strategies at different stages of conservation treatment of iron-gall ink-inscribed paper.

The Protocols for Iron-gall Ink Treatment Group has been a successful collaboration of the paper- and book- conservator team members and a successful collaboration of the Conservation Division staff, which provided essential

feedback on the toolkit as it was developed. In a sense, it was, and continues to be, a collaboration among dozens of conservators, charged with preserving the important national collections at The Library of Congress.

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The National Archives C 104/3 "The Wool Sample Books"—Conservation-Digitisation-Historical and Scientific Research-Public Access

ABSTRACT

The National Archives C 104/3 (Bull versus Jesser) contains letters and documents, dating from 1724 to 1736, which relate to the dyeing and clothier business of the Whitchurch family of Frome, Somerset, England. These include six dye recipe books that give the dye recipe with a colour sample alongside.

The Wool Sample Books themselves, besides being fascinating visual documents, are a source of incredible value for textile, social and industrial historians. They are also a source for interdisciplinary cooperation initiated by our conservation team.

Recipe books, like these early eighteenth-century Wool Sample Books, were a day-to-day working tool in a dyeing factory. Once out of use, they hardly ever survived. Therefore, these Wool Sample Books are a rare source of original dye recipes and matching samples. They are also exceptional in the reliability of the sample colour to be achieved, as they have not been exposed to light for about 280 years and have kept their original appearance. Dye and fibre analysis will provide strongly connected databases of both recipes and spectra.

The books will provide historians with detailed information about the wool industry in Frome, Somerset, and its related branches such as sheep farming and the production and import of dyeing ingredients. Since Somerset has been strongly connected to the wool industry, these books and their related documents may prove to be a valuable resource in understanding its social history.

True colour digitisation and transcription of the text will provide necessary research tools for both historians and scientists. Finally an online exhibition, created by education and conservation teams from The National Archives, could provide detailed information about the conservation of the books, research outcomes, and visually appealing images.

However, to date, access to these books has been limited due to their poor physical condition. Although hardly ever touched during the last 280 years, heavy usage at their date of origin, subsequent poor housing, and the structure of the books themselves have caused severe damage to all of them.

The main problem has been the distortion of the leaves caused by the weight and bulk of the wool samples and a certain degree of iron gall ink degradation. This did not allow a) the books to close properly and means the volumes were wedge-shaped and therefore very vulnerable to dust, and b) for common methods of flattening while introducing moisture. In-situ treatments have led to a very satisfactory result. These include: mechanical surface cleaning, dry flattening, gelatine-based mending of tears, and appropriate reattaching and housing of the wool samples in consultation with textile experts at the Textile Conservation Centre/ University of Southampton. To ensure the long-term chemical stability of the Wool Sample Books, a monitoring system will be implemented to document the state of the iron gall ink and the wool samples and their changes over a period of time. Specially designed boxes will keep the books in their newly achieved conformation.

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HOLLY H. KRUEGER

Conservation of the Library of Congress' Gandhara Scroll: A Collaborative Process

ABSTRACT

Buddhism is one of the world's major religions and can trace its origins to 450 BC when its founder, Guatama Buddha, attained enlightenment under the Bodhi tree. Buddhism spread from India, northward, into the Peshawar Valley (present day Northern Pakistan and Afghanistan). The region, Gandhara, stood as a thriving center for Buddhism before spreading eastward along the Silk Roads. Until recently, no original manuscripts had been found documenting the development the Gandharan doctrine of Buddhism. A group of materials dating from the first century BC to the second century BCE were unearthed in the 1990s, and the Library of Congress acquired a birch-bark scroll from this collection. It fell to the Library's Conservation Division to unroll, document, and devise a long-term preservation strategy for this most fragile and ancient object. To accomplish this task, conservators relied upon myriad colleagues and expertise, both inside and outside of its own walls.

BACKGROUND

The 2008 AIC annual meeting theme of collaboration provided the inspiration to share a project that not only exemplified the theme, but tested, in some ways, a conservator's natural instincts. In 2005, the Library purchased a scroll purported to contain the oldest writing related to Buddhism. The scroll arrived inside a familiar Parker Pen box, lying on a bed of cotton and was obviously a most fragile object (fig. 1). The Gandhara Scroll, as it has come to be called, belongs by genre to a group of materials that were unearthed in the 1990s and are now in the British Library. These thirty scrolls and fragments are the earliest Buddhist texts found to date. They are written in carbon ink on birch bark strips in the Gandharan language in Kharoshti script. They were ritualistically interred in terra cotta jars and buried inside of *stupas*. *Stupas* are Buddhist religious structures constructed to hold reliquaries and are the principal architectural and religious elements of the monastic community. Because Kharoshti script died out in the third century BCE, there are only a handful of scholars in the world who can read it today. Until recently, they had to content themselves with inscriptions on coins, statues, and architectural elements. Gandhara is the ancient name for the Peshawar valley in Northern Pakistan and Afghanistan. Although currently this region is tumultuous, between the third century BC and the sixth century BCE it stood as a flourishing seat of civilization, strategically located on the Silk Roads and a thriving center for Buddhism. Its geographic location as a gateway to the Indian subcontinent, and oasis cities of the silk roads in the Tarin Basin, in part explains the wide-ranging influences on the Gandharan culture in ancient times as a crossroads and melting pot. Most of us are familiar with Gandharan art and its melding of Indian and Greek motifs. Buddhism was brought to the Gandharan region by Asoka, the great emperor of the Mauryan dynasty in India and Buddhist patron in the third century BC. By the first and second centuries BCE, Buddhism began to extend into Iran and China with Gandharan monks instrumental in this expansion. Thus, it can be argued that the Gandharan form of Buddhism was particularly influential in the cultural history of Asia due to its strategic location in geography and time.

Fig. 1. Gandhara Scroll in its original housing

Presented at the Book and Paper Group session, AIC 36th Annual Meeting, April 21–24, 2008, Denver, Colorado.

Abundant physical evidence of a flourishing Buddhist center can be found in the Gandharan region by the first century BC, in dedicatory inscriptions, sculptures, and coinage. The textual content of Gandharan Buddhist doctrine, however, remained obscure, as no primary texts from this early period had been found-although it was theorized that there must have a rich written tradition. Original manuscripts obviously provide the best source, but since early manuscripts were written on birch bark or palm leaves, neither of which is a stable material, few manuscripts earlier that the seventh century BCE had been found in the Indian subcontinent. The dry climate found along much of the Silk Road is much more conducive to preservation and many early Buddhist manuscripts from the seventh century BCE or later were found and "transferred" to Western cultural institutions by Aurel Stein, et al. The rush to explore long-lost cities along the Silk Road yielded unprecedented, rich discoveries of the thriving civilizations in these now desert climes and further evidence of the Gandharan's region key position in later Buddhist development. The discovery in the early 1990s of the first and second century BCE scrolls in excavated *stupas* led to a relative explosion in available textual information related to this early period. Akin to the Nag Hammadi and Dead Sea Scrolls, the Kharoshti scrolls are the earliest known textual material related to Buddhism. Carbon 14 results place most of the material from the first century BCE although the Library's scroll was dated a bit earlier. Most unfortunately, the region these manuscripts are in is highly unstable. Rory Stewart writes in *The Places In Between,* an account of his epic walk across Afghanistan just after the Taliban fell, of the most amateurish collecting and plundering of ancient sites by villagers. The sad fact that no official excavations are being carried out will obviously result in the loss of more original material, making the rarity of the few manuscripts that do survive even more compelling.

DESCRIPTION

Birch bark has a long history of use other than as a writing substrate. Its oils provide protection against biological attach and the bark possesses medicinal qualities as an analgesic. Additionally, birch bark has been used as a building and artifactual material in many cultures since ancient times. Birch is a common and prolific tree, growing abundantly in most temperate zones across the world. The Gandhara Scroll is most likely from Himalayan birch, common to the high altitudes of the area.

Birch bark is one of the three main writing materials of the ancients, along with palm leaf and papyrus. Q. Curtius's *History of Alexander* notes the use of tree bark as a writing material at the time of Alexander's invasion of India in 300 BC. Pliny also mentions "the bark of certain trees" being used as a writing material before papyrus in his *Natural History*. The bark is prepared for writing by making two circular incisions around the trunk several feet apart and wedging the bark away from the vascular cambium. The surface is then oiled and polished to produce an appropriate writing surface. Finally, the sheet is cut to size and stored flat between wooden boards. Strips of birch bark were sometimes sewn together to create larger sheets.

Birch bark is composed of several very thin layers, adhered to one another by pectin, a natural adhesive, as well as by physical knots and streaks. The outer tissues are cork cells, or phellem, composed of suberin, an unsaturated fatty acid that accounts for the cell wall impermeability to water. The cells are laid longitudinally, structurally held together with lenticels, spongy areas of cells arranged horizontally that allow for gas exchanges between the inner and outer tissues. The fatty acids between the cell walls, as well as those applied during processing, may naturally exude, creating a whitish material on the surface (fig. 2). This aging process, as well as the lessening of the adhesive strength of the natural pectin, serves to undermine the adhesion between the layers. This is the main conservation problem encountered with manuscripts on birch bark. To find a two thousand-year old sample is truly remarkable given this inherent instability. The scroll's ritualistic internment into a terra cotta jar and placement into a *stupa* undoubtedly accounts for its survival at all.

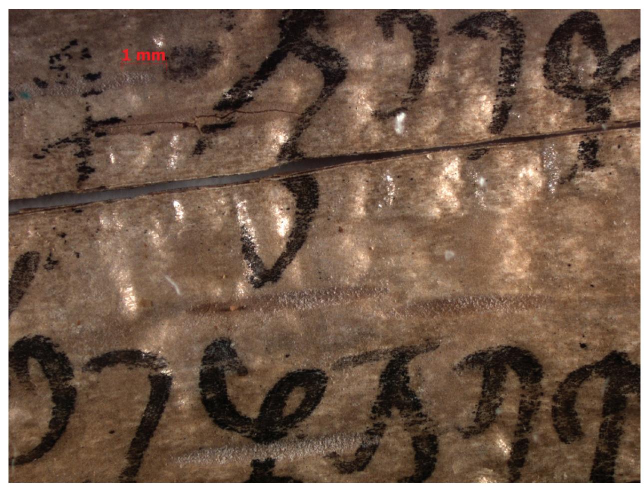

Fig. 2. Photomicrograph showing white exuded material

Published work on the challenges and possible preservation solutions applied to birch bark substrates reflects myriad approaches and materials. Various lacquers and waxes have been employed as consolidants with limited success. A group of birch bark scrolls from Bamiyan brought to the Musée Guimet in Paris was immersed in hot paraffin wax to allow unrolling and consolidation. Research done by O. P. Agrawal and D.G. Suryawanashi at the National Research Library in Lucknow, India revealed that while the natural oils in birch bark make it relatively impervious to water, it is highly

soluble in some organic solvents. Dr. Agrawal details a successful treatment similar to paper splitting wherein individual layers of the bark are separated and pasted back together with a new interleaving Japanese paper. Obviously this is only possible with the most robust of manuscripts.

Various encapsulation methods have been reported, from pasting silk gauze to either side of a manuscript to lamination with cellulose acetate. The Bodleian Library reported on the preservation of the Bakhshali Manuscript by encapsulation between mica sheets and hinging the resultant package onto card stock. The successful conservation of the Gilgit Collection of two thousand birch bark sheets in the National Archives of India using a modified "silking" was reported in 1957. Mylar encapsulation had been recently recommended but would be highly problematic with delaminating, fragile material such as our scroll due to its lack of rigidity and its static charge. Encapsulation between sheets of glass has been the "gold standard" of preservation of ancient manuscripts but there are serious drawbacks with this approach as well. Although lacking the static charge of Mylar, sheets of glass are heavy, presenting difficult handling and storage issues. Additionally, some glass is inherently chemically unstable.

In considering how best to conserve the Gandhara Scroll we had to take into account two main points. The first was the scholarly world's understandable impatience to have the scroll unrolled and the information it contained preserved and disseminated, particularly cognizant of the unstable political situation. The second was in reconciling the various treatment options with the physical realities of such a fragile and ancient object. The Library's scroll continues to suffer loss in even the most benign of circumstances. During our initial examination under the microscope a crack was observed spontaneously forming. This early experience undoubtedly shaped our eventual approach. Even if a treatment could be designed to address the fragility and inner-layer cleavage of the birch bark, there remains in the literature much caution regarding the long-term effects of conventional conservation treatments on ethnographic materials. These include adversely affecting the organizational structure with aqueous treatments and removing vital structural and natural inhibitors with solvent treatments. It became increasingly apparent that once the scroll's secrets were made available, its long-term preservation would be dependent upon environmental and access policies. Our basic treatment strategy was to handle the scroll as little as possible and to ultimately place it between sheets of inert glass (Borofloat) until such time in the future as more options may be available. There still remained the daunting task of physically unrolling the scroll.

TREATMENT

As luck would have it, a colleague, senior book conservator Yasmeen Khan, was going to London on business and agreed to meet with the British Library's chief conservator, Mark Barnard, who had performed the unrolling of their collection of thirty Kharoshti scrolls. Although she came back from her visit armed with an exact description of the process, we became convinced that our proper role in the unrolling aspect of the treatment would be as "a second pair of hands." One of the most pivotal pieces of information shaping this decision was the fact that ancient buried cellulosic materials behave and handle substantially different than the cellulosic materials to which we are accustomed. Given the fact that there are precious few buried cellulosic materials around to practice on, it was obvious that a collaborative approach was essential. While the treatment proposal was simple enough—humidify and flatten—we felt that more experienced hands than we could provide were in order and arranged for Mr. Barnard to lead the unrolling.

The pre-treatment examination consisted of simply looking at the scroll with normal and multi-spectral lights with and without magnification. Testing was not carried out since any manipulation resulted in loss. We had to rely on Mr. Barnard's considerable experience in how the scroll would respond to the gradual humidification and subsequent manipulation. The unrolling necessarily occurs in one session and a primary aim is to handle it as little as possible, so it is vital before beginning that the rolled structure is as completely understood as possible (fig. 3). Some of the British Library scrolls have been concertina-folded and some reverse directions in the middle. Also, to the extent possible, a map of the structure needs be made that mimics the number of rolls, knot holes, and other visible aberrations. This is necessary for the proper initial placement of the roll on the glass and to anticipate difficult areas. In particular, the naturally occurring knot holes present a challenge, as they are structurally hard, surrounded by material with no structural integrity. Prior to

Fig. 3. End view of scroll showing rolled structure

Fig. 4. Unrolling the scroll

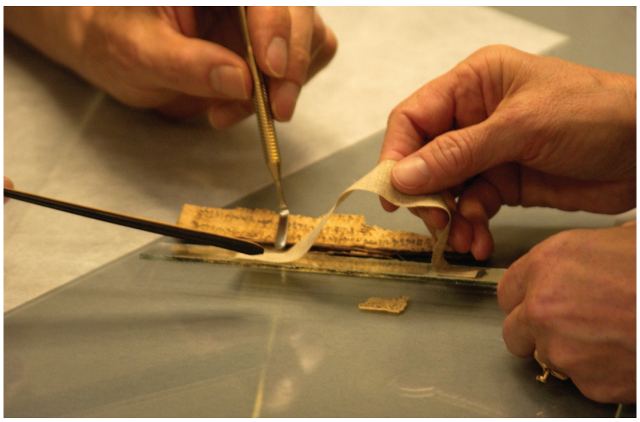

Fig. 5. Setting down the glass weight

Fig. 6. Removing fragments from unrolled section

the actual unrolling, we practiced the entire operation on the paper model, placing it on an extra piece of Borofloat glass. We also practiced unrolling a heavily baked cigar roll. Mr. Barnard felt that was the closest thing he had found to the feel of two thousand year old buried cellulosic material, although the actual scroll was much more fragile. The next step was to humidify the scroll for three days at 80% relative humidity as this had been found to be a good level to gradually introduce moisture without getting the material too wet. The chamber was a simple 11" x 14" photo-tray, fitted with plastic egg crate and a layer of blotter and Hollytex on top of that. The bottom of the tray was lined with a sheet of rHapid gel and damp blotter that had been pre-conditioned for forty-eight hours.

The actual unrolling needed to proceed without interruption once it was started, so we chose a Saturday to eliminate distraction. An area in the lab with the fewest air currents was selected as our work space since the slightest air movement could cause pieces to be dislodged. We prepared specially fashioned tools that included glass weights to which we attached linen strips on the top to allow for maximum control as they were being set down and bamboo tools slightly narrower that we thought the scroll sections would be. The unrolling began simply enough with the object being placed on one sheet of the glass, centered where we thought the top would eventually be based on our paper model. Using our tools we unfolded each roll (fig. 4). As each section of scroll was unrolled a glass weight was slowly set into place to hold it down (fig. 5). One of the challenges encountered was the difficulty in distinguishing between an actual bark layer and an area of inner layer cleavage within a bark layer. Fragments were taken from the place that they were found within a fold and placed on an identical piece of glass in a location corresponding to where it came from (fig. 6). Over the four-hour process, we occasionally had to introduce moisture via a preservation pencil. The humidity stream was aimed at approximately twenty-four inches above the surface of the scroll to allow for very gradual humidification. Once the scroll was fully unrolled the individual glass weights were carefully removed. Detached fragments that were visible to the naked eye were placed on the second sheet of glass as we removed dust from the edges with a soft brush and aligned the strips as possible. This section of the treatment had to be done swiftly and surely to avoid the edges curling up and fragments being lost. Between the time that the last glass weight was removed and the second sheet of glass laid on top, the scroll was at its most vulnerable. The natural conservation instinct for perfection had to be dampened as fussing to align, unfold, and clean up would result in more loss. Laying down the encapsulating glass had to be done exceedingly slowly to prevent air from being pushed out between the layers (fig. 7).

Once the scroll was unrolled and encapsulated we sealed the edges with Filmoplast p-90. The amount of pressure to exert on the two pieces of glass was, again, a judgment call based experience (fig. 8). The scroll retains considerable three-dimensional qualities that need to be saved while keeping the scroll in its place on the glass. Attempts at securing previous scrolls to one of the pieces of glass encapsulation have all resulted in further tearing of the birch bark, so the only thing holding our scroll is the weight of the glass and the slight pressure induced by the sealing.

Fig. 7. Laying down encapsulating glass

Fig. 8. Sealing with Filmoplast p-90

The secondary housing consists of specially constructed clamshell boxes made by senior book conservator Dan Paterson. We consulted with Mervin Richard, deputy chief of conservation and head of loans and exhibition conservation at the National Gallery of Art, for strategies to dampen vibration and impact within the box. Based on the dimensions and weight of the encapsulated scroll, the base of the box was fitted with a layer of specially fashioned Volara foam. A drawer is included in the box to hold all the tiny bits (dust) of the scroll that were left. A one-to-one color reproduction of the verso is housed next to the scroll with the intent of discouraging custodians from turning the scroll over. A second box is made to hold the glass-encased fragments. The boxes are housed in the "Top Treasures" vault, ensuring an extra layer of security, environmental stability and access control. The conditions within vault are 50% F and 50% relative humidity.

CONCLUSION

It is obvious from this presentation that the Gandhara Scroll was not conserved in the way that we normally think of conserving an object (figs. 9–10). It remains an incredibly fragile item and we had made a decision early in the process to preserve the maximum amount of information, resigned to the fact the every time the piece is handled, it deteriorates a bit. Our strategy for long-term preservation of the scroll itself is to minimize environmental impact and limit handling. During the process, we came to the conclusion that our instincts to address the basic issue of the inherent instability of this material through treatment would not serve us well. Additionally, despite the Library's large staff and considerable, varied experience, we had to seek outside help. While these ideas are not revolutionary they may be worth repeating.

Figs. 9–10. After treatment, recto (left), verso (right)

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MATERIALS/SUPPLIES

rHapid Gel sheet
Art Preservation Services
www.apsnyc.com/html/control.html

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Save the Plants: Conservation of Brendel Anatomical Botany Models

ABSTRACT

For over one hundred years, the University of Florence Department of Plant Biology has owned a collection of anatomical plant models once used for teaching purposes. This collection was produced by the Brendel Company of Germany that had specialized in these models since the 1860s. The company brought together expert model makers and botanists to produce accurate plant models using basic materials: papier-mâché, wood, plaster, and gelatin. By the end of the nineteenth century, these models were renowned across Europe and the Americas for their accuracy and usefulness in the classroom.

By the start of this century, the University's models were badly neglected. Not only were the models left unprotected in a damp basement, but the collection appeared never to have been inventoried, and all the original documents had long since been mislaid.

This paper describes the project to conserve the Brendel models: an interesting, thought-provoking, and instructive study into how to treat these objects. It will consider the historical and pedagogical context of the models, as well as the complexities of their conservation, requiring the close collaboration of conservators and curators from different disciplines: botanist Graziana Fiorini, paper conservator Luana Maekawa, and objects conservator Peter Stiberc.

BACKGROUND

The late nineteenth century and first decades of the 1900s was a time when science, technology, and culture were quickly changing and developing, leading society into a new, modernized era. The World's Fairs were major attractions for participating countries and enterprises, often featuring outstanding architectural designs and introducing significant inventions to showcase their achievements intended to accelerate development into the next century.

During this period the rational principles of illuminist and scientific methods were also being formed, and there was great intellectual fervor as the scientific disciplines gained new impulse.

Industry in general, including agriculture, needed to create a new body of highly educated, specialist workers with an understanding of how to apply these new technical advancements. Education, particularly in the technical sciences and medicine, was changing rapidly. With heightened interest in teaching botany, zoology, anatomical embryology, and mineralogy, high schools and universities required support material for adapting their teaching methods to the scale of demand. Developments in chemistry had made new substances and reagents available, new instruments were invented, and developments in optical microscopy to study live tissue and cytology opened new possibilities in the study of natural sciences and medicine.

The invention of the camera introduced scientific images and innovative techniques, such as photomicroscopy, were soon tested and explored. Images of magnified microscopic dimensions, hard or impossible to see with the naked eye or with a magnifying glass, presented a brand new world to discover and study in biology, crystallography, and physics. However, the microscope was not readily available to all (as is the case still today). There was a need to find a new way to demonstrate to large audiences of both high school and university students the microscopic detail of these new discoveries.

By the end of the nineteenth century, schools at all levels were busy modernizing and bringing teaching methods and science disciplines up to date. The demand for teaching models was substantially increased.

MODEL MAKING

During the eighteenth century wax models were used for the study of human anatomy, zoology, and botany, providing

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not only lifelike anatomical structures, but, with the introduction of the microscope, creating enlarged versions of the "unseen" world as well. The famous Florentine waxworks (established for the traditional manufacture of Christian votives in wax) of the eighteenth and nineteenth centuries created limited numbers of anatomical and botanical wax models and accepted commissions only from a select few clients: wax sculpture was a lengthy and costly process that only the most wealthy institutes could afford. Gaetano Zumbo (1656–1701), Clemente Susini (1754–1814), Paolo Mascagni (1755–1815), Francesco Lorenzuoli (1796–1829), Luigi Calamai (1800–1851), and Egisto Tortori (1829–1893) all were renown for their high-quality anatomical wax models (Collezioni della Specola, Museo di Storia Naturale dell'Università di Firenze).

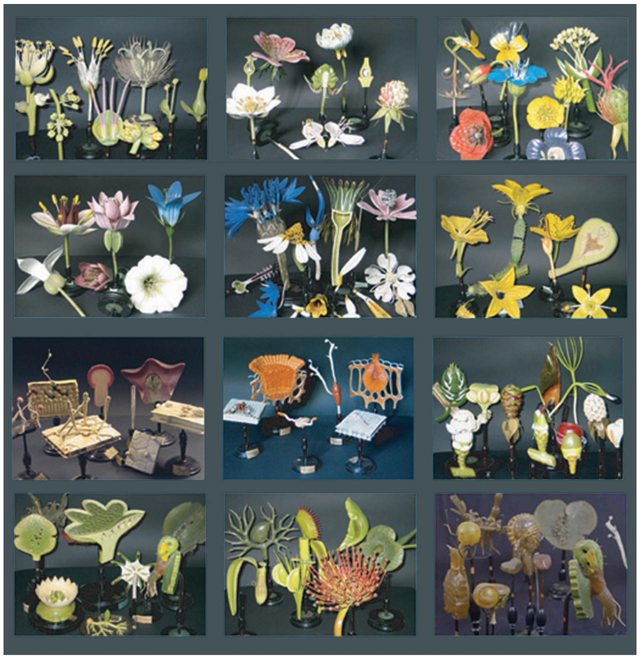


Fig. 1. University of Florence Brendel models

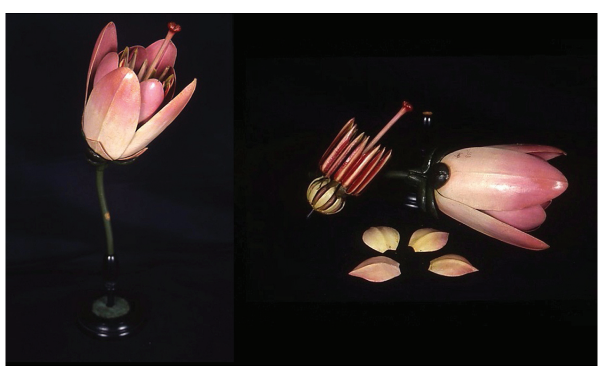
Fig. 2. Model enlarged 1500x. *Brachytecium acetabulum* Br. (six pieces), Bryopsida. R. Brendel, Berlin, no. 1

Many European countries, particularly France and Germany, established factories making models for schools and institutes. Models had to be scientifically accurate, relatively cheap to produce, and sufficiently durable to survive several generations of students. Papier-mâché was an economical and appropriate material for serial model making in large-scale production, along with other readily available materials such as plaster, wood, gelatin, textiles, and metal.

Among the more noteworthy model reproductions were Louis Auzoux's (1797–1880) splendid papier-mâché models for human anatomy, Leopold (1822–1895) and Rudolf (1857–1939) Blaschka's insuperable glass models of flowers and marine invertebrates, and Brendel's models for botany: flowers, histological vegetal series, mushroom and fern cycles, inflorescences, and phylotaxy structures were highly appreciated and were sought by the best schools. Considering their scientific precision and realism, the educational value of nineteenth-century models has not diminished in the least, and indeed some schools are using them still today.

THE BRENDEL COMPANY

The Brendel company was founded in 1866 by Robert Brendel, in Breslau, now in Poland. Brendel enlisted scientific guidance from a local pharmacist, Dr. Carl Leopold Lohmeyer, and botanical advice from the Professor Ferdinand Cohn, director of the Breslau Agricultural Station. It was Professor Cohn's suggestion to diversify away from medicinal plants and to include other species used in agronomy or



LEFT TO RIGHT

Fig. 3. *Fumaria officinalis* L. (four pieces), Fumariaceae. R. Brendel, Berlin, no. 89

Fig. 4. *Calluna vulgaris* Salisb. (five pieces), Ericaceae. R. Brendel. Berlin, no.103

crop production, as well as a systematic approach to botany and vegetal anatomy.

The models (fig. 1) were created from molds and assembled by expert model-makers, using a wide variety of basic materials: papier-mâché, wood, plaster, gelatin, etc. The Brendel models were characterized and appreciated especially for their overtly large size (fig. 2) and by the novel feature of being able to dismantle and reassemble the pieces (figs. 3–4), adding an extra dimension to the role of the model in the classroom. Over time, production became richer and incorporated a wider range of models, close to two hundred, into their repertoire.

The models were sold via illustrated catalogs, either through correspondence or through a network of dealers, notably Giorgio Santarelli and Alberto Dall'Eco in Florence, Václav Friĉ in Prague (then Austro-Hungary), and, in the United States, James W. Queen and Company of Philadelphia, the largest wholesaler of such models at the time. The catalog bears detailed descriptions of some two hundred models, some with illustrations, and highlights the choice between basic models for elementary schools, and more detailed versions for colleges, universities, and agricultural academies (fig. 5). There were also scientific instruction manuals, in effect support material for teachers, edited by university botany professors.

By the time Robert Brendel died in 1898, the company was famed and respected across on both sides of the Atlantic, having diversified into zoology, anthropology, crystallography, and mineralogy. They had won gold medals at shows in Moscow in 1872, Cologne 1890, and at the World's Fair in Chicago in 1893.

Brendel's son Reinhold took over the business, moving production to Grünewald, just outside Berlin. Further awards flowed in, medals from the Exposition Universelle in Paris in 1900; Santiago, Chile, in 1902; the 1904 World's Fair in St. Louis; and in 1910 awards in Brussels and Buenos Aires. After Reinhold passed away in 1927, the records of the company's history become unclear. This is perhaps understandable, given the tremendous social and political upheaval that Germany went through during the next twenty years. There is, however, a German company PhyWe (in Göttingen) who continued producing models under the Brendel name, and their logo can be seen on some of the later twentieth century models seen in Florence (figs. 6–6c). Brendel models are often discovered by chance in public and private high schools throughout Florence and other Italian cities, or in antique shops. Few are in good condition; most appear to be clinging precariously to life in a moderate-to-poor state of preservation. It was quite fortunate that the University plant models were not tossed away or left to decay in the damp basement, and that their intrinsic value was recognized. Today there are perhaps as many as one thousand Brendel models still in Florence, spread between the school of agronomy, the science

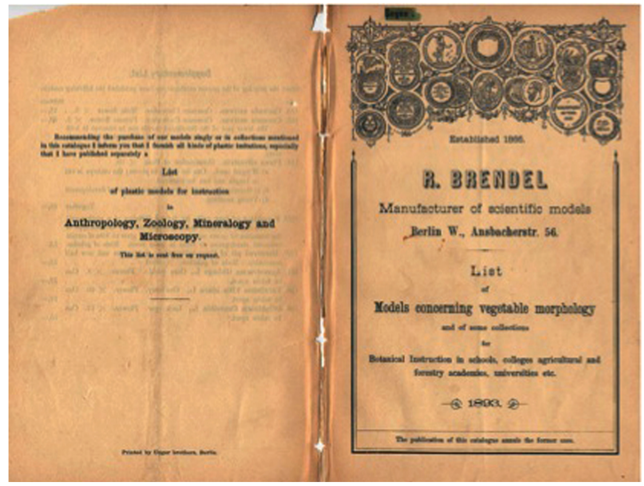


Fig. 5. R. Brendel's *List of Models*, 1893

Figs. 6–6c. PhyWe's model stand (top) with their label (middle) and "RB" logo (bottom, left), and 1963 tags (bottom, right)

Fig. 7. Different Brendel model bases

museum, and several high schools, and there are Brendel collections to be found in Europe, the United States, and Australia. Whilst the same quality and craftsmanship shows through on each model, there are minor differences in color, size, and detail that can be noted, including changing styles of the base units (fig. 7).

THE UNIVERSITY COLLECTION

The study of botany in Tuscany has a long and distinguished history. The world's first botanical garden was established in Pisa in 1543, by Italian ruler Cosimo I, so that medical students at the University of Pisa could study and gain firsthand experience of medicinal plants. Unfortunately, that was soon destroyed, and two years later he built a new one, this time in Florence. These plants, known as "semplici", gave their name to the gardens, still known today as the "Giardino dei Semplici".

Over time, the study of plants grew into the creation in 1775 of the Imperial-Royal Museum of Physics and Natural History at La Specola's Botanical Garden, which in turn blossomed into the Royal Institute of Botany in 1898. It was during these years that the Institute moved and transferred to its newly restructured area and created the new Botanical Garden at the Giardino dei Semplici. Indeed, right next to the ancient garden is where the University of Florence Department of Plant Biology is located today.

Like many of its peers, the Florence Institute of Botany recognized the value of the new teaching materials available and invested in a collection of Brendel models. According to the 1906 inventory register, the first models were purchased from Giorgio Santarelli (a Florentine resale company of science materials) during 1898–99. Professor Oreste Mattirolo, then Director of the Botanical Institute, purchased a collection of sixty-six specimens, principally fungi, mosses, flowers, and insectivorous plants, for the grand sum of ITL 3,777 (equivalent to around $19,500 today, or $300 per model.) There are 168 Brendel models in the collection today; unfortunately, it was never thoroughly inventoried and documents detailing its provenance have been lost or forgotten. Extensive research through the University's archives, however, pieced together a fragmented history of the collection.

The 1898 collection was augmented in 1921 by a further eleven models. Thereafter there are no records of any further purchases, yet today there are ninety-two more than records suggest were purchased. Thirty-seven are labeled as belonging to the Royal Institute of Higher Studies for Women, since absorbed into the University of Florence. These are from the same period and include several duplications, for which the conservators were very grateful later on. Further eighteen models still bearing the original Brendel labels were catalogued, thirty-five unlabeled models, and two labeled differently, a French model bearing the name of Émile Deyrolle in Paris (the store still exists today on Rue du Bac), and one labeled as "Dall'Eco" in Florence. It was common practice for dealers to relabel goods under their own label, and there is no doubt that these are Brendel models from the same factory and period.

DESCRIPTION AND CONDITION OF THE MODELS

Each model is glued to a vertical or bowed rattan rod which easily fits into a knob mounted on wooden base, both well-turned and polished in black lacquer. There are bases with one, two, three, or four knobs, depending on the

Figs. 8a–b. Single model bases (left) and two- to four- knobbed model bases (right)

Figs. 9–10. Circular and rectangular Brendel model labels

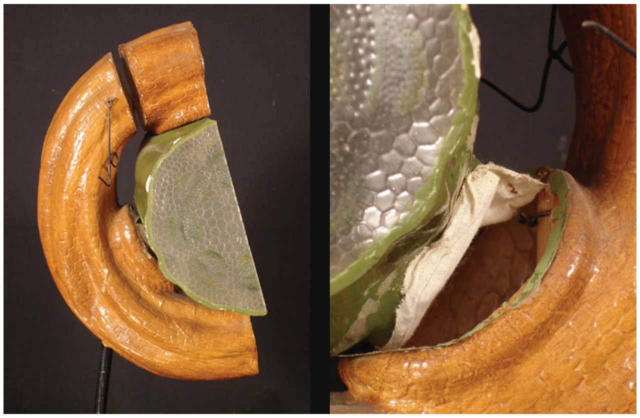


Fig. 11. *Cuscuta trifolii* Bab.–R. Brendel, Berlin, no. 108

LEFT TO RIGHT

Fig. 12. *Aristolochia sipho* 1'Herit. (insectivorous model), Aristolochiaceae. R. Brendel, Berlin, no. 102

Fig. 13. *Mentha cervina* L.–R. Brendel, Berlin, no. 62 (ex R. Ist. Sup. Femm. FI)

number of plant elements represented (figs. 8a–b); others have the models directly attached. A circular or rectangular paper label identifies the model and is glued or affixed to the base with small brass nails. Some bases also have smaller slit knobs where labels were once exhibited. The circular labels on the bases are very detailed: there is the Latin nomenclature, the generic common name in German, the series number, the magnification of the object printed in black ink on green card, and the company name, *R. Brendel Berlin* (figs. 9–10). Earlier models seem to be written only in German whereas the later model generic names are also written in English, French, and Italian.

Fig. 14. *Ficus carica* L. (two pieces), Urticaceae. R. Brendel, Berlin, no. 136 (ex R. Ist. Sup. Femm. FI)

Fig. 15. *Salvinia natans* embryo model–R. Brendel, Berlin, unlabeled, (ex R. Ist. Sup. Femm. FI, no. 87–2), Anteridio (cellular division) R. Brendel, Berlin, no. 81(1); *Pellia epiphylla* embryo model, R. Brendel, Berlin, no. 74 (1)

Together with their respective bases the models measur on average 50 to 60 cm in height. Most of the bases' diameters measure 12 or 14 cm, the smallest 10 cm and the largest, 20 cm.

The unusual shapes and awkward sizes of some of the models result in irregular weight distribution, making them unstable if handled incorrectly. Metal hooks and hinges are used to open and close some model parts or to secure them in place. Also some of the detachable elements had become badly worn, so that they no longer fit properly in place and tended to fall.

A wide variety of materials was used to form the different structures and appendages found on the models. These include wood, papier-mâché, cardboard, plaster, reed pith, metal, string, feathers, gelatin, glass or bone glue beads, and treated cloth. Many appendages are also formed of metallic thread, and other different fibers (horsehair, hemp, or silk threads). Some elements were made directly by plying rush twigs into the desired shape, while leaves, bracts, and flower petals or entire models were made from pressed cardboard or papier-mâché, primed and painted by hand (figs. 11–15).

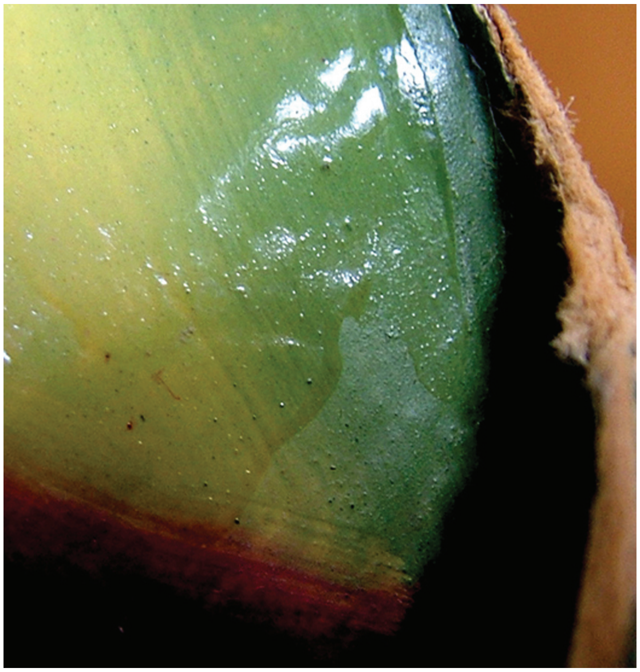


Fig. 16. Shellac over painted surface, detail *Calatide* (two pieces), R. Brendel, Berlin, no. 170b

Other shapes and models are in plaster and all details are painted by hand. The color used is pigment in a water-based medium, protected by a shellac varnish (fig. 16).

Some models are composed of a transparent, gelatin-based material (these are asterisked and noted in the Brendel catalogs (figs. 17–18). Certain parts of the plant structure, such as the spores, filaments, membranes, receptacles, and dissected organs, are also gelatin-based. These are completely painted over and their gelatin structure was revealed only through areas where the layers of pigment had flaked away from the surface. The models in gelatin are also those in the most precarious state of preservation. Indeed, at the time of writing, appropriate solutions are still being sought for treating these models.

In general, the botanical models were poorly preserved. The factors that contributed to their degradation varied from constant handling to natural aging in time, but above all, it was the result of exposure to unstable preservation conditions in an unsuitable environment (stored in cardboard boxes in a damp basement). The more severely damaged models were those that could be dismantled or those with complex projecting structures. These were often broken into fragments, with damage to both the main structure and those attachments that were more delicate and susceptible to breakage, such as the bristles, thorns, anthers, and sepals (fig. 19). Moreover, previous inexperienced and unqualified repair attempts had been summarily performed on some of the models with Scotch tape and/or inappropriate glues, and these had partly damaged the painted surfaces (fig. 20). In addition to the dust and surface dirt accumulated on the models and their bases, there were areas with raised surfaces and losses of color, and many labels had become unstuck and were partly torn.

The general precariousness of the models was exacerbated by a more widespread form of damage—namely, cracks, fissures, complete disintegration of parts, and loss of adhesion of the whole structure; quite simply, they were just falling to pieces (fig. 21).

The support bases for the models were in reasonable condition, although many had suffered structural damage with cracks and holes where the wood had split or distorted.

LEFT TO RIGHT

Fig. 17. Gelatin-based models: *Equisetum arvense* L., Sphaenopsida. R. Brendel, Berlin, no. 5. *Utricularia vulgaris* L., Utriculariaceae. R. Brendel, Berlin, no. 135, and *Pinus silvestris* (3600x) (three pieces), R. Brendel, Berlin, no. 156

Fig. 18. Gelatin-based models: *Pteris serrulata* L. (four pieces), Pteridopsida. R. Brendel, Berlin, no. 6, and *Aspidium filix-mas* Sw., Pteridopsida. R. Brendel, Berlin, no. 8

Fig. 19. Damaged sepal in gelatin with delaminated paint. *Lycopodium clavatum* L., Lycopsida. R. Brendel, Berlin, no. 193

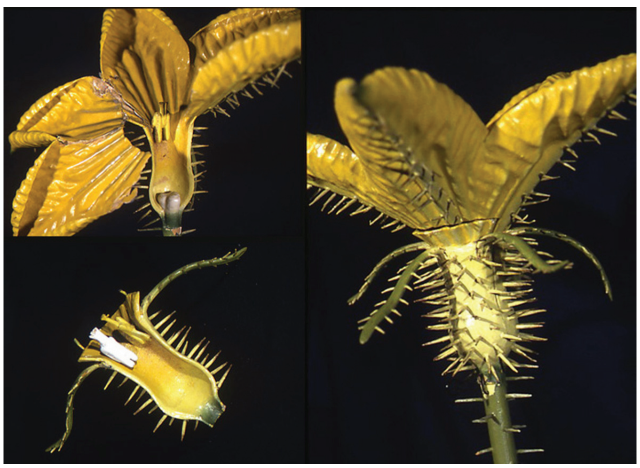


Fig. 20. Damaged paint surface and structure caused by use of inappropriate glues and handling, during treatment. *Cucumis sativus* L. (m) Cucurbitaceae. R. Brendel, Berlin, no. 152

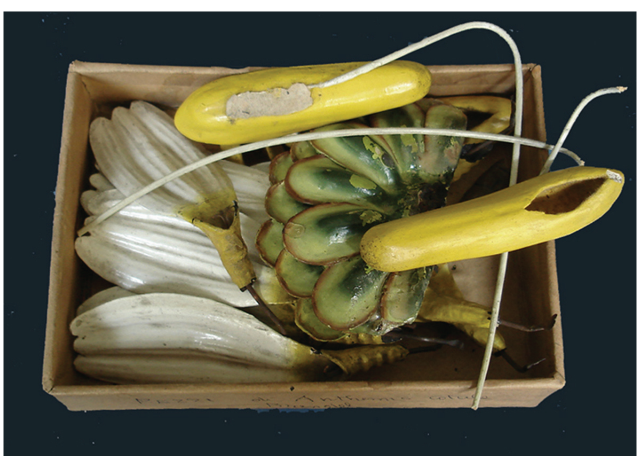


Fig. 21. Damaged fragments

Almost all the bases evidenced woodworm holes and traces of xylophagous insects.

CONSERVATION OF THE BOTANICAL MODELS

The project to save the Brendel models from further degradation presented an interesting, thought-provoking, and instructive case study. The peculiarity of the collection and the wide range of materials used to construct the models presented a complex conservation task. Yet it was quite amusing to find the studio transformed, filled with brightly colored giant flowers, odd-looking translucent creatures, and miniature *maquette*-like sculptures, quite different and unusual from treating drawings and prints, crucifixes, and polychrome sculptures.

It was decided to divide the conservation treatment in two phases: the first to treat the support bases, and the second, the models. Tasks were also divided for handling and treating the paper elements and the other materials used between the paper and objects conservators and the scientist who was available for botanical consulting.

The fascinating synergy that was created between the three specialists is a fundamental aspect of the project that cannot be overlooked. In fact it proved to be a most pleasant and enjoyable learning and sharing experience. For example, take the *Equisetum arvense* (horsetail) models: with the aid of diagrams and live specimens, the botanist explained all phases of this non-flowering weed, in order to appreciate—with great fascination—the accuracy and precision of the Brendel models in reproducing even microscopic spore levels (fig. 22).

Whenever the conservators were faced with undecipherable fragments and there were no duplicate models on hand, the scientist's botanical expertise, supplemented as

Fig. 22. Horsetail "in bloom" at the Giardino dei Semplici (top picture); two live samples of strobilius and sporangiophores (6 cm) and Brendel model (60 cm) *Equisetum arvense* L.-Sphaenopsida. R. Brendel, Berlin, no. 2. Gelatin models of the horsetail's microscopic phases; *Equisetum arvense* L. (20–100x) (four pieces), Sphaenopsida.R. Brendel, Berlin, no. 3; *Equisetum arvense* illustration in Tonzig, S., *Elementi di Botanica*

appropriate by live specimens and/or scientific drawings, was invaluable in helping to understand from a scientific perspective the fine detail required to reconstruct the broken or missing pieces (fig. 23). The botanist was equally fascinated to learn of all the different materials that had been used to create the models, as well as of the conservation techniques used to restore and preserve them.

To proceed in a systematic and orderly manner, all of the models were numbered, photographed, and filed individually, and then divided in groups according to dimension, materials, and types of damage that required treatment.

Fig. 23. Phases during treatment. *Peronospora viticola*—Eumycetophyta, Oomycetales. R. Brendel, Berlin, no. 5

Fig. 24. Treatment of base

Treatment of the bases

The models were removed from their bases and each placed vertically in a temporary container. All bases were preventively treated with a Permethrin-based insecticide solution (Permetar) in turpentine. Excess amounts of hardened glue used in the earlier "do-it yourself" fix-it attempts were removed from the base surface before proceeding with consolidation. Where necessary the damaged areas were reconstructed and the woodworm holes stuccoed with a two-component epoxy putty (Araldite HV427), and then in-painted with black pigment. Some of the smaller holes were sealed with wax-based stucco tinted with black pigment. Lastly all the bases were treated with a protective layer of microcrystalline wax in turpentine (fig. 24).

The paper labels whose edges and corners were loosened or torn were adhered to the base with an acrylic emulsion (Plextol B500), while the holes and gaps were filled with pretinted paper pulp or paper inserts. The labels in the most precarious condition, with brittle paper and with numerous tears, were removed from their base and treated apart. Once the labels were consolidated with Japanese paper and methylcellulose adhesive, they were re-glued to the bases. The surface of the labels was then treated with a protective layer of Klucel G, 20% solution in ethanol.

Treatment of the models

For secure, effective, and controllable surface cleaning, a system using small cotton swabs dipped in 2% solution of oxgall was selected. This surfactant allowed for cleaning the polychrome surface. The areas with flaking color (fig. 25)

Fig. 25. Flaking color

LEFT TO RIGHT

Fig. 26. Before and after treatment: *Zea mays* L. (two pieces), Gramineae. R. Brendel, Berlin, no. 28

Fig. 27. Before and during treatment: *Clematis integrifolia* L.–R. Brendel, Berlin, no. 63 (ex R. Ist. Sup. Femm. FI)

were treated and refixed to the surface with Acril 33, a pure acrylic resin in aqueous dispersion.

Consolidation of the model's structure consisted of three different aspects:

- Readhesion of detached single elements
- Complex readhesion of multiple elements
- Readhesion and reintegration/reconstruction of missing parts

In all three cases, vinyl and epoxy rapid-setting adhesives were used with plastic or wooden clamps, depending on the weight and structural stability of the element under treatment (figs. 26–27).

Whenever possible, materials similar to the originals were used to reconstruct the missing parts. For example, wooden toothpicks were used for the fine bristles (fig. 28), cotton threads for the filaments, silk gauze for the sepals, and new metallic hooks replaced damaged or missing hooks on models with movable or detachable parts.

Reconstruction of missing elements was undertaken only where necessary for coherence or for restoring structural stability. A few model parts could be reconstructed looking at the duplicate models from other collections mentioned earlier. The missing parts were reconstructed using either paper or papier-mâché, cast on polyvinyl silicone molds (as used in dentistry), created from corresponding original parts (figs. 29–31). The more compact shapes were reconstructed with araldite, primed with a plaster and glue preparation, and then painted (figs. 32–34).

The surfaces with color loss were restored with pigmented, wax-based stucco. All of the restored polychrome elements with small or large gaps were inpainted with pigment and Mowilith 20 (vinyl acetate) in ethanol.

The packaging phase of the restored models was just as important and as indispensable for safely transporting the models back to the University's Department of Botany. It was fascinating to learn that in 1826, French model maker Louis Marc Antoine Robillard d'Argentelle, returned to Paris aboard the *William Wallace* from Mauritius, where

Fig. 28. *Papaver rhoeas* L. (two pieces), Papaveraceae. R. Brendel, Berlin, no. 87

he had spent twenty-four years creating 112 wax tropical fruits and plants: the *Carporama* exhibited there today, at the Musée Nationale d'Histoire Naturel. In less than a day, he had them packed ready for shipment in wooden crates reinforced with metal; despite what must have been a rough passage by modern transportation standards, each and every one survived intact! In the case of the Brendel Collection, funds were not available for the construction of bespoke (custom-made) cases for each model. The alternative was to devise secure and economical packaging for the journey across town. Firstly, each model was wrapped in lightweight paper and then with bubble wrap. Three to four models were then carefully placed and securely fitted into large cardboard boxes so that they could not nudge against each other or tip over during transportation by van to their final destination.

CONCLUSION

Model makers worked side by side and in close collaboration with scientists, along the fine line where the artist becomes scientist and the scientist an artist. Both artisan and



LEFT TO RIGHT

Fig. 29. Integration and reconstruction with paper and papier-mâché. *Brassica napus* L. (two pieces), Cruciferae. R. Brendel, Berlin, no. 19

Fig. 30. *Taraxacum vulgare* Schrank (three pieces), Compositae. R. Brendel, Berlin, no. 119 (or no. 238)

Fig. 31. *Viola tricolor* L. (two pieces), Violaceae. R. Brendel, Berlin, no. 90

scientist worked to create replicas of nature, devising ways and choosing materials that could best represent or imitate the specimen. Though these were modular, standardized creations—the products of modernized factory work—the series of models were all painted, assembled, varnished, and lacquered by hand, conferring a unique quality to each model. Are these stylized, curvilinear designs incorporating floral and other plant motifs, or are they scientific, oversized imitations of life? Does one see smoothed, polished surfaces and abstraction in the service of pure design, or factual interpretations in the service of scientific learning?

For the Brendel collection, it was the close collaboration of expert curators in different disciplines that determined and delivered the appropriate treatments, techniques and methodology required to overcome the challenges and to preserve the models. In such disciplines, the opportunities for collaboration are rare and greatly appreciated. Above all, however, each is honored to have had the opportunity to appreciate at close quarters both the technical skills and the scientific accuracy of the master model makers of Brendel. It is hoped that these collaborative efforts will have helped to prolong the shelf life of these living plants so that for years to come, others will share the sense of wonder and delight that these botanical beauties generate. It is also hoped that schools, Scientific Institutes and Museums will become more aware of their forgotten or hidden historic model collections and perhaps stumble across "new" Brendel models to add to the list of "plants to be saved" around the world.

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Figs. 32. Reconstruction with araldite and gesso, then inpainted. *Pinus sylvestris* L. (f) (two pieces), Pinophyta, Pinaceae. R. Brendel, Berlin, no. 41

Fig. 33. *Taxus baccata* L. (f) (three pieces), Pinophyta, Taxaceae. R. Brendel, Berlin, no. 40

Fig. 34. Detail of figure 33

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LINDA OWEN

Fire and Paper: An Examination of the Materials and Techniques of Lee Bontecou's Soot Drawings

ABSTRACT

Using soot from an acetylene torch, American artist Lee Bontecou created a series of drawings on paper, beginning in the late 1950s. Soot has been used for centuries as a pigment, and carbon blacks in general have been used as pigments for both artists and industry. However, Bontecou's method of directly applying the soot to the paper support with an acetylene torch was a new approach. The treatment of an early soot drawing, *Untitled*, from 1958, was the impetus for this research, and an understanding of the medium was necessary before treatment. Bontecou's working method and manipulation of the medium were investigated with visual examination and mock-ups. Discussion with the artist provided further insight into her technique, materials, and use of fixative. While very similar in many respects to other friable media, soot has some distinctively different characteristics and properties. Although the main component of soot is carbon, organic species are present due to incomplete combustion and contaminants. Paper samples covered with acetylene torch soot were analyzed. This innovative use and application of a traditional medium by a contemporary artist has presented interesting questions for treatment, display, and storage.

INTRODUCTION

In the late 1950s, the American artist Lee Bontecou, born 1931, began experimenting with the use of an oxy-acetylene torch for drawings on paper. While soot has been used for centuries as a pigment, Bontecou's use of the welding torch to directly apply the soot to the paper, with no intermediary steps, was an innovative and unusual approach. Her ability to manipulate and control the soot created works of art of an ethereal, striking beauty. Bontecou's discovery of the technique was a breakthrough in her work. She said that "[g]etting the black…opened everything up" (Hadler 1994, 56). As the art historian Mona Hadler proposes, the series of soot drawings mark a pivotal point in Bontecou's career and lead directly into her best known works, wall-mounted sculptures generally consisting of a welded steel frame with found materials such as canvas around a central void (1992) (fig. 1).

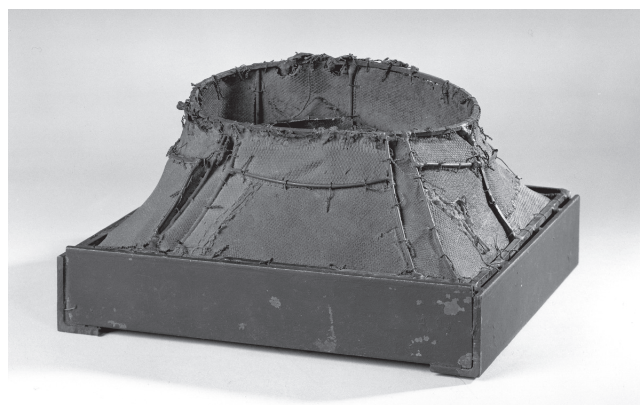

Fig. 1. Lee Bontecou, *Untitled*, 1960, metal and canvas relief, 17.1 x 19.1 x 10.2 cm. Gift (partial and promised) of Mr. and Mrs. Carl J. Gerwitz, Department of Visual Services, National Gallery of Art, Washington DC, 1992.52.1

One of these early soot drawings, *Untitled*, from 1958 (fig. 2), came into the paper conservation lab at the National Gallery of Art (NGA) for assessment. A long, vertical mark in the right portion of the drawing raised some questions. It appeared to be a scratch, approximately ten inches long and half an inch wide. Once it was confirmed with the artist, through the intermediary of Knoedler Gallery which represents the artist, that the mark was damage and not part of the drawing, the curator requested that the drawing be treated. An understanding of the medium was necessary to determine an appropriate approach to treatment and long-term preservation. Bontecou's working method and manipulation of the medium were investigated with visual examination and mock-ups. Visits to other institutions and private collections

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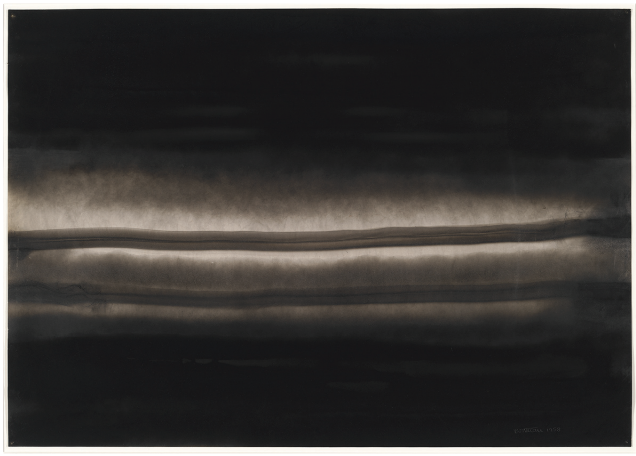


Fig. 2. Before treatment, Lee Bontecou, *Untitled*, 1958, acetylene soot on paper, 70.0 x 99.8 cm. Promised gift, Department of Visual Services, National Gallery of Art, Washington DC, 130745

provided additional examples of the artist's work, and discussion with the artist allowed further insight into her technique. While very similar in many respects to friable media such as pastel and charcoal, soot has some distinctively different characteristics and properties.

Instrumental analysis helped to resolve some questions about the stability and structure of the soot drawings. While the main component of soot is carbon, organic species are present due to incomplete combustion and reactions with carbon radicals. Paper samples covered with acetylene torch soot were tested for lightfastness. Paper fibers coated with soot were examined with scanning electron microscopy (SEM) to gain an understanding of the soot agglomerate morphology and the interaction between soot and paper.

THE ARTIST

Lee Bontecou was born in Rhode Island in 1931 but raised in New York. From 1952 to 1955, the artist attended the Art Students League in New York, and learned to weld at a summer program at the Skowhegan School in Maine. A Fulbright Scholarship brought Bontecou to Rome in 1956, and she remained there until 1958. During her time in Rome, Bontecou created a series of terracotta animals with a welded steel structure (Smith 2003). For her welding she used an oxy-acetylene torch. The oxygen and acetylene gases are mixed to create a hot, controllable flame suited to welding steel. Bontecou realized that when she turned off the oxygen and ran the torch solely from the acetylene she could draw with the heavily sooting flame. The acetylene burns at a much lower temperature and the combustion is incomplete, resulting in copious amounts of soot or settling that flows off of the flame in a plume. The low temperature of the flame is also helpful in preventing the paper from burning.

Bontecou called the series of drawings "worldscapes" (Hadler 2003); she found the deep blacks to be reminiscent of outer space. The velvety black of the drawings was a natural precursor to the dark voids so characteristic of her sculptures. She would often fill the central voids with soot or black velvet to further enhance the feeling of depth and space.

Bontecou became well-known for her sculpture and had a solo exhibition at Leo Castelli Gallery in New York in 1960, which also represented Jasper Johns and Robert Rauschenberg. One of only a few women on the art scene at the time, Bontecou's career took off in the 1960s (Duncan 2004). Her thought-provoking sculpture and waifish look attracted widespread attention, leading to articles in *Art in America* as well as *Vogue* and *Cosmopolitan*. However, as her work evolved in a new direction and her life changed, Bontecou completely withdrew from the art world in the early 1970s (Smith 2003). She never stopped making art and in 2003 a major retrospective organized by Elizabeth A. T. Smith of the Museum of Contemporary Art in Chicago and the Hammer Museum rekindled interest in her work. Her early soot drawings in particular generated excitement, which Bontecou finds ironic since their reception was decidedly unenthusiastic when she brought them back from Rome (Bontecou 2007). Her early soot drawings are now in the collection of the Museum of Modern Art (MoMA), the Los Angeles County Museum of Art (LACMA), and private collections. There are only around ten of the drawings still in existence. Bontecou lives in rural Pennsylvania and works in a large barn that is converted to a studio, much as she has for the last forty years. Bontecou still uses welding in her sculptural work occasionally, but for the most part no longer uses soot in her drawings (Bontecou 2007).

SOOT AND CARBON BLACK

Soot, as described in technical literature, "is a randomly formed particulate carbon which in addition to carbon contains a large variety of inorganic and organic impurities" (Bansal and Donnet 1993, 67). The exact mechanism of soot formation is still not completely understood, but is likely a combination of the dehydrogenation of the fuelstock to atomic carbon or carbon radicals and/or the formation of a large hydrocarbon which is then dehydrogenated to soot (Bansal and Donnet 1993). The size of an individual soot particle is extremely small, in the order of one nanometer or less. However, during soot formation the particles quickly form aggregates, 10–50nm, and then agglomerates of much larger size, up to 1mm in length (Bansal and Donnet 1993). The fuelstock will effect the composition of the soot. Wax or oil will produce a greasy soot with a high level of organic impurities and small particles of the original fuel (Spafford-Ricci and Graham 2000).

Soot has been characterized in the conservation literature primarily in the context of damage from fire or smoke.

Methods of surface cleaning soot are discussed, and its composition has been analyzed for that purpose (Roberts et al. 1988, Spafford-Ricci and Graham 2000). Organic greasy materials and carbon can penetrate and become embedded in surfaces; the adhesion to the substrate is increased by electrostatic attraction (Spafford-Ricci and Graham 2000). Even though the soot produced by the acetylene torch is not as tarry as soot from more heterogeneous sources, acetylene soot still contains numerous organic species that are formed by the carbon radicals.

Purified soot or combustion products are used extensively as black pigments, but that use accounts for only 10% of the production of carbon black (Kuhner and Voll 1993). Carbon blacks are used extensively in plastics and rubber manufacturing as a conductor, a UV inhibitor, filler, and strengthening agent. The tire industry accounts for the majority of carbon black production (Bansal and Donnet 1993). As a pigment, carbon black is indispensable in xerographic toners for its ability to hold an electrostatic charge (Donnet et al. 1993). This ability plays a very important role in the characteristics of soot as a media. The highly charged particles are attracted to the paper substrate, and the charge helps to hold them in place.

Historically, carbon blacks are some of the oldest pigments known to mankind. Charcoal was used in cave paintings and graphite has been identified at ancient Egyptian sites (Winter and West FitzHugh 2007). Lamp black has long been used to produce Chinese or India ink (Mitchell 1937). Bistre is ink produced from oily soot that is completely unpurified; in fact, the organic impurities produce the desired yellow-brown hue that is characteristic of the ink. Bistre is known to be sensitive to light, as a result of the organic components (Winter 1983). This tendency of bistre to fade raised the concern that some portions of Bontecou's soot drawings might be fugitive as well. The lighter portions of the artist's drawings, where the soot has a brown hue, were considered to be the most likely to fade. In order to have a better understanding of the characteristics of soot as a pigment, further study using mock-ups was necessary.

TECHNIQUE

Samples were created to better comprehend the soot's properties and Bontecou's technique (fig. 3). The samples were made with soot from an oxy-acetylene torch and papers that were similar to Bontecou's—white, heavyweight, smooth, and wove. Some points became obvious during the construction of the samples. The movements needed to be quick because lingering in one area too long led to a heavy deposition of soot, and the paper support would start to smolder. A few passes of the torch could also cover any lighter areas. Lighter passages, therefore, must be deliberately reserved. The soot was also extremely sensitive to abrasion, and extensive loss could occur with a light touch. With the knowledge gained from making the samples, a better understanding of Bontecou's technique was possible.

Bontecou created some of the soot drawings in a careful build-up of layers, reserving the highlights in some areas and allowing a heavy layer of the fluffy soot to form in others. She maintained very good control of the torch and could achieve the effects she desired easily. Bontecou used masks to help protect lighter sections from accidental deposition of soot, which were taped down to the surface of the drawing (Bontecou 2007). Two soot drawings, one from LACMA and one in a private collection, have pressure-sensitive tape residues along the edge; it is possible that these are the remnants of a mask. Bontecou also used fixative between the layers of soot to help protect the lighter areas and stabilize the darker areas. The final layer of soot would remain unfixed in order to preserve the velvety, matte texture of the soot.

Tack holes along the margin are evidence that the artist secured her paper while drawing with the torch. The tack head protected the paper beneath it, resulting in less soot being deposited and a lighter spot. An early photograph from the artist's Rome studio shows soot drawings tacked to the wall, although she could have put them up for display. When discussing the matter with Bontecou, she could not say specifically if she worked horizontally or vertically. Bontecou also spoke about the effects that she could obtain by holding

Fig. 3. Making soot samples with oxy-acetylene welding torch

the torch beneath the drawing and allowing the soot to blow upwards (Bontecou 2007). The language that she used also indicates that the drawing may have been vertical at the time.

The majority of Bontecou's early soot drawings from 1958 are composed only of soot. The range of color obtained is very impressive as are the different surface textures that she produced. For example, there is a light brown that is the result of very little soot deposition and smaller agglomerates. A cool blue gray with a slightly graphitic sheen occurs when she has rubbed or burnished the surface. In some areas a speckling of the soot is apparent that occurred during the application. The deep black is a much more three-dimensional layer; it is extremely matte and reminiscent of velvet. The underlayer of blacks that was fixed appears significantly less saturated than the unfixed top layer and reads as lighter in value.

The careful layering is an additive technique, but Bontecou also used a subtractive method. She would lay down a heavy layer of soot and then work back into it. The soot layer would not cover the entire surface of the paper support. The major components of the composition would be blocked out with the torch and then intricate details scraped in. With a variety of tools, the artist would remove soot, sometimes only the top layer, and at others scraping all the way down to the paper surface and disrupting fibers. Bontecou recalls using a brush to remove the soot (Bontecou 2007), and it is evident that she also used razors and her hands to further manipulate the medium. The MoMA drawing (fig. 4) is an example of the subtractive technique; here, Bontecou has removed the majority of the soot with razors, patterning the surface with staccato scraping. Only in one drawing from this series, at the Knoedler Gallery in New York, has she added other media. The drawing is in the subtractive technique with extensive working of the soot layer. Charcoal and black ink lines have been drawn in to continue the scratched lines in the soot (fig. 5).

Fig. 4. Lee Bontecou, *Untitled*, c.1958, soot on paper, 76.2 x 101.6 cm. Judith Rothschild Foundation Contemporary Drawings Collection, Museum of Modern Art, TR12112.253

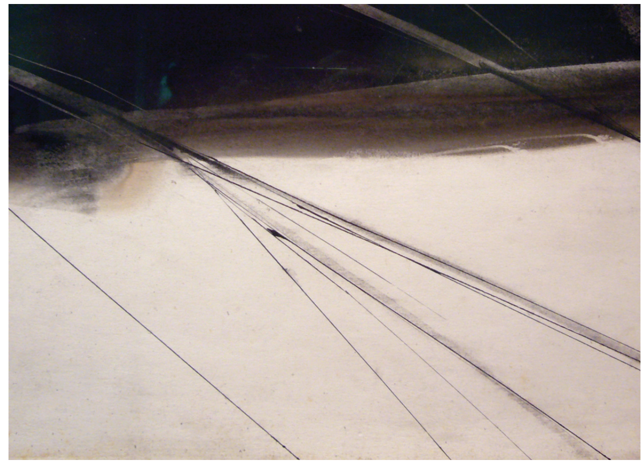


Fig. 5. Detail of Lee Bontecou, *Untitled,* c. 1958, soot on paper, 68.6 x 99.1 cm. Collection of the artist, Knoedler Gallery

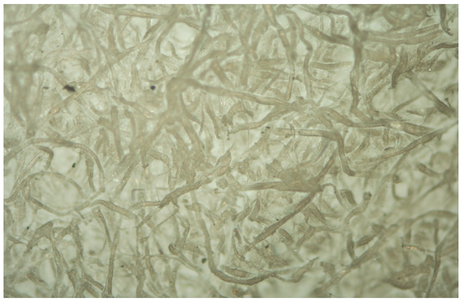
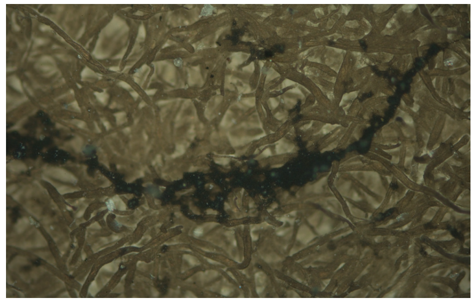
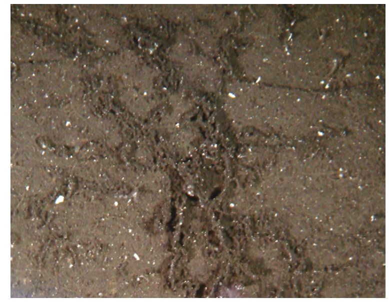
All of the soot drawings examined were dated 1958 or "c. 1958," so establishing a chronology is somewhat difficult. It is possible that Bontecou started with the subtractive technique, and then, as she became more adept at controlling and manipulating the torch, moved on to the additive technique. She may have stopped relying on tools to rework the surface and been able to use the torch to achieve the effects she desired.

ANALYSIS

Some instrumental analysis was done in order to better understand how the soot interacted with the paper support and to answer questions about display, handling, and storage.

The soot samples were initially examined with a stereobinocular microscope. Under magnification, the soot appeared as a continuous coating. In the lighter areas of application shown in figure 6, the soot barely covers the paper fibers. In the midtones (fig. 7) the soot completely coats the fibers, but the structure of the fiber network is still evident. The deep blacks are three-dimensional; the soot has built up to such a degree that the paper fibers are no longer visible as in figure 8.

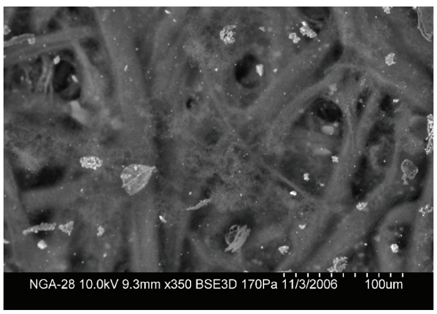
Scanning electron microscopy (SEM) was performed on the prepared samples to try to further resolve the interaction between the soot and fibers. Individual soot particles are too small to be captured with SEM, but images are possible with transmission electron microscopy (TEM). Images of individual carbon black particles can be found in the technical literature (Hess and Herd 1993) so it was not thought necessary to try and discern the individual particles. As seen in figure 9, the paper fibers are coated with soot, which appears as a diaphanous layer on the fibers. When compared with the control paper sample in figure 10, it is apparent how completely the soot covers the paper fibers, penetrating into the interstices of

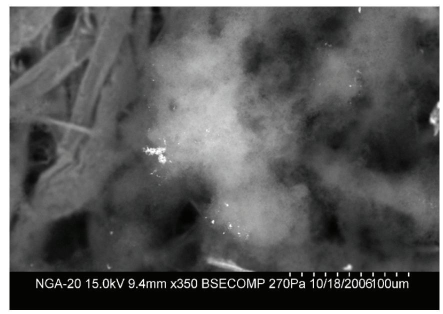




LEFT TO RIGHT

Figs. 6–7. Photomicrograph of soot sample, 100x, polarizing light microscope

Fig. 8. Photomicrograph of soot sample, 25x, stereo-binocular microscope





Figs. 9–11. Photomicrograph of soot sample, 350x, scanning electron microscope

the fiber network. Figure 11 shows the soot agglomerates in an area of very heavy application. The large soot agglomerate rests lightly on the surface of the paper fibers; it becomes clear how very little mechanical action would easily remove the larger agglomerates.

One of the most interesting things about soot was that while it was incredibly sensitive to touch, it was remarkably stable to shock. When the samples were held over a white sheet of paper facedown and tapped forcefully on the verso, no loss occurred. The most heavily coated samples were selected, with very large soot agglomerates, and after tapping, some eventually fell off. The majority of the soot was stable to shock; only the largest agglomerates proved vulnerable. This is where the ability of carbon to hold a charge becomes evident. The attraction between the soot particles and the paper fibers is so great that it can overcome the effect of some shock. While soot certainly appears to be more stable than pastel to shock, it is still a particulate material and should be treated with care. One of the drawings in a private collection did have a few deposits of what appeared to be soot on the window mat bevel, indicating that losses may be possible.

There was some concern that the organic components of the soot might be susceptible to fading. The microfading tester was selected to gauge the light sensitivity of the soot. Rather than unframing the sensitive drawing for testing, the prepared samples were used in its place. Different colors and applications of the soot were tested, from light brown to black. All of the samples exhibited no change; generally, if a substance is light sensitive, some fading will occur. The soot, therefore, was very stable and not fugitive. The Bontecou drawings are fixed, so it is possible that the fixative may yellow slightly with light exposure.

A small sample from the darkest black area was tested with Fourier transform infrared reflectometry (FTIR) with attenuated total reflectance (ATR) in an attempt to determine the fixative used. In 1958, acrylic fixatives had been introduced to the market, but earlier fixatives, like nitrocellulose and shellac, were still in use (Ellis 1996). Bontecou remembers using a mouth-blown atomizer to apply the fixative and that it had a terrible taste, but she does not recall the brand that she used. Currently she uses matte spray fixative, which has an acrylic base (Bontecou 2007). The results from the ATR FTIR were inconclusive; the weak peaks observed could not be definitively attributed to a specific fixative. Bontecou has experimented with new materials and techniques throughout her career, and so it seems possible that she might have adopted the new acrylic fixatives early on.

TREATMENT

With the information gained from the mockups, analysis, and examination of other Bontecou drawings, it was possible to proceed with the treatment phase of the project. Overall the drawing was in very good condition, considering the

fragility of the medium. The drawing was received matted and framed. Japanese paper hinges were located along the top and sides. The hinges were not released because the current matting was of good quality, and the treatment did not require access to the verso. Examination of the verso, therefore, was not possible. Numerous scratches, fingerprints, and small abrasions were present along the perimeter, especially along the right and left edges. An area of burnishing or erasure was in the middle of the left edge. The long vertical scratch passed through several different applications of the soot near the center of the right side. After consulting with the curator, it was decided to inpaint the areas of loss within the vertical scratch to minimize its appearance.

When discussing the drawings with Bontecou, she explained how she had retouched them herself occasionally. Again using masks to protect lighter or undamaged areas, she would go over the damage with the welding torch (Bontecou 2007). Given the nature of the soot, this method would only have worked well on the unfixed, heavily applied layers, and would not have been effective on the scratch in question. The vertical nature of the scratch, and its location in the lighter areas of application would have made retouching with the torch nearly impossible. Retouching with the torch would also cover undamaged parts of the drawing, which would be unacceptable for ethical reasons.

To test inpainting materials, the soot samples were scratched to replicate the damage. Watercolor, dyes, acetylene soot, and powdered pigments were all tested on the samples. Watercolor and dyes proved to have too much surface gloss, and the acetylene soot collected from the samples held such a static charge that it would not release from the brush. Powdered pigment applied with a brush was the most effective, especially in the lighter areas of soot. To achieve the look of the darker areas, wetting of the powdered pigment with a small amount of ethanol was necessary to obtain the right depth of color. Trying to apply the pigment, however, was problematic. Any attempt to touch the soot on the mock-ups resulted in further loss. In fact, the charged soot particles could be chased away with the dry brush, without even touching the particles directly. In order to disperse the charge, a very fine line of water was painted just shy of the edge of the loss. The inpainting material could then be applied and would flow up to the edge of the water line.

For the treatment of the drawing, dry powdered pigments applied with a brush were sufficient and the wetting of the pigments was not necessary. The majority of the damage occurred in the lighter areas. By breaking up the line of loss, its appearance was greatly diminished and no longer visually distracting (fig. 12). Ivory black and raw umber were the best color matches. Once the large scratch was diminished, the smaller scratches at the sides gained prominence and the curator found them to be distracting. A few of the scratches on the right and left side were then inpainted. Although the lower layers of the drawing were fixed, the top layer of deep black was not, so extreme care was taken not to disturb it.

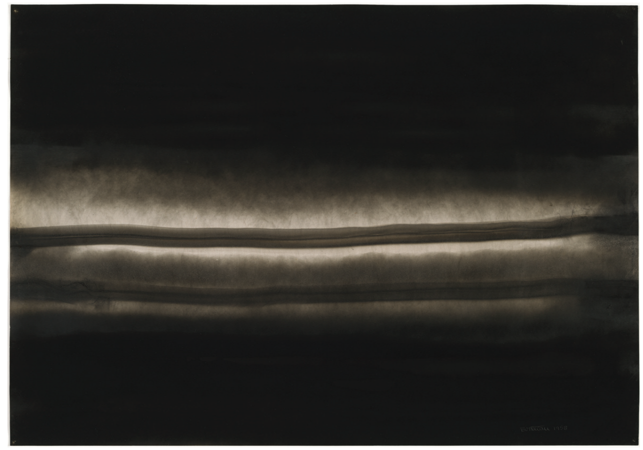


Fig. 12. After treatment, Lee Bontecou, *Untitled*, 1958, acetylene soot on paper, 70.0 x 99.8 cm. Promised gift, Department of Visual Services, National Gallery of Art, Washington DC, 130745

During treatment, the accumulation of dust and fibers on the surface of the drawing became problematic. Due to the sensitivity of the medium, it was desirable to have the treatment proceed as quickly as possible, and not leave the drawing unframed and vulnerable for a prolonged period of time. The drawing was covered at all times, except when it was being actively worked on. Even during the relatively short period of time that the drawing was uncovered, dust and fibers collected on the surface. The large dust particles and light colored fibers that landed on the drawing stood out quite clearly. The largest particles and fibers were removed with a small, pointed rubber artist's tool. The charged dust particles would leap off of the surface of the drawing and onto the rubber tool. Lightly rubbing the tool on cloth built up enough of a charge to overcome the attraction between the dust and the soot and attract the dust to the tool instead. The dust was removed without having to touch the delicate surface of the drawing, by overcoming the static charge that held the dust to the soot.

The fact that Bontecou used fixative on her drawings greatly adds to their stability, but it should always be kept in mind that the top layer is unfixed and vulnerable. The drawing is unframed only when absolutely necessary, and it is stored framed and shipped in a double crate when it travels. When asked how she had shipped the drawings back to the U.S., Bontecou replied that she had interleaved them with paper and rolled them up. Retouching with the torch and masks had been necessary upon her return to the New York (Bontecou 2007). Although the drawings are in good condition overall, it is due in part to their maintenance by Bontecou.

CONCLUSION

Bontecou's willingness to experiment and innovate was evident early in her career when she began using the welding torch to create drawings. These drawings are unique works of art with specific characteristics that are unlike traditional drawing media. Despite soot's sensitivity to abrasion, a property that it shares with pastel and charcoal, soot is much more stable to shock than other friable media. As artists continue to innovate and experiment, the resulting art works will continue to pose new questions and challenges to conservators.

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ANALYTICAL TECHNIQUES

Microscopy

The samples were examined with a Leica DMRX polarizing light microscope equipped with a Canon EOS-1 Ds Mark II digital camera.

SEM

The samples were examined with a Hitachi S3400-N scanning electron microscope fitted with an Oxford ATW2 Si(Li) detector and the INCA 300 energy dispersive spectroscopy analysis system. Analysis was carried out at a working distance of 10 mm and with an accelerating voltage of 20 eV.

ATR FTIR

The sample was analyzed using a Fourier-transform infrared Thermo Nicolet Nexus 670 FT-IR Bench equipped with a Spectra-Tech Continuum IR Microscope both by transmission through a single diamond cell window and by reflectance using an attenuated total reflectance accessory (ATR-FTIR). The microscope has a liquid nitrogen-cooled MCT-A detector (11,700–600 cm^{-1}) and a 15X infinity-corrected Reflachromat objective fitted with an adapter for a slide-on ATR Si crystal. 512 scans at 8 cm^{-1} resolution were collected using Nicolet OMNIC version 7.4. Spectral searching was done using OMNIC and the Infrared Users' Group (IRUG) libraries.

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The Effectiveness of Two Cationic Fixatives in Stabilizing Water-Sensitive Dye-Based Inks on Paper

ABSTRACT

Temporary fixatives such as cyclododecane and Paraloid B-72 have long been used by paper conservators to protect water-sensitive media during aqueous treatment of paper artifacts. Recent research has focused on the application of ionic fixatives used in the textile industry to preserve modern synthetic dye-based inks on paper during aqueous deacidification. This study examines the effectiveness of two commercial ionic fixatives currently used in the paper and pulp industry, Cartafix GS and Cartafix NTC liquid fixatives, in improving the wet-fastness of inkjet ink on common office paper during immersion in a water bath. Analytical techniques used in this study include optical microscopy, spectrophotometry, and Fourier transform infrared spectroscopy (FTIR).

INTRODUCTION

Aqueous washing is an essential technique in the repertoire of the paper conservator that can often improve the stability and appearance of the paper artifact. When a conservator is faced with water-soluble inks or dyes on a paper support, the decision arises to either forego washing or to use a temporary fixative on the sensitive media in order to protect it during treatment. The choice of fixative is guided by these provisions: that it be applied easily, that it neither change the appearance of the media or the paper nor decrease their stability, that it effectively protect the media during treatment, and that it be easily removed.

Film-forming fixatives such as cyclododecane and Paraloid B-72 have long been used by paper conservators to protect water-sensitive media during aqueous treatments. Each of these materials has its pros and cons. As mentioned above, two important considerations in choosing a temporary fixative are the application and removability of the fixative. While B-72 has been known to require toxic solvents in both its application and removal, cyclododecane has the added advantages of solvent-free application when used in the molten state, and effortless removal from the surface of the paper by gradual sublimation. Effectiveness of the cyclododecane film during aqueous treatment can, however, be variable. Due to the dimensional change differential between the film and the swelling paper fibers experienced during washing, very small cracks may result which can allow water to creep into the protected paper and cause bleeding of the media. Though suggestions have been made regarding a double application of cyclododecane on front and reverse using both pressure and heat (Brückle et al. 1999) and even an ingenious dual-layer technique using both cyclododecane and the more flexible B-72 (Muñoz-Viñas 2007), the problem with film-forming fixatives is that the fixed area remains inaccessible to water and thus does not receive the benefits of treatment. The use of butyl or propyl alcohol as a temporary water resist has also been suggested (Dwan 1998), and while this system, like cyclododecane, is also easily reversible upon evaporation, it requires extreme vigilance during treatment. The problems associated with any localized treatment also apply to the use of these temporary masks, and include possible formation of tidelines, and a difference in aging properties of the treated and untreated areas (Keynan and Eyb-Green 2000).

An alternative to film-forming fixatives like cyclododecane and B-72 is a chemical fixative that interacts with the ink on a molecular level and changes its chemical structure, rendering it insoluble in water. This type of fixative is most appropriately used with inks containing dyes of an ionic nature. If an oppositely charged ionic substance is added to the dye, the dye can be precipitated in the form of an insoluble complex. Thus, cationic fixatives will precipitate anionic dyes and anionic fixatives will precipitate cationic dyes.

CHOICE OF INK AND FIXATIVES

Past research has focused on the application of ionic fixatives used in the textile industry to preserve modern synthetic dye-based inks on paper archives during aqueous

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deacidification (Bredereck and Siller-Grabenstein 1988; Leroy and Flieder 1993; Blüher et al. 1999; Hanus et al. 2004). Bredereck and Siller-Grabenstein (1988) report that most dyes used in modern inks are anionic in character. Inks which contain anionic dyes include ball point pen ink, some fountain pen inks, some stamp inks, and inkjet ink. Inkjet ink is commonly used in printing documents and photographs in the office or home and was chosen as the media to be fixed in this study. Its range of colors allows the examination of different inks containing various dyes. In addition, its ability to be applied to a paper substrate in a consistent manner by a printer made it a good choice for producing standardized samples used for testing. Since cationic fixatives are required to fix anionic dyes, cationic fixatives were chosen as the focus of this research. In past studies, cationic fixatives which showed favorable results with a variety of anionic dyes on paper included Sandofix WE, and Rewin EL (Leroy and Fleider 1993; Blüher et al. 1999). Sandofix WE, a polymer of dicyandiamide, formaldehyde and ammonium chloride, was especially successful in fixing red, blue, green and black dyes.

Due to a restructuring of the manufacturing company and changes in product line, suppliers of the above-mentioned cationic fixatives were difficult to locate. In their stead, similar fixatives currently used in the paper and pulp industry were procured. This study examines the effectiveness of two commercial cationic fixatives, Cartafix GS and Cartafix NTC liquid fixatives (available from Clariant Corporation), in improving the wet-fastness of inkjet ink on common office paper during immersion in a water bath. These products are used in the pulping process to fix dyes added to pulp in order to make colored papers. The fact that these fixatives are already used with cellulosic material such as wood pulp made them a logical choice for fixing dye-based inks on common office paper which is primarily made of wood pulp.

It should be mentioned here that a third fixative was considered for testing, Cartafix SWE, but after poor performance in initial mock-up experiments it was discarded as a possible fixative for use in conservation. These preliminary results were surprising, as this particular fixative is advertised as a polymer of dicyandiamide and was expected to produce similar results to those achieved with Sandofix WE based on its similar chemical structure. It may be that proprietary formulas are actually very different even when the listed active ingredient is the same. Also, it is possible that the textile fixatives differ in strength or action from the paper pulp fixatives.

METHODS

Preparation of Samples

Cyan, magenta, yellow, and black color swatches were printed on Boise X-9™ copy/multi-purpose paper using an HP Deskjet 6122 printer with HP Inkjet print cartridges #78 (tri-color cartridge) and #45 (black cartridge). A set of closely spaced lines printed in each color was also included with the color swatches on the samples. Printed samples were then pre-aged in a Blue M aging chamber operated at 50°C and 70% RH for approximately 20 hours. The temperature and relative humidity were chosen as a standard aging setting for multiple users. This step was taken to allow the newly printed media to bond well with the paper substrate.

At the suggestion of the product manager of the Paper Division of Clariant Corporation, a 5% aqueous solution was prepared from the concentrated Cartafix NTC and GS liquid fixatives with deionized water. Bredereck and Siller-Grabenstein (1988) mention the necessity of having a stoichiometric proportion of ions in the dye and in the fixative in order to achieve successful precipitation of the dye. However, this seemed nearly impossible to accomplish using the unknown starting concentrations of the proprietary fixatives. In their testing, Leroy and Fleider (1993) used a 10% Sandofix solution and Blüher et al. (1999) used 3–3.5% solutions, therefore a 5% concentration seemed appropriate and in keeping with previous testing of similar materials.

Fixatives were applied overall with an airbrush on a suction table to both the reverse and the front of the printed samples as Blüher et al. (1999) describe. A spray application on a suction table (as opposed to application by immersion) offers the advantage of being able to monitor any migration of the inks during the application process by inspection of the blotter beneath. The reverse was coated first so that any mobile ink would be drawn out through the front of the paper and into the underlying blotter. After allowing the applied fixative to dry under suction, the front was also sprayed and allowed to dry under suction. The fixed samples were allowed to rest in an environment of around 20°C and 50% RH for 3 days before immersion washing was undertaken.

Washing of the samples was done in separate baths of 20°C deionized water adjusted to pH 7 with calcium hydroxide. Samples were first humidified by misting with water in order to allow even wetting during washing. The samples were then immersed for 25 minutes, then removed from the bath and placed on blotters, and finally transferred to screens to be air dried.

The following samples were prepared: a control sample (C) which was not treated beyond initial pre-aging, one that was fixed with Cartafix GS and not washed (GS), one that was fixed with Cartafix NTC and not washed (NTC), one that was fixed with Cartafix GS and washed (GS-W) one that was fixed with Cartafix NTC and washed (NTC-W) and a sample that was washed without being fixed (W). Another set of samples was prepared in the same way and reserved for future accelerated aging.

Monitoring Color Change and Ink Migration

A GretagMacbeth Color-Eye spectrophotometer was used to make color measurements of each color swatch (cyan,

	GS	GS-W	NTC	NTC-W
Paper	**2.58**	**2.89**	0.60	0.67
Cyan	**2.50**	**2.14**	**3.55†**	**3.72†**
Magenta	**1.75**	**1.77**	**14.18†**	**12.60†**
Yellow	0.83	0.80	**19.16†**	**18.76†**
Black	1.05	1.00	**3.99†**	**2.90**

	GS-W	NTC-W
Paper	**4.37†**	**3.63†**
Cyan	**4.22†**	**7.63†**
Magenta	**2.87**	**20.61†**
Yellow	**2.95**	**25.21†**
Black	**1.93**	**4.87†**

Figs. 1–2. Total color difference (ΔE*) observed after fixing (left). Total color difference (ΔE*) observed after washing (right)

Numbers in bold indicate "noticeable" color difference, which is defined as ΔE*>1.6. A dagger (†) indicates "unacceptable" color difference, which is defined as ΔE*>3.2 (Michalski and Dignard 1997)

magenta, yellow and black) as well as of the paper substrate on prepared samples before and after fixing and after washing. A 2mm area was measured at a 10° observer angle, using the D65 illuminant and the CIELAB color space.

A Zeiss Axio Imager reflected light microscope was used to monitor lateral bleeding of the inkjet inks in the printed black lines included on the samples. Because the black lines are actually a mixture of cyan, magenta, yellow, and black inks, changes in all four inks could be observed at once. Photomicrographs were taken of the same pair of lines on representative samples at 50X magnification before and after fixing and after washing.

Cross sections of the black swatches on representative samples were also prepared in order to compare the depth of ink penetration into the paper substrate. Cross sections were cut with a sharp razor blade and soft-mounted into metal clips for viewing on the microscope. Traditional mounting in epoxy resin was avoided as solubility of the inkjet inks in the resin could present problems. Photomicrographs were taken of the cross sections at 200X magnification.

FTIR Analysis of Ink and Fixatives

The infrared spectra of the fixatives and the cyan, magenta, yellow and black inkjet inks were collected using a Continuum microscope (Thermo Spectra Tech) coupled to a Magna 560 FTIR spectrometer (Nicolet). Samples were applied to MirrIR glass slides and placed in a desiccator for two weeks to remove any water content. Spectra were collected by transflection and were compared to a reference library of spectra in order to determine the chemical makeup of the fixatives and the inks.

RESULTS

Colorimetric Analysis

L*a*b* values of the color swatches and the paper substrate were recorded before and after fixing of the samples, and after washing. The total change in color (ΔE*) of the swatches was calculated by the spectrophotometer software. This data is presented in figures 1 and 2. While a conservation treatment would never consist of fixing without washing, color measurements were taken after fixing in order to quantify the amount of ink migration which may have occurred during application of the fixative.

Optical Microscopy

After the application of Cartafix GS, it was noted that the colored inks lost some of their saturation and bled somewhat. After washing, the colors appeared more neutral and faded. The black ink, however, remained intact. A comparison of photomicrographs taken before and after fixing with Cartafix GS and after washing offers a sense of the amount of bleeding/fading that occurred in the ink (fig. 3). After fixing with Cartafix NTC, it was found that the magenta ink clearly bled and faded, while the yellow ink all but disappeared. The remaining cyan ink also showed evidence of bleeding. The dark black ink dots, however, retained their original appearance. After washing, there was almost no magenta left on the sample, and the cyan ink was a mere shadow of its former self (fig. 4). After washing, an unfixed sample appeared completely devoid of magenta, cyan and yellow. Again the black ink remained in place on the paper substrate, without any noticeable color change (fig. 5).

Photomicrographs of cross sections taken from the black color swatch on representative samples were used to examine the penetration of the inkjet ink into the paper substrate before and after fixing and after washing. Four to five measurements on each cross section were averaged to find the mean ink depth. These values are listed in figure 6. While the control sample showed a distinct layer of ink about 23 microns deep, the sample fixed with Cartafix GS demonstrated that the inks had been pulled further into the paper substrate, with the magenta ink staining the paper fibers. The cross section of the sample fixed with Cartafix NTC revealed

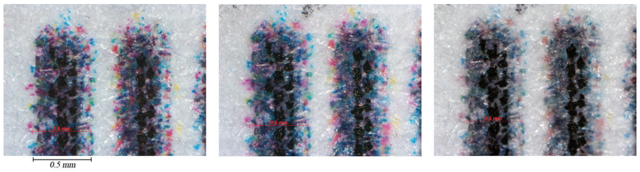

Fig. 3. Photomicrographs of printed black lines before (left) and after (center) fixing with Cartafix GS, and after immersion washing (right). Note the very slight bleeding of colored inks after fixing and slight fading after washing, while the black ink remained intact

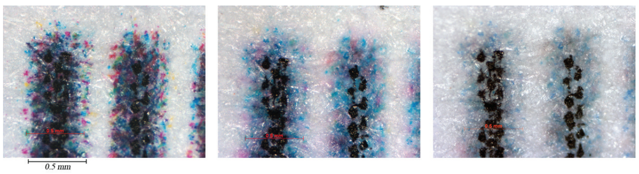

Fig. 4. Photomicrographs of printed black lines before (left) and after (center) fixing with Cartafix NTC, and after immersion washing (right). Note the marked bleeding and fading of colored inks after fixing and further fading after washing, while the black ink remained in place

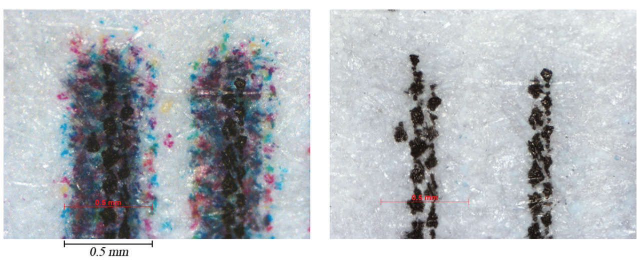

Fig. 5. Photomicrographs of unfixed printed black lines before (left) and after (right) immersion washing. Note the complete disappearance of colored inks and the stability of the black ink

Sample	Mean Ink Depth (µm)
C	23.40
GS	31.64
GS-W	45.28
NTC	22.47
NTC-W	24.25
W	32.32

Fig. 6. Mean ink depth on representative samples, in microns

how the inks had bled such that discrete ink spots were no longer very apparent. Migration of the magenta ink further into the paper substrate had also occurred, leaving the cyan ink as the dominant color at the surface of the paper. The cross section of the washed sample illustrated the stability of the black ink, as it was still visible on the surface of the paper as distinct dark spots. Remnants of colored inks, however, were difficult to find. Interestingly, the paper substrate of the unfixed washed sample had a slightly dull or grayed appearance, most likely caused by staining of the fibers with a mixture of the soluble colored inks. UV fluorescence microscopy was attempted, but no fluorescence of the inks was noted.

FTIR Analysis

Spectra of the inks collected by FTIR (fig. 7) were complex and impossible to identify by comparison to a reference library. The spectra were all consistent, however, with a material that most likely contains a number of components including a binder, a synthetic organic dye, a humectant, a surfactant, and a biocide.

Spectra of the fixatives (fig. 8) also failed to produce matches with known reference spectra available in the library. A few insights were gained, however, by examination of the spectra. The presence of a sharp peak at around 2200 cm^{-1} in the spectrum of Cartafix GS indicates the C≡N stretching of a cyano group, while characteristic peaks around 1630 cm^{-1} and 3200 cm^{-1} point to an amide group.

DISCUSSION

Before an interpretation of colorimetric data is presented, a few words should be said about the state of current color-measuring technology. Ongoing research continues in the search for better color difference equations which more accurately match human perception of color difference (Berns 2000). Some of these newer equations are being used in current research, however, a familiarity with the color equation based on the L*a*b* color space $[\Delta E^\star = \mathrm{I}\ (\Delta L^\star)^2 + (\Delta a^\star)^2 + (\Delta b^\star)^2\ \mathrm{I}^{1/2}]$ supports its continued use. Michalski and Dignard (1997) offer color quality standards based on $\Delta E^\star$ in their research on the appearance change of powdery paint after consolidation. They define “noticeable” color change as a total color change greater than 1.6, while a “just perceptible” color difference is reported between 0.25–0.5 $\Delta E^\star$ units. An “unacceptable” color difference is characterized by $\Delta E^\star$ greater than 3.2. These thresholds are adopted in this study in order to qualify the numerical color data produced by the spectrophotometer.

Colorimetric analysis of fixed samples shows that a noticeable color change resulted in almost all color swatches after application of both Cartafix GS and Cartafix NTC. Cartafix NTC generally effected much more drastic color changes than Cartafix GS, with unacceptable change in the magenta and yellow color swatches. The examination of cross sections taken from representative samples also revealed the migration of colored ink into the paper substrate during fixing, which was most likely the result of fixative application to the front of the samples while under suction. Photomicrographs of the

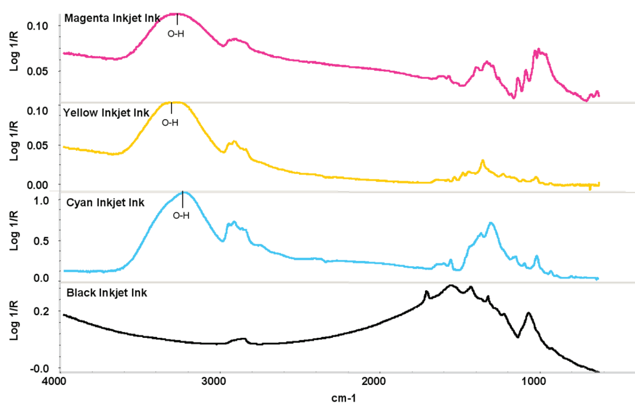

Fig. 7. FTIR spectra of HP inkjet inks. Note the absence of an O-H stretch in the spectrum of the black ink

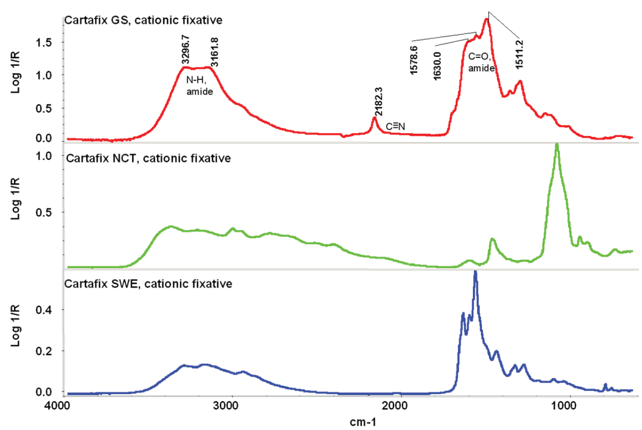

Fig. 8. FTIR spectra of Cartafix cationic fixatives. Note the characteristic peaks of amide and cyano groups in the spectrum of Cartafix GS

fixed samples (figs. 4–5) provide visual evidence to support the colorimetric data, while images of the unfixed sample before and after washing (fig. 5) illustrate exactly how water-soluble the colored inks are. The cyan, magenta and yellow inks appear to be totally fugitive, while the black ink appears quite stable. This suggests that the black ink may have a very different composition from the colored inks. It is quite possible that the black colorant is a pigment rather than dye, or that a water-insoluble binder such as wax or resin is used.

FTIR analysis of the inks supports the observation that the colored inks are fundamentally different in composition from the black ink. The absence of the large O-H stretch in the FTIR spectrum of the black ink could be evidence that its binder lacks the hydrogen-bonding functional groups which make the other colored inks so water-soluble (fig. 7). FTIR analysis may also provide some explanation for the more successful fixing characteristics of Cartafix GS. Evidence of cyano and amide functional groups in the FTIR spectrum for Cartafix GS suggests that this fixative, like Sandofix WE, may be a derivative of dicyandiamide (fig. 8). This could account for its generally better performance as a fixative for the inkjet inks. Interestingly, the lack of a cyano group in the spectrum for Cartafix SWE brings into question Clariant Corporation's description of this particular fixative as a dicyandiamide. This misrepresentation could explain why Cartafix SWE did not perform on par with Sandofix WE, as was expected, whereas Cartafix GS demonstrated the best fixing results.

In the bigger picture, results show that the inkjet inks were not entirely fixed by the application of Cartafix GS and Cartafix NTC. The question remains, however, whether the inks are partially soluble after fixing because of other water-soluble components of the ink, such as a possible gum binder, or because of a failure of the dye-fixative complex. It was hoped that FTIR spectra of the inks would shed some light on their composition, including the type of dye and possible binder; however, reference spectra did not provide conclusive matches. In order to choose an appropriate fixative for a modern ink, it is imperative to know the exact composition of the ink. Research by Goode et al. (2007) into the chemistry of ballpoint pen ink is a step in the right direction.

FUTURE WORK

As previously mentioned, a second set of samples was prepared and reserved for eventual accelerated aging. Future work will include tracking color changes induced during an appropriate regimen of accelerated aging. Tensile testing of treated and untreated aged samples would also shed some light on the fixative's long term effect on the strength of the paper substrate.

Further research using samples printed on a variety of papers would be helpful since inkjet inks adhere differently to different papers. As McCormick-Goodhart and Wilhelm (2000) note, the stability of inkjet prints depends on both components of the printing system: the type of ink and the type of paper.

Also, an in-depth exploration of the effect of fixative concentration on successful fixation of dye-based inks is necessary, as the experimental concentration chosen for this study was based on concentrations used with other proprietary products mentioned in the literature and not on actual testing of the materials used in the study. In addition, characterization of the inkjet inks using a combination of microchemical tests and chromatographic techniques would aid in understanding their composition. Isolation of the dye colorant from the other components in the ink may allow better examination of the extent to which the fixative complexes with the dye. Experiments using the fixatives in conjunction with one another may also prove useful, as various dye molecules present in the inks will react differently with the various cations in the fixatives. For example, if one fixative is particularly successful in fixing the cyan colorant and another in

fixing magenta, then a mixture of the two fixatives may offer more complete fixation of multi-colored inks.

CONCLUSION

Based on this study, cationic fixatives used in the paper and pulp industry do not appear to be as effective in protecting inkjet inks on paper during aqueous treatments as was originally hoped. While both Cartafix GS and Cartafix NTC did improve the wet-fastness of the ink when compared with the unfixed sample, the amount of bleeding and fading which resulted after washing would be considered objectionable when performing an actual conservation treatment. In the case of Cartafix NTC, application of the fixative alone was enough to cause substantial migration of the ink resulting in unacceptable color change. Better fixation of the media may be achieved if more is known about the exact composition of the fixatives and the dye-based inkjet inks, including the chemical structures of the active cation in the fixative and the anionic dye molecules in the ink.

In conclusion, even if further research of commercially available ionic fixatives finds products that will successfully stabilize certain dye-based inks on paper, the use of ionic fixatives in conservation will be a matter of personal judgment. Since the inks are permanently changed by interaction with the ionic fixative, their use goes against the notion of reversibility, which is often a key factor when considering conservation treatment. While a suitable ionic fixative should not change the appearance of the ink, it does change its chemical structure. This brings up questions regarding the preservation of art historical information present in an artist's materials. If an artist used inks with certain known characteristics, including solubility in water, is it ethical to change those characteristics? Understandably, treatments which preserve the appearance of a material but change its chemical composition are met with skepticism by some conservators. While such treatments may be practically applicable, they may not be considered ethically acceptable.

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SOURCE OF MATERIALS

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Larger Than Life: Discovery and Restoration of an 1878 "Buffalo Bill" Billboard

ABSTRACT

In spring 2002, a construction crew discovered a tattered 26' x 10' paper billboard beneath a crumbling brick wall in Jamestown, NY. The billboard proved to be a rare artifact advertising an 1878 show by William Cody and his theatrical troupe, the "Buffalo Bill Combination, at the historic Allen Opera House. Following an award in October 2004 to the Reg Lenna Civic Center (billboard owners) of a federal "Save America's Treasures" grant from the National Endowment of the Arts, Laura Schell, a paper conservator in private practice, conserved the entire billboard.

The extremely degraded, ephemeral, paper billboard consisted of multiple oversized text sections and illustration panels; its conservation was a complex, four-year project. Several, specific challenges emerged as the project proceeded, including overall fragmentation and significant losses within the text sections. Ultimately, an unusual collaboration between paper conservator and graphic artist was required to reconstruct the missing text.

Dating from early in Cody's theatrical career, the billboard is one of the earliest, most rare, and largest Buffalo Bill items known. Research indicates that it may be the oldest existing twenty-four-sheet billboard in the country.

BACKGROUND

In spring 2002, the Reg Lenna Civic Center, a non-profit arts organization located in Jamestown, in western New York State, dismantled a crumbling brick façade from one of its buildings. The bricks were collapsing outward, and needed to be taken down in a controlled manner. Because the multi-story building was located in an area with high tourist traffic, the dismantling procedure was scheduled at night. Despite low light levels, one of the crew members discovered tattered paper remnants of faces and text attached to the wooden wall underlying the bricks. Portions of the text were intact enough to decipher the words "Buffalo Bill".

An entire 10' x 26' ephemera advertisement for a very early Buffalo Bill, aka. William Cody, theatrical touring show from 1878 was attached to the wooden wall. Cody and his theatrical troupe (the "Buffalo Bill Combination") had performed a melodrama in Jamestown's historic Allen Opera House soon after the billboard was posted. The enormous advertisement had been pasted up on a building that was then undergoing construction, subsequently bricked over, and eventually forgotten.

Concealment from the elements enabled the ephemera object to survive over a century, although it sustained many damages. Through the years, the billboard's wood pulp-based paper substrate had taken on the acidity, color, and even discernible grain pattern of the wooden boards it was pasted to. The billboard had torn into hundreds of fragments in conjunction with movement of the underlying boards in response to climactic changes. The edges of adjacent fragments were often very rough, without obvious joins. The surface was covered with dirt, mortar grit, and soot from a previous fire in close proximity.

After the brick façade was taken down, the majority of the billboard simply fell off the wall in many pieces. The fragments varied in dimension from large sections approximately 48" high to scraps the size of a thumbnail. All fragments were extremely degraded by age and brittle to the point that even the most careful handling could cause breakage and/or shattering. A quickly organized corps of volunteers from the Jamestown community gathered every fragment possible before they scattered to the winds. The hundreds of salvaged fragments were sorted by color, gathered into seventeen large, shallow boxes, and stored for safekeeping in the vaults of the nearby Roger Tory Peterson Institute (RTPI). The billboard fragments remaining on the wall were temporarily protected from the elements with tarps until they could be faced with Japanese tissue/methylcellulose for support and steamed off (fig. 1). The faced fragments were numbered, boxed, and stored with the rest of the billboard at RTPI.

Presented at the Book and Paper Group session, AIC 36th Annual Meeting, April 21–24, 2008, Denver, Colorado.

Fig. 1.

Extensive research proved Jamestown's 1878 Buffalo Bill billboard to be the oldest twenty-four-sheet paper billboard of this size actually used for advertising still existing in the United States. According to Juti Winchester, curator of the Buffalo Bill Historical Center, the Jamestown billboard is historically important for several reasons:

- It is one of the earliest, most rare, and largest Buffalo Bill items known. The ten years Cody spent with the Buffalo Bill Combination were prior to his spectacular Wild West period, for which he is most famous. Cody's Combination years are largely under documented. This billboard helps to fill a gap concerning the nature of Cody's theatrical enterprises in the late 1870s.
- The object is genuine ephemera. It was actually used—not bought by collectors and immediately put into storage.
- The object is currently displayed at the site where Cody performed in 1878, and retains a high level of historic integrity. The program the billboard was printed for, and period when the billboard was posted, are documented facts.
- To date, a billboard matching this size, scope and age has not been found to exist anywhere else in the world. (Winchester 2007)

HISTORY OF BUFFALO BILL

William Frederick Cody, aka. Buffalo Bill, was a true larger-than-life celebrity of the nineteenth century (fig. 2). At the height of his career as an entertainer, Cody was lionized both in the United States and Europe. Born in 1846, Cody worked at a variety of dangerous jobs from a young age, including Pony Express rider, stagecoach driver, civilian and military scout, and dispatch bearer through hostile Indian territories. Cody soon acquired a reputation for being brave, dependable, and an exceptionally skilled marksman and horseman. Cody acquired the public name of Buffalo Bill after his prowess at killing buffaloes that were used to feed the tracklayers of the Kansas Pacific Railroad in 1867–68 (Carter 2005).

In the early 1870s, Cody occasionally guided visiting high-ranking officials, and even royalty, on western big-game hunting expeditions (Carter 2005). Journalists from one of these outings invited him to circulate in high society in New York City, where the eastern population was curious about the untamed, still-wild West. The charismatic Cody in his buckskin garb was well received by New York society. Ned Buntline, the famous dime novelist and playwright with whom Cody had previously been acquainted, persuaded him to leave the west and perform on stage (as himself) (Russell 1973). After a year on the stage with Ned, Cody struck out on his own and starred in his own theatrical troupe simply titled the "Buffalo Bill Combination".

The Buffalo Bill Combination performed western melodramas from 1872–1882, and initiated Cody's long and illustrious career as a showman. Cody and his entourage of authentic western characters (the likes of "Texas Jack" Omohundro, Wild Bill Hickock, and John Nelson) played

Fig. 2.

themselves on stage and drew heavily from their own adventures. The Combination presented a realistic, occasionally fictitious, highly entertaining account of the true west that was currently in the process of disappearing through the spread of white civilization. Performances provided genuine action and adventure featuring throwing knives, shooting guns, live animals, and war dances to a receptive public. Cody used the Combination's success as a springboard, and went on to produce and star in his Wild West shows for the next thirty years.

METHOD OF EXECUTION

The billboard was executed in multiple colors via a block printing process from many separate blocks. It was printed with oil-based printing inks on separate sheets of relatively poor-quality, wood pulp-based paper that was not intended to last beyond the event it was advertising (i.e., ephemera). The Jamestown billboard was 10' x 26' in dimension, or what would be classified as a twenty-four-sheet billboard. Printing, distribution, and installation of advertising posters was formulaic:

> …For the most part a one-sheet poster was of a size 28 x 42 inches…with this as the basic unit, there were half sheets, one-sheets, 2, 3, 6, 9, 12, 16, 20, 24, 28, and 32 sheets…[posters] would usually be sent to the show's management with four-sheet sections already pasted together on the shingle plan, that is the upper sheet overlapping the under sheet and thus shedding much rain after the manner of a shingled roof…it took one man about 20 to 30 minutes to unfold, paste-up, and post such a billboard. (Rennert 1976, 5)

ARRANGEMENT/COMPOSITION

The Jamestown billboard included: six oversized illustration panels, each measuring approximately 90" x 48"; opening and signature text panels of comparable size; and a large section of text over the whole (called the text streamer), measuring approximately 28" x 230". The unknown artisan(s) executed the printed advertisement in multiple colors with a high level of craftsmanship and creativity.

Central Double Panorama

The center of the billboard featured a red and black double title panorama (two adjacent, overlapping panels) prominently featuring Buffalo Bill waving a cowboy hat while on horseback (fig. 3). Large letters at the top and bottom of the panels read "May Cody, or Lost and Won". May Cody referred to Cody's sister, whose character often starred in Buffalo Bill dime novels; this particular melodrama involved the kidnap of May and her heroic rescue by Cody.

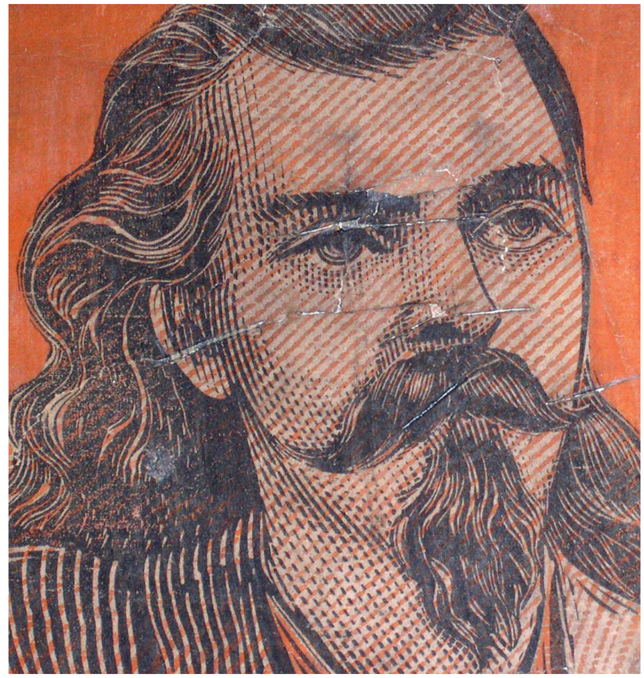

Fig. 3.

Massacre Panels

On each side of the central panorama were two red and black panels containing a total of four different scenes from the Mountain Meadows Massacre of 1857, with Cody prominently featured in the lower half of each panel. The Mountain Meadows Massacre was a bloody incident from the Mormons' early settlement in Utah, in which almost an entire wagon train of white emigrant settlers was killed, including 120 men, women and children; only seventeen children considered too young to tell the tale were spared. Several conflicting versions of the incident exist (in one version, extremist Mormons disguised as Indians killed the settlers; another version has Mormons and Indians working together to perform the slaughter). The incident was initially blamed on the Indians, but eventually John D. Lee, a Mormon elder, was convicted of complicity after a prolonged trial and executed by firing squad in 1877. Both Mormons and the Mountain Meadows Massacre were very much in the public eye in the late 1870s; Cody capitalized on this general interest by including his own version of events in a Buffalo Bill melodrama.

Portrait Panels

Flanking the Massacre panels were full-length portraits of Buffalo Bill (at left) and John Nelson (at right). Buffalo Bill is colorfully depicted as he performed, in buckskin garb, cowboy hat, and rifle.

John Nelson was a white man adopted by the Lakota tribe and given the name Cha-Sha-Sha-O-Pogeo (Red Willow

Holds the Pipe). Nelson started with the Combination as an interpreter for the Lakota Indians hired by Cody to perform onstage as Plains Indians (Russell 1973). However, Nelson soon became a Combination performer due to his excellent shooting skills and horsemanship.

Text Panels

Opening and signature panels—The opening text panel (extreme left side of the billboard) was deteriorated beyond recovery and was unable to be removed from the wall in Jamestown. The paper had completely disintegrated, and only a kind of "shadow" or staining on the wooden boards indicated presence of former text. The signature text panel (extreme right of the billboard) was deteriorated to the point that it was almost indecipherable. Its blue, partially water-soluble printing ink had run and faded over a paper substrate so degraded that it tended to powder when dry, and was prone to dissolving when wet. This panel provided information about the show and its participants. Digital manipulation of the signature panel text on a life-size facsimile will enable access to this information during exhibition.

Text streamer—The text streamer was a block print of large letters, probably printed from hand-cut paper stencils. The streamer spanned the top of the whole billboard, and originally read "BUFFALO BILL COMBINATION".

Bannerette—Also included with the text sections was a narrow strip approximately 7" high (bannerette) that spanned the entire billboard bearing the word sequence "Buffalo Bill Combination. / Allen Opera House!" This text was repeated in an unbroken line, located directly beneath the graphic and text panels.

Jack Kass

Two of the panels, including the right-hand central panorama, and the top half of one of the Massacre panels, prominently featured a small mule or donkey. Although the mule's rider has not been identified, research identified this little mule had the stage name Jack Kass. This particular animal (whose real name was Jerry) actually performed on stage with the rest of the actors (Sagala 2008). Jack Kass must have been important to the Buffalo Bill Combination, perhaps providing comic relief.

TREATMENT CHALLENGES

Conservation of the Jamestown billboard commenced in 2004, funded by a multi-year grant for conservation through National Endowment for the Art's "Save America's Treasures" program. The six illustration panels were completed between 2004 and 2007; the signature text panel, text streamer, and bannerette were completed from 2007 to 2008. Several, specific challenges emerged as the project proceeded.

Fig. 4.

Fragmentation

Initially, the billboard was fragmented to the point that its composition was almost a mystery. The many boxes of fragments contained a jumble of shattered imagery encompassing bits of faces, horses' legs, soldiers, and guns (fig. 4). No one living had seen the billboard in its entirety before treatment; nothing quite like it could be found despite extensive research. The billboard was a gigantic jigsaw puzzle without a box top, and without knowing how many pieces were missing. After reintegration of all fragments to their respective panels was accomplished, each panel was found to have extensive losses up to approximately 40%.

Red panels—Four of the illustration panels were primarily red with black, necessitating simultaneous reintegration of the oversized images from the boxes containing red fragments. These panels were slowly reconstructed from the ground up, with all red fragments eventually reintegrated with their proper panels. Only a small handful of red fragments (from the panels' backgrounds) was unable to be placed.

Buffalo Bill portrait—The Buffalo Bill portrait panel came down from the wall almost entirely in fragments. It wasn't clear this *was* actually a panel until fragments from one particular box were pieced together several years into the project. Upon this discovery, a video crew from Rochester, NY filmed the conservation process of Buffalo Bill's portrait panel from start to finish. This HD film footage is in the pipeline for a documentary to be released to PBS (Machi and Machi).

Fig. 5.

Fig. 6.

Text Sections

Although the billboard's main visual interest lay in the illustration panels, the accompanying text sections were an essential part of the whole. The streamer, which was a block print created from hand-cut stencils (probably cut from paper), presented many challenges. This section of the billboard was exceptionally damaged, with many oversized letters missing from the sequence "BUFFALO BILL COMBINATION". Most of the word COMBINATION was recovered from the wall; those letters that survived required partial reconstruction (fig. 5). However, nothing of the sequence "BUFFALO BILL" survived except small fragments of the last two Ls (fig. 6).

Small letters/fragments at the upper portion of the "COMBINATION" streamer existed (enough to extrapolate the words "OR OF THE"). There *must* have been corresponding small text at the top of the missing "BUFFALO BILL" streamer, but since so much was lost the answer may never be revealed.

The challenge of conserving the text streamer involved properly reconstructing the significant amount of missing text in keeping with the rest of the billboard. This task was made difficult from the many irregularities of the oversized letters. The text did *not* line up perfectly in many places. Several fragments were removed from the wall with the seam between adjoining pieces intact, and misaligned text (as it was pasted up in 1878). Letters were rendered slightly differently from one location to the next within the same line of text. These imperfections were retained as part of the billboard's history and character.

To recreate the missing text, the billboard's font had to be clearly identified, an appropriate reconstruction of the missing letters generated, and the proper placement of missing letters had to be determined in relation to existing font. The missing text spurred much ethical discussion with the project directors. Eventually, recreation was determined to be appropriate, provided the fabricated portion of the streamer was made as historically accurate as possible and clearly labeled as a reconstruction.

Reconstruction of the text streamer required collaboration with a specialist outside of the field of conservation. Toward this purpose, Nathan Arnone, a graphic artist and specialist in typefaces and antique fonts from Jamestown, NY, provided invaluable assistance in the billboard's restoration. After an exhaustive search through turn-of-the-century wood and metal type archives and printer's supply catalogs from this period, Arnone was able to identify the font of the billboard's streamer as a 'display type' in the class of slab serif fonts related to today's Egyptienne.

Contemporary digital versions of Egyptienne do not share exact proportions with the billboard. Specifically, the "slab" portions of the streamer's font are much larger than contemporary Egyptienne. The counters, or enclosed portions of letters like A, and O, are much shorter than compared with the contemporary version. The billboard's letters are also vertically lengthened. The font was probably condensed and stretched to fit the wall in Jamestown, and to impart maximum visual impact to the would-be audience.

CONSERVATION TREATMENT

The entire billboard commenced treatment as many separate fragments (both faced and unsupported), all of which required painstaking surface cleaning to reduce as possible the thick layer of mortar grit, soot, and dirt on front and reverse. Where applicable, the supportive Japanese tissue facing was moistened and carefully coaxed from the faced fragments with tweezers. Each fragment was washed on a suction table to deacidify the degraded paper structure and impart an alkaline reserve. Immediately after washing, the fragments were individually lined with lightweight Japanese paper using a 1:1 wheat starch paste and methyl cellulose mixture. Once the fragments were lined, they were still fragile but could be gently handled without further damage.

Individual panels were pieced together, though significant losses occurred in each. The reintegrated panels required much additional support due to their enormous size, fragile paper, and complicated joins. After inserting toned fills (Japanese paper toned with acrylic washes), the reintegrated fragments were given an overall lining for added strength of heavyweight Japanese paper and wheat starch paste. The panels were then mounted to ½" Tycore honeycomb panels with Lascaux 360 HV adhesive. The overall Japanese paper lining served as a barrier that prevented penetration of the Lascaux to the face side. As Lascaux 360 HV adhesive is reversible with

acetone, the text section may be separated from the Tycore in the future without reversing the water-soluble linings. This formulation of Lascaux is miscible with water in its liquid form, and was highly conducive toward getting the composites of pieced fragments completely flat again. To counteract dimensional warping from transferred water vapor, the panels were weighted with several changes of blotters for approximately forty-eight hours until the adhesive completely dried.

Conservation of Text Streamer (Combination Portion)

The word COMBINATION was reintegrated from its separate fragments, though most of the C and the last N were lost. Enough of the text still existed to reconstruct missing portions of letters after the fills were inserted. Watercolor pencil was used to recreate the letter outlines, and several layers of acrylic wash served to duplicate the streaky, weathered appearance of the text.

Collaborative Efforts

Once the COMBINATION streamer was completed, the accompanying, mostly missing BUFFALO BILL streamer was tackled as a collaborative effort between paper conservator and graphic artist. Arnone was given a full-size tracing of the COMBINATION streamer, and commenced his efforts at re-creating the billboard text based on Egyptienne bold font. Using some math and much artistry, he was able to proportionally manipulate the contemporary style of Egyptienne to the billboard's elongated, condensed version. Using the existing streamer text as a reference, the missing letters were recreated on frosted Mylar with technical pens. The Mylar letter templates were greatly relied on in the restoration process.

Reconstruction of the Buffalo Bill Streamer

Letters needed for the word BUFFALO BILL that existed in the COMBINATION streamer (such as the B, I, A, and O) were traced directly from the completed streamer. Exact copies of these letters were used in the reconstructed BUFFALO BILL streamer. A 28" x 115" section of Japanese paper (same dimension as the COMBINATION streamer) was toned with acrylic washes to duplicate the background color. Existing fragments of the two Ls that remained from the BUFFALO BILL sequence were inserted into the right end of the paper, providing a reference point from which to reconstruct the missing font. Arnone's transparent overlays were placed over the text fragments, and used to determine the lower edge of the entire line of font.

The spacing from the COMBINATION streamer was used to approximate the placement of font from the BUFFALO BILL streamer. After closely examining the existing text on the intact panel, spacing that was consistent could be calculated and applied.

CONCLUSION

The Jamestown billboard was created to attract the general public with its exciting, appealing images. It promised a thrilling stage performance from Buffalo Bill and his Combination. The miraculously discovered Jamestown billboard (and legions of other advertising billboards throughout Cody's career) "…played a major part in the shaping of our image, tradition, and romance of the American West" (Rennert 1976, 3).

The restored billboard has been installed at the scene of the original performance where Cody and his Combination performed in 1878 (fig. 7). Originally the Allen Opera House, the site has been renovated into an award-winning movie palace reminiscent of the 1920s. The billboard will remain in Jamestown on permanent exhibit.

Fig. 7.

ACKNOWLEDGMENTS

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Vortices and Reveries: An Innovative Treatment of Oversized Three-Dimensional Paper Objects

ABSTRACT

Vortices and Reveries, by Karen Stahlecker, is a mixed-media installation composed of nine black conical forms and nine white tree-like forms in the collection of the Smithsonian American Art Museum. Each piece measures nearly twelve feet in height and three feet in diameter. Each was made from handmade and dyed kozo paper, steel hoops, silver wire, wooden dowels, Velcro® and hot melt glue.

Unfortunate mishaps caused by the artist's choice of materials have resulted in damages to the delicate paper elements. Without conservation intervention, the rusted steel armatures, work-hardened silver wire, tenacious Velcro® and hot-melt glue would have undoubtedly contributed to future damages and deterioration of the objects.

The nine conical forms were treated in the Smithsonian's Lunder Conservation Center. Conversations with Stahlecker provided important details about her aesthetics, materials and processes. The damaged objects were thoroughly documented and mock-ups were used to test steps in the treatment proposals. A two step solvent-reactivated adhesive system was developed for reversible mending and the Velcro® used to secure the nine paper cones was replaced with a magnetic system. Due to concerns voiced by the artist, the steel hoops were cleaned and coated rather than being replaced with hoops made from a less corrosive material.

INTRODUCTION

Vortices and Reveries is a multimedia installation which originally consisted of handmade and dyed kozo paper and kozo fibers, steel, silver wire, wooden dowels, Velcro® and hot melt glue. Eighteen objects comprise the installation, each measuring nearly twelve feet in height. There are nine white tree-like forms and nine black conical forms. Each form was suspended from the ceiling with silver wire and supported

Figs. 1–2. Karen Stahlecker, *Vortices and Reveries*, 1993. Dyed paper, dyed kozo fibers, steel hoops, silver wire, wooden dowels, Velcro, hot melt glue. Each object measures 11'9" in height, 35" diameter, Smithsonian American Art Museum, Renwick Gallery (2006.39.1–18)

Presented at the Book and Paper Group session, AIC 36th Annual Meeting, April 21–24, 2008, Denver, Colorado.

from below by sized kozo stalks. The combination and complexity of the materials allowed for exploration and application of inventive techniques to paper conservation. This project also provided an opportunity to collaborate with paper and objects conservators, curators, registrars, exhibition specialists, collection managers, conservation scientists and the artist (figs. 1–2).

The focus of this treatment centered on the mending and stabilization of the nine black conical forms. The black cones had sustained more extensive and severe damages than the white tree forms. This can be attributed to two main reasons. Despite consistencies in raw material, preparation and technique, the white sheets were more robust than their diaphanous black counterparts. In addition, more Velcro® had been adhered to the black cones. As described below, the superfluous use of tenacious Velcro® resulted in damages to the forms during handling, installation and de-installation. Due to time constraints, prioritization had been given to the conservation treatment of the black conical forms, with the hope that the white tree forms will be revisited and considered for similar examination, documentation, treatment and storage.

THE CREATION OF *VORTICES AND REVERIES*: STAHLECKER'S MATERIALS AND TECHNIQUES

One of the most interesting and rewarding aspects to dealing with contemporary art is the communication with the artist. To better understand the materials and processes used to create *Vortices and Reveries*, and to ensure diligent conservation practice, the artist, Karen Stahlecker, was contacted. When asked, Stahlecker enthusiastically supplied the details concerning the manufacture of her forms.

She fabricated her paper sheets, structural ribs and stem-like bases from Thai kozo fibers. The kozo fibers were cooked in lye and hand beaten. To attain a deep, rich black, the black fibers were colored using a two-step process. First, a Procion dye was applied to the slurry. Afterwards additional black pigment was mixed in the vat with a cationic retention aid. Stahlecker used large Tyvek® sheets dammed with plastic as papermaker's moulds. The slurry was poured onto these Tyvek® moulds and then sprayed with a garden hose to produce a network of holes, creating a lace-like paper similar to Japanese amime papers (Stahlecker 2007) (fig. 3).

To retain rigidity, fibers used for structural elements, such as the red ribs and stems, were cooked and beaten to a lesser degree than those used for the diaphanous paper sheets. They were colored with cadmium pigments and sized with methyl cellulose. The red ribs were then arranged on the freshly formed black paper sheets and pressed into contact just before the paper was dried. Once the red ribs were adhered to the black paper sheet, they served as integrated structural supports which upheld the cone's form.

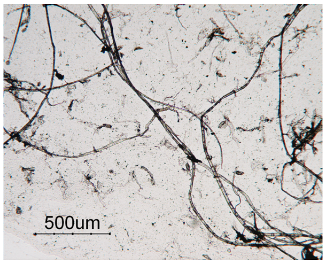
Fig. 3. One of Stahlecker's handmade paper panels from *Vortices and Reveries*. Smithsonian American Art Museum, Lunder Conservation Center

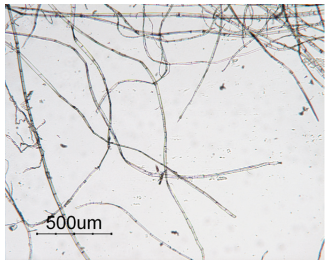
Fiber samples were taken from the black paper panels and the red ribs to confirm the artist's materials for purposes of documentation. Working under the supervision of the Smithsonian Museum Conservation Institute, images of the samples were captured through a polarizing light microscope and compared to known references. As seen in these photomicrographs, Stahlecker indeed used kozo fibers for her paper panels and structural ribs. Although both red and black fibers are from the same Thai kozo source, note the difference in size between the two. This is attributed to the differences in their preparation (figs. 4–7).

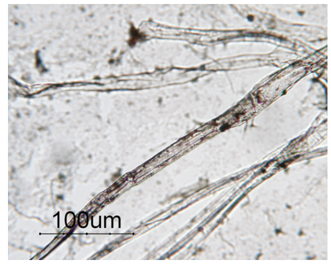
Stahlecker adhered Velcro® swatches along the edges of each panel with hot melt glue to hold the panels together as a cone. All of the Velcro® swatches were applied at irregular intervals, which mandated careful planning to ensure proper configuration of the paper cones. Once in cone formation, each paper form was aligned with the artist's registration marks and secured to its steel hoop with Velcro®. The artist's registration mark was located on along the top of panel A and carefully aligned with the mark painted on its respective steel hoop. Again, the Velcro® swatches were adhered erratically. Therefore coordination between handlers was crucial to ensure proper alignment and attachment of the cone to its hoop without damaging the six foot tall paper form.

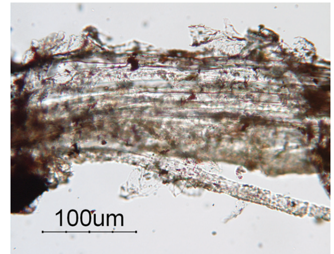
The steel hoops uphold the cone's form and accept the silver wire which suspends each cone from the ceiling. The steel hoop armatures were actively rusting. This rust would inevitably transfer to the paper elements and contribute to the discoloration and degradation of the paper supports over time (fig. 8).

The fine silver wire was selected by the artist because it was less visually distracting than a more substantial stainless









LEFT TO RIGHT

Fig. 4. Black fiber sample from *Vortices and Reveries* through polarizing light microscope, Museum Conservation Institute (2006.39.4)

Fig. 5. Kozo fiber reference sample through polarizing light microscope, Museum Conservation Institute

Fig. 6. Black fiber sample from *Vortices and Reveries* through polarizing light microscope, Museum Conservation Institute (2006.39.4)

Fig. 7. Red fiber sample from *Vortices and Reveries* through polarizing light microscope, Museum Conservation Institute (2006.39.4)

Fig. 8. Detail of paper panels fit around steel hoop while suspended from ceiling in Renwick Gallery, Smithsonian American Art Museum (2006.39.7–8)

steel wire. Unfortunately, the soft silver wire was work-hardened through manipulation during installation. The work-hardened wire failed during the exhibition, resulting in damages to the paper elements after two of the black cones fell. This unfortunate accident made conservation intervention a priority for *Vortices and Reveries.*

INSTALLATION

The piece had been installed at the Renwick Gallery by Renwick and American Art Museum staff with the assistance of the artist. Stahlecker had a system in which she utilized circular templates to mark the placement of each object within a desirable proximity to the others. She also devised and utilized a movable support beam for the assembly and installation of the black paper cones. A steel hoop was suspended from a hook on an overhead support beam so each paper cone could be secured to its hoop with Velcro®. Fortunately for Renwick and American Art staff, Stahlecker had supplied thorough written instructions for installation and de-installation of the objects. Furthermore, the installation at the Renwick was well documented with photographs and videos. Review of the artist's instructions, museum documentation and careful examination of the installed pieces was beneficial when faced with de-installation and disassembly of the forms without the artist's presence. Further insight was gained into the construction and connection mechanisms through the examination of a disassembled piece, which had fallen and was subsequently dismantled and stored in an office (fig. 9).

Despite the wealth of information provided by the various notes, photographs and videos, de-installation of the objects was convoluted. A team of five to seven people were required to safely and efficiently handle each of the components. The tight gallery space urged orchestration and organization throughout the task. As each of the eighteen objects was dismantled, the necessity for conservation intervention became apparent.

The delicacy of the objects was emphasized by the numerous tears and repair campaigns. The precariousness of the installation was illustrated by the failure of some of the artist's materials. The curator of the Renwick's collection clarified her treatment goals: stabilization was first and foremost. As the new custodian of *Vortices and Reveries*, she hoped that a simplified installation procedure would prevent new

damages during installations and exhibitions. The improved installation system could eliminate confusion caused by misinterpretation of complex instructions previously supplied by the artist. Such improvements would also permit the work to travel to other venues for exhibition.

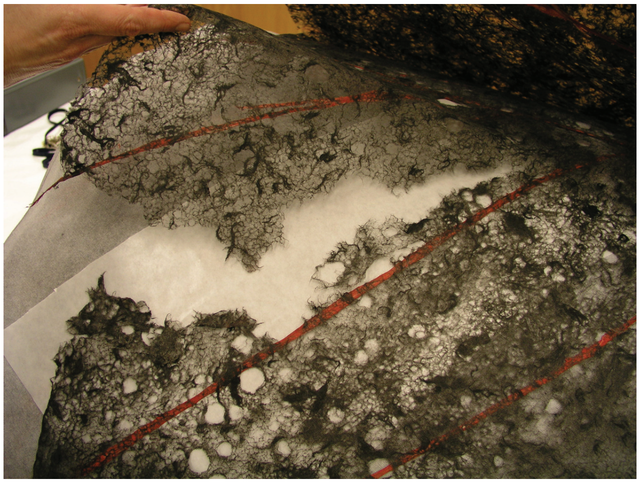


Fig. 9. Detail of damage to paper panel after deinstallation of *Vortices and Reveries* (2006.39.1)

Fig. 10. Detail of artist's label, Smithsonian American Art Museum (2006.39.5)

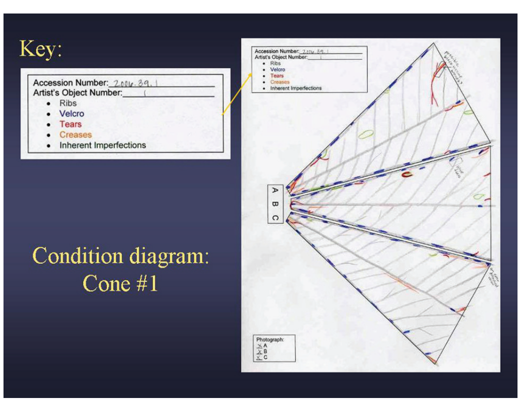
LABELING AND DOCUMENTATION

Each panel was labeled by the artist with an object number (1 through 9) and the panel letter (A, B, and C). Per the artist's instructions, the panels were placed on a contoured support in reverse order, laying piece C first, followed by B, and finally A. A temporary storage container was constructed around the supports for safe transport of the black paper panels to the conservation lab for examination and repair (fig. 10).

Documentation and organization was a challenging component to this project. There are nine black cones, each of which are made up of three paper panels, totaling twenty-seven paper pieces in need of examination, documentation and treatment. Each panel measures seventy-three inches in length, thirty-nine inches in width at the top edge, and two inches at the bottom. Each panel incurred multiple damages. Neither written nor photographic documentation alone could clearly convey the condition of these pieces.

Documentation began with the creation of templates for condition diagrams. Each page represents one full cone. There are 9 pages, illustrating three panels on each page. Each diagramed panel was labeled A, B and C, corresponding with the artist's labels. Each page provided space for the Smithsonian American Art Museum's accession number and the corresponding artist's label. A color-coded key differentiated structures and damages found within each diagramed panel. Grey lines represented the red structural ribs found in each panel, blue dashes identified Velcro® swatches, red marks indicated tears, orange illustrated creases and green represented inherent qualities which may be misinterpreted as damages (fig. 11).

It was important to locate and qualify damages and differentiate them from voids in the paper sheets which were inherent products of the artist's paper formation process. These diagrams clearly denoted the location and extent of damages. These visuals corroborated theories which correlated damages to the use of certain materials, such as Velcro®. Tears



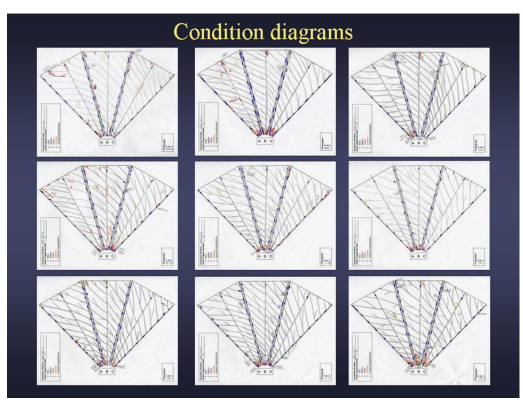


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Fig. 11. Diagram used for condition reports with color coded key

Fig. 12. Nine color coded diagrams used for condition reports of nine black paper cones

along the bottom edge of the paper panels related to where the paper attached to its respective Velcro®-lined dowel. Similar tears and creases were seen throughout all twenty-seven paper panels (fig. 12).

Unfortunately, the panels were not completely flat and when illuminated on a slantboard, gaps between the paper supports and the board created multiple shadows. The optical effects resulted in blurry images. Shadows were eliminated by photographing the panels on an arched support that was fabricated from acid-free corrugated blue boards. To maintain consistency in documentation, the photographs, like the diagram templates, were printed three-to-a-page, with each of the nine pages illustrating a single cone. To better identify damages and repairs, details were also photographed before and after treatment (figs. 13–14).

Fig. 13. Arched support used for photodocumentation of paper panels

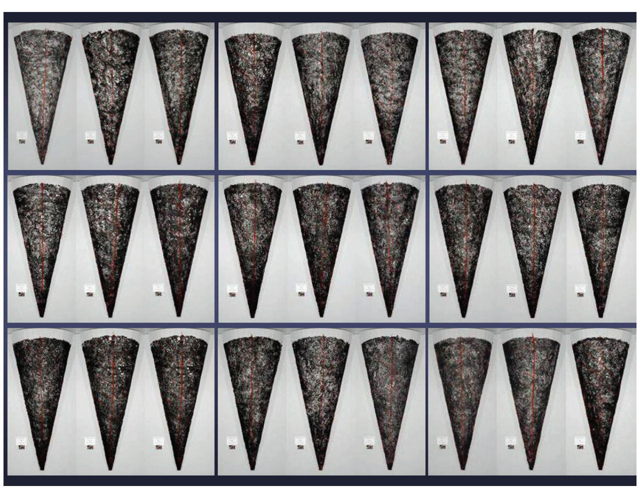


Fig. 14. Before treatment photographs of all 27 panels comprising the 9 black paper cones in *Vortices and Reveries*, Smithsonian American Art Museum, Lunder Conservation Center (2006.39.1–9)

MENDING *VORTICES AND REVERIES*

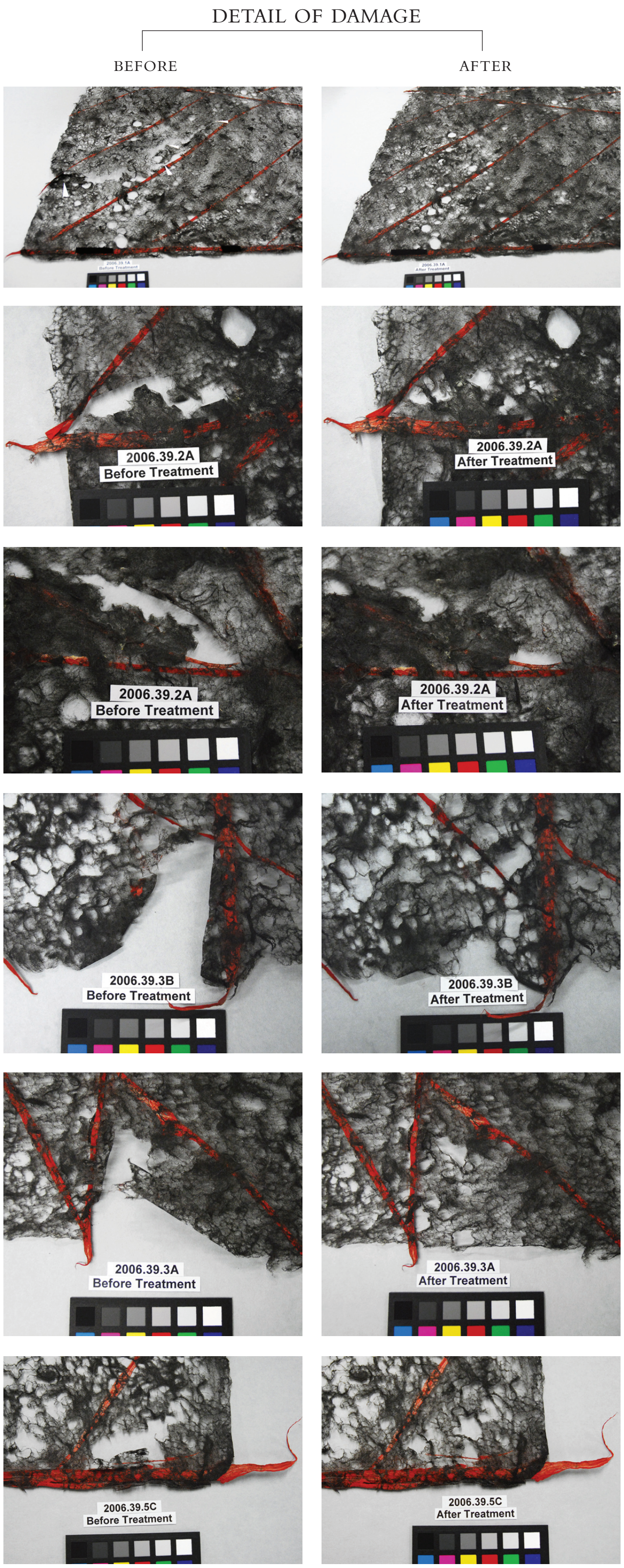
Fortunately Stahlecker is an artist who was selective of her materials and is concerned with the preservation of her work. When the installation was accessioned into the American Art Museum's collection, she was certain to include additional pieces of paper made from the same slurry in the same manner as that used to make *Vortices and Reveries*. These paper pieces proved invaluable during testing throughout the treatment. In preparation for mending, the solubility of the paper colorants was tested. They were sensitive to water but stable in ethanol. Therefore, a non-aqueous adhesive was sought for mending. Both Klucel G and Lascaux 498 HV have been employed by paper conservators, and have proven to be stable over time.

Klucel G can be mixed with a number of solvents including ethanol. It can also be reversed with Ethanol. Lascaux 498 HV is a dispersion which is soluble and reversible in a number of solvents including ethanol, and is also thermoplastic. Therefore, it can be set with heat and reactivated with either ethanol or heat.

The tears were face-mended with a 10% solution of Klucel G in ethanol and the repairs were reinforced with a solvent-reactivated mending tissue (Anderson and Puglia 2003). Lascaux 498 HV was selected as the re-activated adhesive. With this system, the reinforcing tissue could be removed with heat without disturbing the face mends. Conversely, if desired, both mending campaigns could be removed simultaneously with ethanol.

Due to the delicacy of the artist's paper, tengujo was selected to serve as the carrier for the reactivated mending tissue. It was toned with carbon black Golden® fluid acrylic paint. Lascaux 498 HV was brush-applied to the toned tengujo over silicon release Mylar. Once dry, a small section of the Lascaux-coated tissue was reactivated with drops of ethanol and adhesive-coated fibers were teased from the sheet with fine tweezers. The Lascaux-coated fibers reinforced the Klucel G face mends by bridging the broken support fibers.

This mending method was ethically favorable for its stability and reversibility while being practically favorable for its ease and speed. Because the mending materials appeared sympathetic to the original, the mends were also aesthetically favorable as they were visually unobtrusive. Detail photographs were taken to clearly document damages to the paper support before and after repair. With the aid of documentation and proper lighting, a trained eye will be able to identify the repairs so that future custodians will be able to differentiate the conservation treatment from the artist's work (figs. 15–20).



TOP TO BOTTOM IN SETS OF TWO

Figs. 15–20. Detail of damage. Smithsonian American Art Museum, Lunder Conservation Center

THE DECISION TO TREAT THE ORIGINAL STEEL HOOPS

Throughout any treatment, a balance must be maintained between the preservation of the physical object and the artist's intent. In this instance, materials purposefully selected by Stahlecker for their aesthetic qualities have resulted in damages to the art objects and would undoubtedly propagate new damages and deterioration. In order to preserve these objects and prevent damage during handling, installations, exhibitions and storage, it was proposed to clean and alter the steel hoops, and replace the silver wire and Velcro® in addition to mending the torn paper elements.

Replacement of the steel hoops with a less corrosive material could have prevented the transfer of rust to the paper elements. An improved design may have facilitated safer handling and fewer complications during installation. However, Stahlecker had reservations concerning the replacement of the hoops. Because the artist is guaranteed certain moral rights, her concerns cannot and should not be disregarded (Broderson and Goetzl 1991). She hoped to preserve the original steel hoops regardless of their corrosive nature. Despite reassurances that we could replicate the shape of the originals, she felt that the original hoops were integral to the aesthetic and conceptual integrity of the objects. According to Stahlecker, the production of *Vortices and Reveries* began with the fabrication of these steel hoops and the paper panels were successively made to fit these hoops. The artist feared that her engineering would be lost to replacements and that the fit could not be exacted. Therefore, cleaning and coating alternatives were researched.

Because powder coating is a more durable metal coating than conventional paint, it would effectively seal the steel hoops and prevent rust from transferring to the paper elements (Pennisi 2007). Preparation was required before the hoops could be sent for coating (AFI Powder Coating, Inc. 2007). The hoops would be placed in an oven reaching temperatures of 900ºF. All existing coatings, including rust, hot melt glue, Velcro®, silver wire and paint would be burned off in the cleaning process. This included all labels and registration marks applied by the artist. To maintain each hoop's identity and proper alignment with its respective paper panels, numerical steel punches were used. Each hoop is now impressed with its number and each impression was made at one of the artist's original registration marks.

REMOVING AND REPLACE THE VELCRO®

The excessive application and extreme tenacity of the Velcro® resulted in numerous tears to the paper supports. Since the bond between the paper fibers was weaker than that between the Velcro® pieces, the paper was frequently damaged during separation of the Velcro®. Stahlecker selected

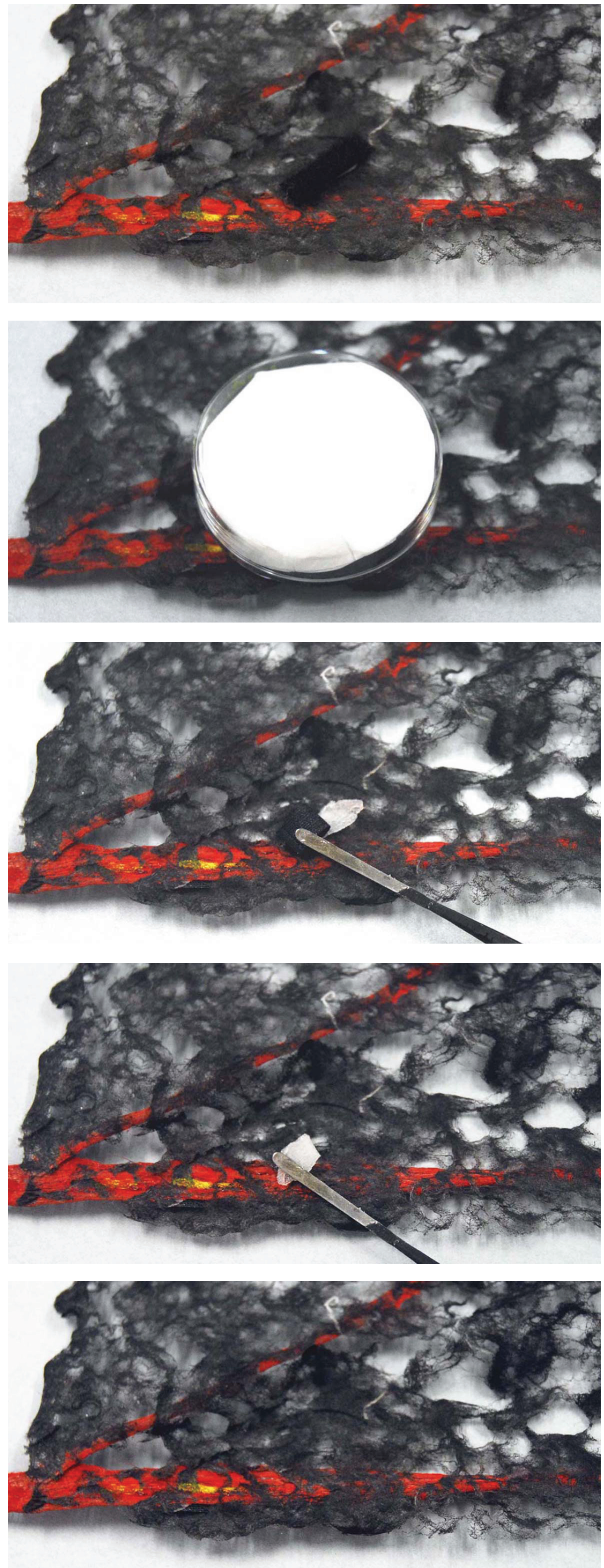
the Velcro® and hot melt glue as a practical attachment system. It was not intrinsically linked to the artist's aesthetic and therefore she had no reservations concerning its replacement. While some hot melt adhesives may be acceptable for storage enclosures, they should not be applied directly to an art object. Hot melt glues are generally inflexible, can yellow and become brittle over time.

The removal of hot melt glue and Velcro® from one of the wood dowels was tested. Several drops of toluene were applied along the Velcro®-dowel interface. The Velcro® was then separated from the hot melt glue surface with a microspatula. The glue did not dissolve but rather swelled and softened when saturated with toluene. A second application of toluene was applied to the glue and the spatula was used to separate the hot melt from the dowel.

Because the Velcro® and hot melt glue released from the dowel readily, a similar test was performed on a Velcro® swatch adhered to one of the red kozo ribs. Again the Velcro® released from the hot melt glue surface with the first application of toluene and the second solvent application reduced the hot melt glue with the aid of the spatula.

To ensure adequate softening of the hot melt glue on the delicate black paper fibers, a solvent chamber was used to increase the adhesive's exposure time to the toluene. After fifteen minutes, the Velcro® peeled away from the hot melt glue with ease, exposing the adhesive layer. With careful manipulation, the hot melt glue was rolled back at a low angle to the paper, and peeled away in a single piece leaving little residue and no damage to the paper fibers. Because the Velcro® and hot melt glue was successfully removed from the object's surface, the Velcro® could be replaced with a magnetic system (figs. 21a–e).

A product known as Magically Magnetic Paint (Magically Magnetic, Inc. 2007) was selected for the new attachment system. This concentrated powder additive contains microscopic metallic particles which are attractive to magnets. Any surface or material coated with paint containing this product then becomes attractive to magnets. Sekishu was selected and toned with carbon black Golden® fluid acrylic paint. The toned



PICTURED RIGHT, TOP TO BOTTOM

Fig. 21a. Detail of Velcro® adhered to paper support with hot melt glue (2006.39.9)

Fig. 21b. Detail of toluene solvent chamber used to soften hot melt adhesive (2006.39.9)

Fig. 21c. Separation of Velcro® from hot melt adhesive with micro spatula (2006.39.9)

Fig. 21d. Separation of hot melt adhesive from paper support with microspatula (2006.39.9)

Fig. 21e. Detail of paper support after removal Velcro® and hot melt adhesive (2006.39.9)

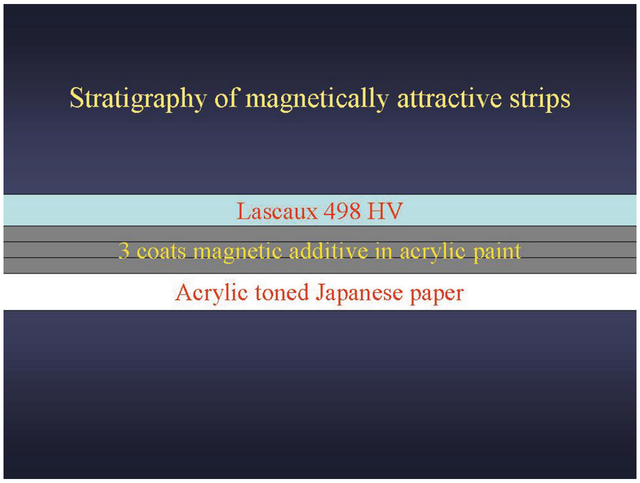


Fig. 22. Diagram of stratigraphy of magnetic coated paper strips

paper then received three coats of Magically Magnetic Paint additive mixed with carbon black Golden® fluid acrylic paint. Once dry, Lascaux 498 HV was applied over the metallic paint layer. The Lascaux worked as a reversible thermoplastic adhesive while serving as an isolating layer between the Magically Magnetic strips and the surface of the artwork (fig. 22).

Twelve small Magically Magnetic strips, each measuring ¼" x ¾", were attached at regular intervals along each edge of the black paper panels with a heated spatula. During an exhibition, one small neodymium rare earth magnet was inserted between two overlapping metallic strips on adjoining panels. These tiny magnets measure ¼" x ⅛" x 1/32" and were strong enough to hold the paper panels together in cone formation. Attraction and repulsion forces between magnets of overlaying panels were not an issue since the magnets were completely removed from the paper panels and housed separately for storage purposes.

A NEW ATTACHMENT SYSTEM

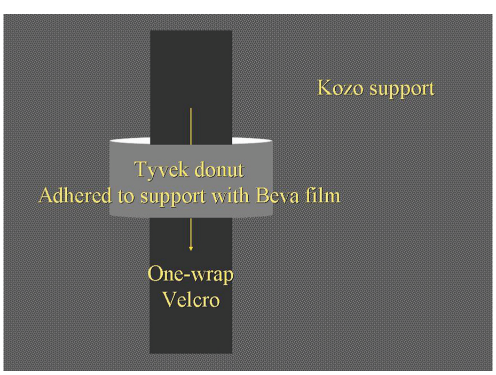
Because the hot melt glue and Velcro® had been removed from the paper panels and the steel hoops, a new attachment method was needed to secure the paper cones to their steel hoops. A more user-friendly system was desired, especially considering that the artist would not be present during future installations to interpret complicated diagrams and instructions.

Tyvek® donuts were made and toned with carbon black Golden® fluid acrylic paint. They were then adhered to the tops of the red ribs of each paper panel with Beva® film. During installation, One-Wrap® Velcro® was threaded through the Tyvek® donuts, wrapped around the powder-coated steel hoops and attached to itself. One-Wrap® Velcro® is commonly used to wrap electronic cables and has hooks on one side and loops on the other. Therefore, it requires no adhesive and attaches to itself. With this system, there are no static attachment points between the paper cones and the steel hoops. The paper panels can be shifted on the hoop if necessary. The arduous task of aligning the paper panels and hoops in accordance to obscure registration marks was diminished. Like the magnets, the Velcro® can be completely removed from the objects during storage (figs. 23a–b).

To prevent future damages arising from the failure of the silver wire, the original was replaced with a nylon-coated stainless steel wire. The steel provides the strength necessary to suspend the cone without fear of failure, while the nylon coating offers a soft buffer between the stainless steel wire and the newly powder coated hoops. The selection of a stainless steel wire similar in gauge to the original silver wire maintained Stahlecker's aesthetic.

TEST INSTALLATION AND LONG-TERM STORAGE

The material replacements and installation mechanisms were tested during a temporary installation in the Smithsonian American Art Museum's Lincoln Gallery. The magnets proved strong enough to hold the paper pieces in cone formation. The powder coated hoops appeared as the artist had originally made them. The nylon coated steel wire was no more distracting than the artist's silver wire. The simplified system relied on two to three handlers to install each form, as opposed to the previously required five.



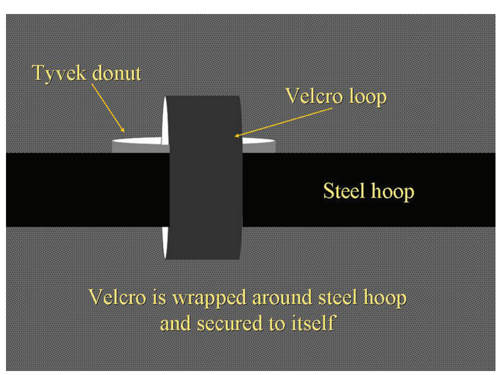


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Fig. 23a. Diagram of Tyvek® donut (adhered to paper support) and One-wrap Velcro®

Fig. 23b. Diagram of One-wrap Velcro® securing paper support to steel hoop

In addition to material tests, the temporary installation gave me an opportunity to participate in the Lunder Conservation Center's public outreach efforts by speaking about conservation and this particular project with museum visitors and staff. Although technical questions were asked and answered, the majority of the gallery talk focused on the ethical considerations given to multi-media, contemporary works of art. Artist intent and moral rights were addressed in addition to decisions regarding the replacement of certain components as opposed to their repair (fig. 24).

Once the object was de-installed from the gallery, the objects were prepared for storage. New enclosures were engineered for long-term storage. An arched support was fabricated from acid-free corrugated blue board to hold all twenty-seven black paper panels with glassine interleaves. Three separate containers were constructed from corrugated plastic sheets to hold each group of components: the supported paper panels, the powder coated hoops, and the kozo stalks. The corrugated plastic sheets will protect the objects from water, while minimizing the weight of the package. Diagrams, notes and material lists have been included in the Smithsonian American Art Museum's permanent file for future review. These designs can be modified to fit the white tree-like forms so as to properly house and preserve the other half of *Vortices and Reveries* (fig. 25).

CONCLUSION

Due to the comprehensive and complex nature of this installation and its treatment, collaboration among numerous departments and individuals in the Smithsonian American Art Museum and outside was essential to the success of this project. The damaged paper elements have been repaired and restored to their original appearance. The removal of tenacious Velcro® will prevent mechanical damages during future installations. The replacement of Velcro® with a magnetic attachment system proved strong enough to hold the paper pieces in cone formation. The simplified system required two to three handlers to install each form, as opposed to the previously required five. The powder coated hoops maintain the artist's original aesthetic, but will prevent the transfer of rust to the paper elements. The nylon coated steel wire was no more visually distracting than the artist's silver wire, and the increased strength will prevent future failure during exhibition. This multifaceted and innovative treatment would not have been possible without the enthusiasm, diligence, cooperation and support of the artist, Karen Stahlecker, the Renwick Gallery, the Smithsonian American Art Museum and the Lunder Conservation Center.

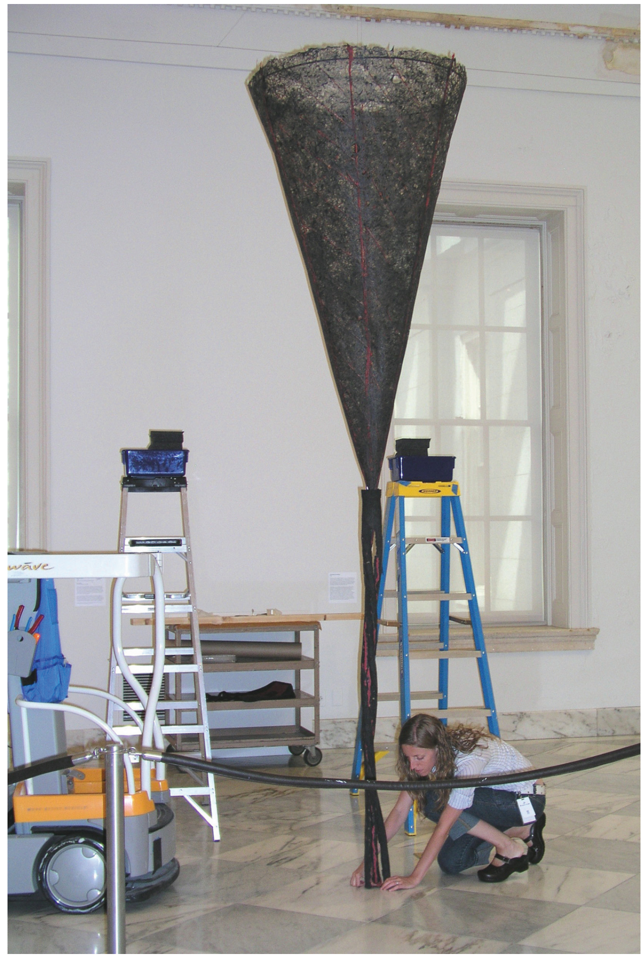

Fig. 24. Test installation in Smithsonian American Art Museum's Lincoln Gallery (2006.39.4)

Fig. 25. Archival support fabricated for long term storage of paper panels, Smithsonian American Art Museum, Lunder Conservation Center

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Historical Bleaching of Ingres Drawings at the Fogg Art Museum

ABSTRACT

The use of chlorine dioxide gas for bleaching artworks on paper was developed by chemist Rutherford John Gettens in the Department of Conservation and Technical Studies at the Fogg Art Museum in the 1950s. After extensive testing, several Ingres drawings in graphite and black chalk were bleached by this method. To determine the cause of their current darkened condition, the drawings were examined along with their original conservation condition and treatment reports, before and after treatment photography, and Gettens's bleaching notebook. Six drawings were analyzed for chlorine residues using scanning electron microscopy and x-ray fluorescence spectroscopy.

INTRODUCTION

The Fogg Art Museum at Harvard University has the largest collection of drawings by Jean-Auguste-Dominique Ingres (1780–1867) outside of France. The drawings were created between 1804 and 1865, years that witnessed a major transformation in papermaking. The gradual adoption of machines for papermaking, the use of lower quality fibers, and the introduction of acidic sizing caused a decrease in paper quality that is recorded in Ingres' drawing papers and may have contributed to their current darkened appearance. Damage from light, poor quality mounts, and foxing have compounded the problem. In the middle of the twentieth century conservators and scientists at the Fogg Art Museum employed several chemical-bleaching methods to reduce the staining in these drawings. This research focuses on the possible connection between the current darkened condition and previous conservation bleaching treatments, evaluating two methods for detecting bleaching residues in paper.

BRIEF HISTORY OF CONSERVATION AT THE FOGG ART MUSEUM

In 1927 the Fogg Art Museum opened a new building under the director, Edward Waldo Forbes, and his assistant, Paul J. Sachs. Forbes and Sachs were committed not only to collecting art, but to understanding the techniques and materials of paintings and artworks. To support research in this area, Forbes created the Department of Technical Studies in 1928 with two staff members: George Stout, an art historian and conservator, and Rutherford John Gettens, a chemist (fig. 1). In the early 1930s Minna Horwitz and Evelyn Ehrlich (fig. 2) began volunteering in the Department of Technical Studies, working on projects such as research into the moisture permeability of surface coatings, oxidation of cellulose by bleach, prevention of mold in adhesives, and the

LEFT TO RIGHT

Fig. 1. George Stout, Head of Conservation (1927–1947) (left), Dr. Rutherford John Gettens, Fogg Chemist (1928–1951) (right). Courtesy President and Fellows of Harvard College

Fig. 2. Evelyn Ehrlich, Conservator (1934–1948) (left), Minna Horwitz, Conservator (1931–1949) (right). Courtesy President and Fellows of Harvard College

Presented at the Book and Paper Group session, AIC 36th Annual Meeting, April 21–24, 2008, Denver, Colorado.

transfer of Asian wall paintings. Under the supervision of George Stout and John Gettens, Evelyn Ehrlich and Minna Horwitz were responsible for paper conservation at the Museum from 1934 to 1949, when Anne Clapp began as a trainee in the department.

HISTORICAL BLEACHING AT THE FOGG

Better known for his work on the corrosion of ancient Chinese bronzes, in 1950 Gettens began investigating the bleaching of artworks on paper. With characteristic thoroughness, his goal was "to establish comparative data on the effect of bleaching agents on the strength and permanence of paper" (Gettens [1950–1951]) by testing nine bleaches: sodium hypochlorite, chlorine dioxide gas, sodium chlorite, chlorine gas, chlorine dioxide in water, alcohol or organic solvent, chloramine-T, hydrogen peroxide, sodium peroxide, and ozone. He was particularly interested in exploring sodium chlorite bleaching because of paper industry claims that it was less damaging to cellulose than sodium hypochlorite, commonly known as Clorox bleach, which had been used at the Fogg Art Museum since 1937. The paper industry studied sodium chlorite for use during the bleaching of paper pulp, but unfortunately, there was no data on its effect on already formed sheets of paper.

Gettens contacted the Mathieson Chemical Corporation which donated sodium chlorite for his use, but did not have the facilities to perform the bleaching tests requested (Gettens 1951a). The chemists in Mathieson's Chlorite Division told him "no rinse or wash is actually needed. However reversion of color is apt to take place due to the oxidized end products still remaining in the paper which may necessitate later bleaching. Please understand this reversion might take quite a long time" (Birkett 1951).

Based on discussions with chemists at Mathieson and his own experiments, Gettens developed three methods of bleaching with chlorine dioxide gas using sodium chlorite. These bleaching methods were extensively tested on Whatman filter paper and blank ledger paper. Physical testing of the samples was carried out at the U.S. Testing Company and at the Mellon Institute of Industrial Research under Dr. Robert Feller (Gettens [1950–1951]; Gettens 1951a). The first method generated chlorine dioxide gas in aqueous solution by combining sodium chlorite with formaldehyde, formic acid, or hydrochloric acid. The art work was immersed in the solution followed by rinsing, similar to the hypochlorite bleaching then in common use. Gettens found that the bleaching results were similar regardless of how the bleach was generated.

The second method involved a complex setup for making chlorine dioxide gas and running it through water to infuse the water with the gas (fig. 3). Again, the artwork would be immersed in the solution and then rinsed.

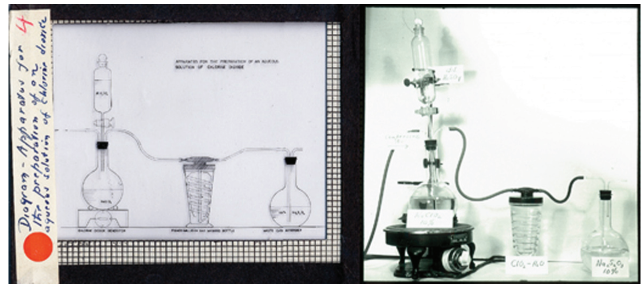

Fig. 3. Schematic drawing (left) and laboratory setup (right) for infusing water with chlorine dioxide gas. Courtesy President and Fellows of Harvard College

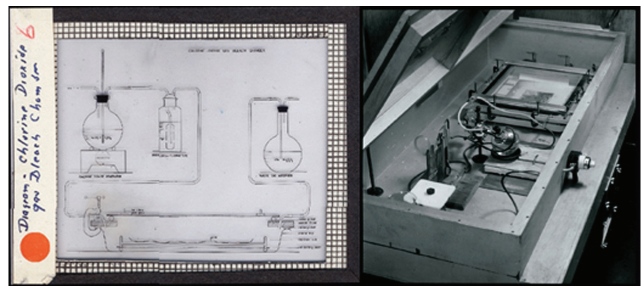

Fig. 4. Schematic drawing (left) and laboratory setup of chlorine dioxide gas bleaching chamber (right). Courtesy President and Fellows of Harvard College

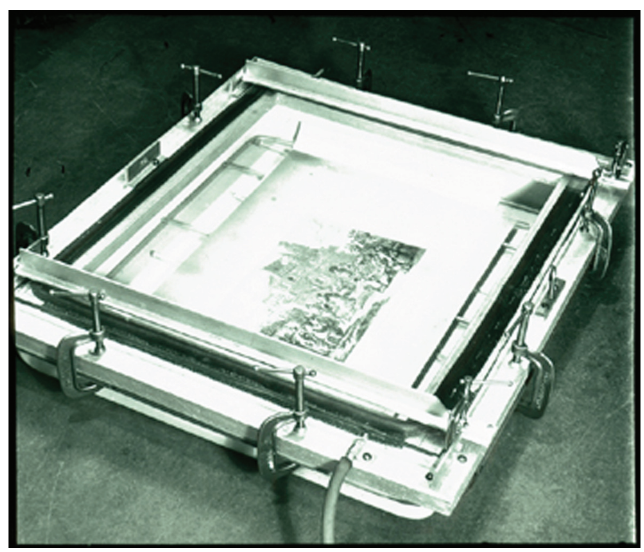

Fig. 5. Close-up view of the gas bleaching chamber with a print inside. Courtesy President and Fellows of Harvard College

The third method was only recommended when the artwork could not be immersed in bleach and rinsed afterward. The artwork would be exposed to chlorine dioxide gas in a bleaching chamber (figs. 4–5). The gas was generated in the flask in the upper left in the diagram, and then passed through tubing into the sealed chamber at the bottom. The additional

flask was for neutralization of the gas after bleaching was complete. At the lower right is a close-up of the chamber with a print inside. These images are from glass slides made to illustrate Gettens's research and used for teaching in the Fine Arts Department at Harvard.

During his research, Gettens tested the bleaching effect of chlorine dioxide gas on wet and dry papers, dyed test papers, foxed ledger paper, Japanese woodblock prints, hand colored French prints, book pages, newsprint, fragments of illuminated manuscripts and plain parchment, adhesives, bistre, sepia, iron gall and other inks, red chalk, lead white, and watercolor samples (figs. 6–7). He found that the gas bleaching was more effective when the paper was damp or wet, vellum and casein turned a pinkish color, iron gall ink and the other inks feathered and faded, and the gas completely bleached out certain pigments, especially yellows and reds. As a result of these experiments, chlorine dioxide gas bleaching was only recommended for black-and-white prints and drawings.

Fig. 6. Pages from Gettens's bleaching notebook: chlorine dioxide bleaching tests on Windsor & Newton's Artists' Water Colours, May 7, 1951

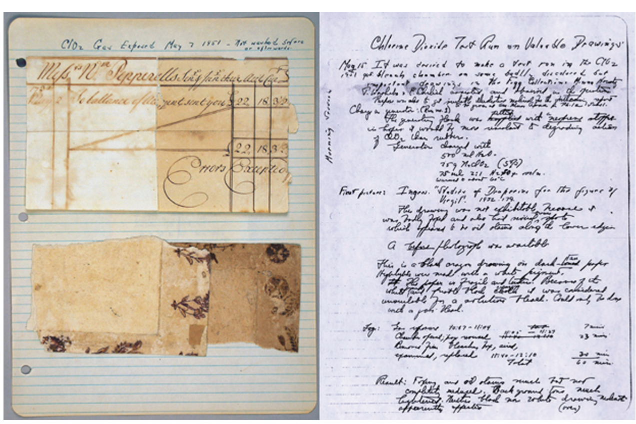

Fig. 7. Pages from Gettens's bleaching notebook: chlorine dioxide gas bleaching test on iron gall ink, May 7, 1951; chlorine dioxide gas test run on valuable drawings, May 15, 1951

Finally, Gettens began his "Chlorine Dioxide test run on valuable drawings" (Gettens [1950–1951]). These "badly discolored, but important drawings" included a drapery study by Ingres, drawings by John Ruskin, Toulouse Lautrec, Bronzino, and with the permission of the owner, a drawing on loan to the Fogg attributed to Tiepolo.

Gettens presented the preliminary results of his bleaching experiments at the American Association of Museums meeting in Philadelphia in May 1951. In correspondence with the chemists at Mathieson, Gettens said "I am reluctant to burst into print just yet before my colleagues have had a chance to try out the process in other laboratories," (Gettens 1951b) but he didn't think he could return to this research. His article, "Bleaching of Stained and Discoloured Pictures on Paper with Sodium Chlorite and Chlorine Dioxide," (Gettens 1952) was published in the journal *Museum* shortly after he began working at the Freer Gallery of Art.

From research in the Fogg conservation files, it appears that chlorine dioxide gas bleaching was only used during the period of Gettens's experiments from 1950 to 1951. In all, about twenty-five prints and drawings were bleached using his three methods. Of the thirty Ingres drawings examined, only three were bleached with chlorine dioxide gas. The complicated apparatus for generating the gas and the danger of an explosion were probably responsible for this bleaching method's falling into disuse at the Fogg after Gettens left. The most commonly used bleach at the Fogg remained sodium hypochlorite, probably introduced by George Stout in the early years of the Fogg and used through the mid-1970s (Bowen 2006–2007). Eleven of the Ingres drawings examined were bleached with sodium hypochlorite; two were bleached with chlorine dioxide gas and then bleached with sodium hypochlorite when the gas proved ineffective. In 1950 Chloramine-T was first mentioned in the treatment records and it was also used until the mid-1970s. Four of the drawings studied were bleached with Chloramine-T. Overall, there was no correlation between the current color of the drawings and the types of bleach that were used. In general, the papers of earlier drawings were lighter than the later drawings, which may relate to the changes in paper manufacture mentioned earlier.

EXAMINING A BLEACHED DRAWING

Utilizing the glass slides, original treatment files at the Fogg, and Gettens's bleaching notebook, about thirty Ingres drawings in pencil and black chalk treated between 1946 and 1953 were examined. Ingres' drawing, *Study for the drapery of Virgil in the 'Apotheosis of Homer,'* a study for a painting in the Louvre, is a good example of the complex sources of discoloration (fig. 8). On the left is the before treatment image of the drawing from 1932 and on the right the after treatment

Fig. 8. J.-A.-D. Ingres, *Study for the drapery of Virgil in the 'Apotheosis of Homer,'* c. 1847, black and white chalk over graphite on tan wove paper, 39.3 x 27.3 cm, Harvard Art Museum (1932.179); before treatment image 1932 (left), after treatment image 1951 (right). Courtesy President and Fellows of Harvard College

Fig. 9. J.-A.-D. Ingres, *Study for the drapery of Virgil in the 'Apotheosis of Homer,'* c. 1847, black and white chalk over graphite on tan wove paper, 39.3 x 27.3 cm, Harvard Art Museum (1932.179); the drawing in 2007, front view (left) and back view (right). Courtesy President and Fellows of Harvard College

image from 1951. The edges of the images are irregularly cropped by the black tape sealing the slides, which is also why they appear slightly different in proportion. In Gettens's bleaching notebook, he described the condition of the drawing and the reasons for its treatment. "The drawing was not exhibitable because it was badly foxed and also had several brown spots which appeared to be oil stains along the lower edge…. Because of the white pigment and friable black chalk it was considered unsuitable for a solution bleach. [It] could only be done with a gas bleach" (Gettens [1950–1951]). The drawing was exposed to chlorine dioxide gas for sixty minutes after which he noted: "Foxing and oil stains much but not completely reduced. Background tone much lightened. Neither black nor white drawing material apparently affected. M. Horwitz did some additional hand work on the larger stains" (Gettens [1950–1951]).

In fact, the drawing was later returned to the chamber for further bleaching. Even so, two months later it was brought back to the department because "dark spots had reappeared all over the drawing. [The] cause of this reoccurrence could not be explained. Spots coincided with some of the spots in the before treatment photograph—…but not all—and they were different in shape" (Gettens and Horwitz 1951a). Gettens surmised that the spots had previously been treated locally, and that the chlorine dioxide gas reacted with these local treatment areas. The current appearance of the drawing is shown in figure 9.

As Gettens noted, the foxing was replaced by halos of darker paper, which probably darkened from local treatment without rinsing. At the lower left and along the right edge, the paper is very mottled in tone. This is visible in the after treatment slide and was probably the result of the "additional hand work" mentioned in Gettens's notes. The light marks in the upper corners are from the hinges on the back. The pale vertical line at the lower right edge is a repaired tear which is also visible in the 1951 slide. The back of the paper is cream, not darkened by light exposure like the front. Originally, the paper would have provided a middle tone for the black chalk and white highlights of the drawing. The locally bleached foxing stains are visible as brown spots on the reverse, and the white chalk highlights show as lighter areas where the calcium carbonate in the chalk protected the paper from discoloring. The condition of the white chalk itself is another question. Today the dry chalk strokes are not very visible and appear to have sunk into the paper, though Gettens clearly went to great lengths not to immerse the drawing. During a preliminary presentation of this research to staff at the Fogg Art Museum, it was discovered that a bleaching treatment was performed in the mid-1960s at the request of the curator, Agnes Mongan. The paper had become very dark brown and Ms. Mongan requested that paper conservator Jerry Cohn bleach the drawing before it went on display in the Ingres Centennial Exhibition in 1967. The drawing was immersed in sodium hypochlorite bleach and rinsed in a water bath (Cohn 2007). Though treatment documentation photos have not been found for comparison, Cohn believes the paper has not darkened again, but has maintained the tone achieved by bleaching.

BLEACHING CHEMISTRY

A brief review of bleaching chemistry may help explain the spread of the foxing spots and why the paper darkened

after the original chlorine dioxide gas bleaching treatment. Bleaching lightens paper by changing the chemical structure of the chromophores, or the coloring matter, present. The term "chromophore" can refer to many dissimilar molecules that share one feature: conjugated bonds that cause them to be colored. Conjugation is the repeating single-bond, double-bond pattern [-C=C-C=C-] seen in the ring system of the sulphite lignin fragment at the left in figure 10. A very simplified explanation of the diagram is that most bleaching breaks conjugated bonds through oxidation, creating smaller, non-colored molecules that are soluble in alkaline solutions. Each arrow represents another oxidation reaction, creating smaller and smaller molecules. If this material is not removed from the paper, over time it can reform a colored, conjugated system. It may not form the same chemical structure, however, which could be why the darkening may appear different than the original stain. This phenomenon is often generically called color reversion, though it may involve both color reversion and conversion. This problem underlies the need for rinsing after all bleaching treatments.

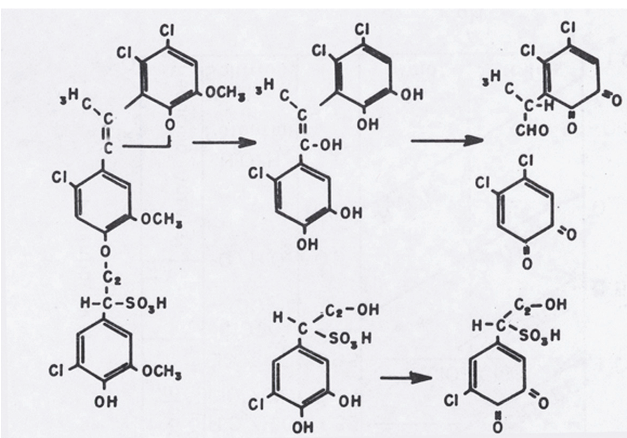

Fig. 10. Oxidation of chromophores by chlorine in aqueous solution; adapted from Robert Feller, *Bulletin of the IIC-AG* 1971

ANALYTICAL TESTING OF BLEACHED PAPERS

Another aspect of this research project was to determine if bleaching residues could be detected using analytical instrumentation. Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM-EDX) and X-Ray Fluorescence Spectroscopy (XRF) were tested for their effectiveness in detecting chlorine in paper and their appropriateness for use on artworks. Bleached paper samples prepared for previous research (Smith 2005) at Buffalo State College were analyzed. Seven papers from the eighteenth, nineteenth and twentieth centuries, including Whatman filter paper, were bleached with Chloramine-T, an oxidizing bleach that lightens by the same chemical mechanism as sodium hypochlorite. Samples were bleached in two ways: either brushed with 2% Chloramine-T several times without rinsing, or immersed in a 2% solution and then rinsed.

Kathy Eremin, Conservation Scientist at the Fogg Art Museum, analyzed these samples with SEM in the facilities of the Museum of Fine Arts, Boston. SEM analysis requires that a sample be placed in a vacuum chamber, limiting its use with artifacts, though small artworks may be analyzed in low-vacuum SEM chambers. Chlorine was successfully detected in the samples, and images of the paper surface helped locate and identify possible bleaching residues embedded in the fibers, such as sodium chloride and potassium salts (fig. 11).

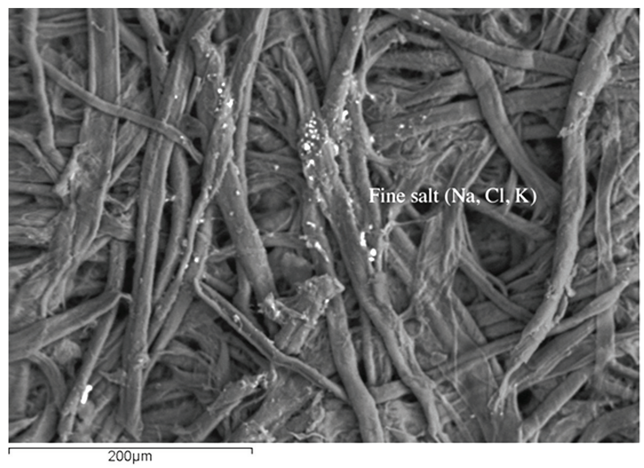

Fig. 11. Scanning electron microscope image of handmade, nineteenth-century, gelatin-sized, Whatman watercolor paper, after bleaching and aging; image captured by Dr. Kathy Eremin

XRF analysis was performed at the Straus Center for Conservation. XRF also detected chlorine in the bleached samples. Those that were bleached and rinsed showed significantly lower levels of chlorine than papers that had been bleached without rinsing, as expected. Because of the non-destructive nature of the testing, six Ingres drawings were able to be analyzed by XRF. The drawings were hung suspended from their hinges, while their mats were supported horizontally on a table and weighted in place (fig. 12). The drawings were hung in this manner because the material of the mat board or any other solid support would be analyzed along with the drawings, complicating the XRF spectra. Air behind the drawings greatly simplified interpretation of the data.

The six drawings were chosen based on their bleaching history and ability to be suspended in this manner. Three of the drawings had been bleached with Chloramine-T, three with chlorine dioxide gas, and one was bleached with chlorine dioxide gas and then further bleached with

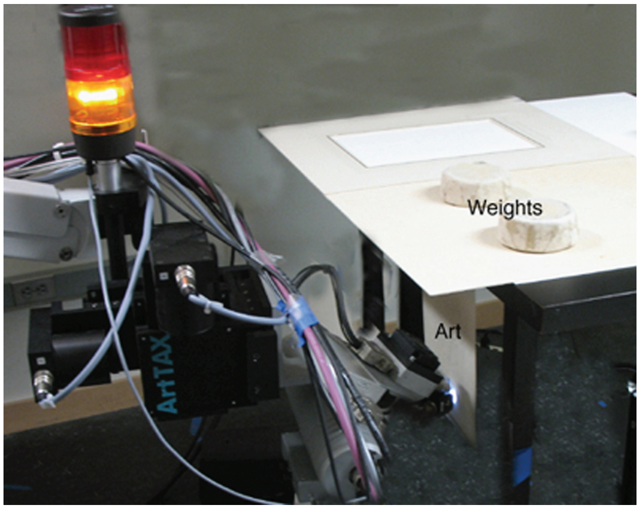

Fig. 12. Setup for XRF analysis of mounted drawings at the Straus Center for Conservation

Fig. 13. J.-A.-D. Ingres, *Portrait of Princess Letizia Murat*, 1813, graphite on cream wove paper, 26.1 x 17 cm, Harvard Art Museum (1942.43); front view in 2007. Courtesy President and Fellows of Harvard College

sodium hypochlorite. The XRF data showed that five of the drawings had insignificant levels of chlorine, meaning that the measurements were so low, statistically speaking, they were not significantly different from zero. Only one drawing had a measurable amount of chlorine (fig. 13), and it was very low compared to the bleached paper samples. This drawing was bleached to treat overall foxing stains and was never rinsed (Gettens and Horwitz 1951b). After treatment photographs show that the bleaching treatment was successful. Today the paper has not darkened, but the foxing has returned. There was no difference in the method of bleaching that would explain the higher detected chlorine in this particular drawing; however, the structure of the drawing support is different. The drawing is lined overall, which probably made it a candidate for the gas bleaching in the first place, and the second layer of paper or the layer of adhesive may have contributed to the retention of the chlorine.

Chlorine is volatile and its residues will dissipate over time. But quoting a chemist in the Chlorite Division of Mathieson, "[t]he odor of chlorine dioxide gas may be left in the paper quite some time after the treating. This is actually residual chlorine dioxide gas. The more gas removed from a surface, the harder it gets to remove residual amounts" (Birkett 1951). If the observed darkening of the Ingres drawings was caused by chlorine residues, and not color reversion, then the damage must have occurred before the chlorine dissipated. Ironically, the drawing with the most chlorine residues is not the darkest. Since chlorine wasn't detected in most of these drawings, it seems there may be a finite window of time after bleaching in which the damage occurs, and in which it might be prevented by rinsing the residues from the paper. Experience at the Fogg Art Museum suggests that washing and sun bleaching the drawings now will reduce some types of discoloration, but only in the short term as the color often returns (Bowen 2006–2007).

CONCLUSION

Both SEM and XRF can detect chlorine in paper. SEM requires sampling, but can provide quantitative data and image capture, which may suggest areas for further analysis. XRF can be performed on even mounted drawings to determine if chlorine is present, but neither method is useful in determining if a drawing was bleached in the past if the chlorine has already dissipated. New developments in hand-held XRF technology allow quantitative measurement of even very low levels of chlorine, such as were found in these artworks. For these techniques to be useful and to provide data applicable to actual artworks, many more samples of bleached and unbleached paper must be analyzed by both methods to create libraries of comparable reference spectra. Perhaps in

the future these techniques will help answer questions about the rate of chlorine dissipation from paper.

This study illustrates the challenges conservators face in trying to understand the current condition of an artwork by reconstructing past, possibly undocumented, treatments. During the late 1940s and early 1950s, many U.S. museums and collectors sent drawings to the Fogg Art Museum to be treated and some of these were bleached. Though the literature on bleaching is voluminous, both in the field of conservation and in the paper industry, there is still much about the bleaching of real artworks that is not understood. Analysis and comparison of all the drawings bleached with chlorine dioxide gas at the Fogg Art Museum could help clarify the long-term effect of this bleach on the different papers. Further characterization of bleached historical papers would provide valuable information, not only for the Ingres drawings at the Fogg Art Museum, but for many other collections in the U.S.

This paper is part of a larger research project, *Notes toward a History of Paper Conservation at the Fogg Art Museum, with an Evaluation of Early Bleaching Practices*, undertaken at the Straus Center for Conservation, Harvard University Art Museums, between 2006 and 2007. The project is ongoing and has been expanded to Ingres drawings in other collections, focusing on those treated at the Fogg, and looking at paper manufacture, current condition, and treatment histories. Nine drawings have been examined in the collection of the Art Institute of Chicago, one of which was bleached both at the Fogg Art Museum and at the Metropolitan Museum of Art. With the support of a fellowship from the Harvard University Library, a research trip to New York City is planned to look at Ingres drawings in the collections of the Metropolitan Museum of Art, the Pierpont Morgan Library, and the Frick Collection. In the long term it is hoped that this research will begin to identify connections between nineteenth-century paper manufacture and the outcomes of conservation treatment, allowing conservators to make better-informed treatment decisions for the works under our care.

ACKNOWLEDGEMENTS

I am grateful to Craigen Bowen, whose interest in the history of conservation and keen insights inspired this research. Thanks also to Jerry Cohn, Anne Driesse, Penley Knipe and Francesca Bewer at the Straus Center for Conservation for their thoughtful comments on this research. Special thanks to Drs. Narayan Khandekar and Kathy Eremin in the Straus Analytical Lab, William Robinson and Miriam Stewart in the Department of Drawings, Susan von Salis, Jane Callahan and Insley Julier in the Harvard Art Museum Archives, Emily Hankle in the Agnes Mongan Center for Prints, Drawings and Photographs, and the Department of Information and Visual Resources for making electronic versions of many photographs available to me.

Outside the Harvard Art Museum, I would like to thank Dr. Richard Newman at the Museum of Fine Arts, Boston, MA for providing access to the SEM equipment; Dr. Joyce Hill Stoner and Sharra Grow for assistance with the materials in the FAIC Oral History Archive, Winterthur Library, Wilmington, DE; Paul Jett, Head of Conservation, Freer Gallery of Art, Washington DC for providing generous access to the Rutherford John Gettens Archive and Harriet Stratis at the Art Institute of Chicago, Chicago, IL.

Craigen Bowen and the Straus Center for Conservation funded my travel during this research. Finally, I want to thank the Bryant Fellowship Committee of the Harvard University Library for funding the next stage of this project.

NOTES

1. SEM-EDX was performed at the Museum of Fine Arts, Boston, on a JEOL JSM-6460 LV Scanning Electron Microscope with an Oxford Instruments INCA x-sight EDX Spectrometer.
2. XRF was performed in the Analytical Laboratory of the Straus Center for Conservation on an ArtTAX Spectrometer with a molybdenum tube, operating at 50kV and 602μA current, using a helium flush. The measurement diameter was about 70 microns and each measurement lasted 200 seconds.

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Hierarchical Recording of Binding Structures

ABSTRACT

The Ligatus research unit of the University of the Arts, London has undertaken the recording of the binding structures and materials of the manuscripts and early printed books from the library of the Saint Catherine Monastery in Sinai, Egypt. Conservators from many different countries have been engaged in both the examination of the books and the formation of a recording methodology for binding structures. About 4500 books have been examined one by one. The detail with which the recording was done resulted in a large amount of information about each book's individual components. Organizing this information has been a challenging task and a variety of data structuring models were assessed for storing the collected data. Our assessment showed that hierarchical data structuring is an efficient way to record binding information. In this paper, a cording methodology with XML hierarchies is presented, based on the experience from the Saint Catherine's collection.

The root of the hierarchy represents the concept of the specific book being recorded and the rest of the binding components are mapped as developing branches from the root. The hierarchy offers an "infinite" number of developing branches allowing space for every piece of information about the material or structure of the book. The hierarchy acts both as a storage system for the observations and as a consistency checking mechanism which ensures that the recorded information is complete and, to a certain extent, correct. XML is a good tool for implementing hierarchies with many additional benefits. These include the long-term preservation of the recorded data, the great potential for multilingual implementations and the good support by almost all major programming languages.

The proposed methodology has successfully been tested at the Saint Catherine's library collection, and it is proved ready to be tested on other collections.

Presented at the Book and Paper Group session, AIC 36th Annual Meeting, April 21–24, 2008, Denver, Colorado.

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LINDA BLASER AND SUSAN M. PECKHAM
DISCUSSION GROUP CO-CHAIRS

The Archives Discussion Group 2008: Sharing Information about Environmental Monitoring

Susan and I wanted to bring together a group of experienced professionals to discuss the pros and cons of various environmental monitoring systems. We wanted to learn about which monitoring systems worked best in different situations. The panel we brought together included:

Rachel Perkins Arenstein
Conservator in Private Practice
(Rachel also presented for Samantha Alderson, American Museum of Natural History, New York)

Barbara Brown and Jane Boyd
Head of Photo Conservation and Assistant Paper Conservator
Harry Ransom Center, University of Texas at Austin

Joan M. Brink
Conservation Liaison, Dept of Preservation & Collection Maintenance
Cornell University

Eliza Gilligan
Smithsonian Libraries

Nancy Lev-Alexander
Head, Preventive Conservation Section
Library of Congress

Vasare Rastonis
Columbia University Libraries

Emily Kaplan
Smithsonian National Museum of the American Indian

This open discussion took place on April 24, 2008, during the AIC 36th Annual Meeting, Denver, CO. The moderators organized the panelists, led the discussion, and recorded notes. Readers are reminded that the moderators do not necessarily endorse all the comments recorded and that although every effort was made to record proceedings accurately, further evaluation or research is advised before putting treatment observations into practice.

We had several questions we presented to our panel in preparation for our discussion. Questions included:

- What type(s) of environmental monitor(s) do you use?
- What do you like about the system you are using?
- What don't you like about the system you are using?
- Can you relay any lessons learned?
- Beyond the conservation staff, who else at your institution understands the concept, the data, and the system you are using?
- Have you used your system in an effective way to address environmental problems at your institution? If so, please explain.
- Have you developed any unique applications to monitor special items in your holdings?
- Have you encountered any resistance to environmental monitoring? If so can you explain why there was resistance and how you have worked to counter that resistance?
- How large is an average sized archival storage space in your facility and how many monitors do you place in the space? Do you have a strategic plan for monitor layout?
- Do you use monitors in other spaces, e.g. exhibit hall, processing room, research room, and conservation lab?
- How often do you calibrate the loggers and how do you accomplish this task?
- How does cost affect your equipment decision?
- Does size play a role in your equipment decision? If so, in what way?
- How many people are charged with this task at your institution? How large is your institution?

RACHAEL PERKINS ARENSTEIN

SO MANY OPTIONS, HOW DO I CHOOSE?—THINGS TO CONSIDER WHEN SELECTING A DATALOGGER

There are lots of great dataloggers, which makes it difficult to choose one specific product. The best way to choose which logger to use is by evaluating your needs.

Question 1: Do you actually need dataloggers?
Hygrothermographs remain readily available and, assuming that they are properly cared for, can provide years of service. Dataloggers allow the user to set sampling intervals. Dataloggers' electronic sensors are more durable and respond faster than hair hygrothermographs. Unlike hygrothermographs, dataloggers generally do not require frequent calibration. Some dataloggers are cheaper than hygrothermographs. Ultimately, the greatest advantage of dataloggers over hygrothermographs is the ability to easily analyze the data. If data analysis is not necessary and you just need to walk by your unit and check the environmental conditions—then you can stick with a hygrothermograph.

- Datalogger advantages include
  - User set sampling intervals
  - Quicker response times for electronic sensors
  - Less frequent calibration
  - Can be cheaper
  - Increased ability to analyze data

Question 2: What is your budget?
Everyone's goal is to get the best value, meet the needs of the institution, and stay within budget. The price of the unit generally reflects the quality of the sensor, the longevity of the battery, the durability of the casing, the flexibility of the software and any additional features such as displays or alarms. Some of the necessary accessories cost extra. There are situations where an inexpensive logger can be appropriately utilized such as when you want to capture data in multiple locations and extra features are less important.

- Unit price reflects
  - Sensor quality
  - Battery longevity
  - Casing durability
  - Software flexibility
  - Additional features
  - Displays
  - Alarms
- Extras
  - Software
  - Cables
  - Probes

Question 3: What are you monitoring?
There are two broad monitoring categories although they are not mutually exclusive. *General trend* logging is done to develop an environmental profile of a particular space. This profile is established by capturing data over a long period of time, which means that the logger must be reliable, have lots of memory and a long battery life. For special short term projects, such as exhibits or temporary storage spaces, other factors may come into play such as size, LCD display or alarm capability.

- General trend logging
  - Reliability
  - Memory
  - Battery life
  - Real-time/networking?
- Project oriented logging
  - Accuracy
  - Size
  - Display
  - Alarms
  - Real-time/networking?

Question 4: Do you need real time data collection capability?
If your building has a Building HVAC Management System, ask for access to the system so that you can monitor the system in real time. If that type of system does not exist, it can be expensive to add. Real time data collection is beneficial when there are so many monitoring points that downloading data becomes labor intensive. This type of system can also facilitate data collection from off-site storage facilities.

- Pay a premium
- Useful for
  - Off-site storage
  - When large numbers of loggers are involved
  - Proven history of collection vulnerability
- Utilize existing HVAC Building Management System

Question 5: How do you assess datalogger features?
It can be challenging to evaluate different loggers in relation to each other because each manufacturer writes their products specifications differently.

- Memory Capacity: The total number of readings that the logger can hold—on how many channels.
- Battery Life: At a minimum, a logger should have battery life substantial enough to provide one full year of monitoring but you must check with the manufacturer to ensure that a logger with a one year battery life will actually achieve that if the logger is set to take frequent readings. It is critical to know whether or not the logger saves the data if the battery dies.

- Sensor range and accuracy: A logger calibrated at three points across its range should take accurate high and low readings, while a logger calibrated at one midpoint closer to ambient temperature may not be accurate at the extremes. It is important to determine if the application requires accuracy within 0.5% or 5% RH, and note how accurate the system is required to be to suit the needs of your institution.
- Size, appearance and construction: Will it fit in the assigned space? Will it detract from the exhibit? Is it sturdy?
- Visible display, alarms and probes: While extremely useful for certain projects but these features generally increase cost and decrease battery life.

Question 6: What else should you consider?

- Download speed and options: Portable download units, infrared downloading and speed are all extra features to consider.
- Calibration: Can you calibrate the logger yourself or do you need to send it back—at what cost?
- Software: Ask to see a trial version to determine how easily you can start and stop logging, print graphs or generate statistics. If you are using a Mac—check to see if the software is compatible or available.
- Customer service and technical support: This is important because companies go out of business, software becomes outdated as platforms are upgraded, and products are discontinued. Ask for a free 30-day trial if you are planning to make a major purchase.

Environmental monitoring is a means to an end. Ultimately it is how you use your data and work with your colleagues that will ensure good environmental conditions for your collections.

SAMANTHA ALDERSON

DATALOGGER USE AT THE AMERICAN MUSEUM OF NATURAL HISTORY

An overview of logger use in the Anthropology Conservation lab of AMNH with special attention to ACR SmartReader loggers which can be connected to a network and calibrated by the user. (Also discussion of using salt chambers to check accuracy of datalogger RH sensors.)

Overview

The lab first purchased dataloggers in 1996. We now have 80 loggers (2008):

- 27 ACR SmartReader 2 or 2 plus
- 33 Onset Hobo Pro
- 18 Onset U12-011
- 2 PEM

Loggers are used to monitor

- Permanent exhibit halls at American Museum of Natural History (AMNH).
- Temporary exhibitions spaces at AMNH.
- Storage spaces (at AMNH and off-site).
- Conditions at traveling venues.
- Case interiors (permanent exhibit halls, temporary exhibitions at AMNH and traveling venues).
- Traveling crate interiors.

ACR Loggers

- ACRs are used for long term monitoring in the Museum and off-site storage.
- ACRs are used for more permanent installations due to long battery life, dependability, and the ability to connect them to the network.

Onset Loggers

- Hobo Pro and Onset U12 loggers are less expensive and have also proved reliable over time. They are used for temporary and traveling exhibitions.

ACR Smart Reader 2 Loggers

- ACRs can be used with an external probe, which is useful where size or visual impact in an issue, such as in a case interior or on a gallery wall when the designers want minimal intrusion.

ACR Loggers

- The ACR loggers were networked because the institution was not ready to invest in the high cost of a wireless system like Hanwell, and they already owned many ACR loggers.
- Some of the advantages of ACRs include high quality sensors, long battery life, ability to connect them to a network, and the ability to calibrate them yourself.
  - Dependable high precision sensors.
  - Long battery life (10 years or more).
  - Can add external probe.
  - USB or Serial Cable can be used.
  - Recently updated software (TrendReader 2).
  - Can be networked.
  - Can be calibrated by users.
- Some disadvantages of the ACR system is that networking requires IT support and installation fees, or personal IT expertise and perseverance. The system will not work with a large number of logging locations.
  - No wireless capability.
  - Networking has limitations.
  - Requires some tech knowledge and support.

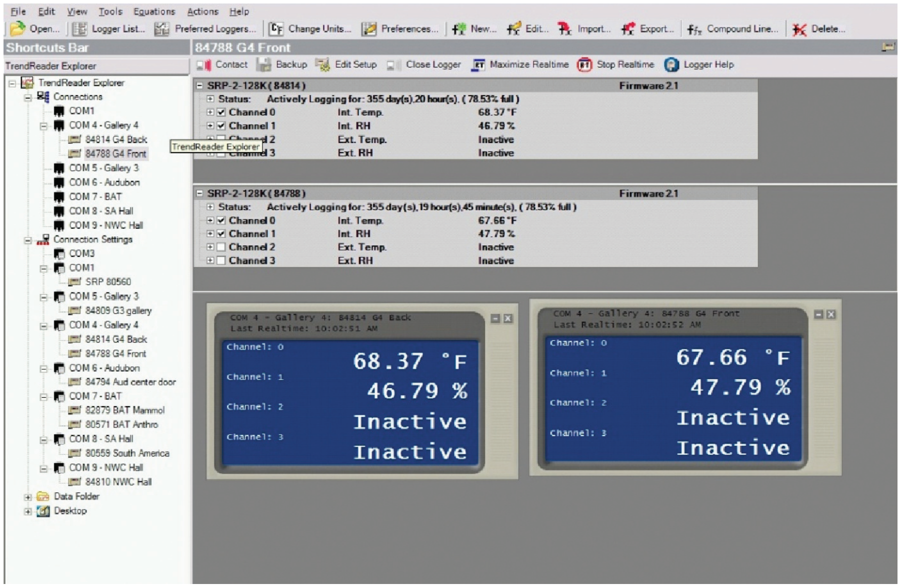


Fig. 1. Graphs can be easily customized, labeled, and saved in various formats (.CSV, .JPG, .PDF) for exporting or sending as an e-mail attachment

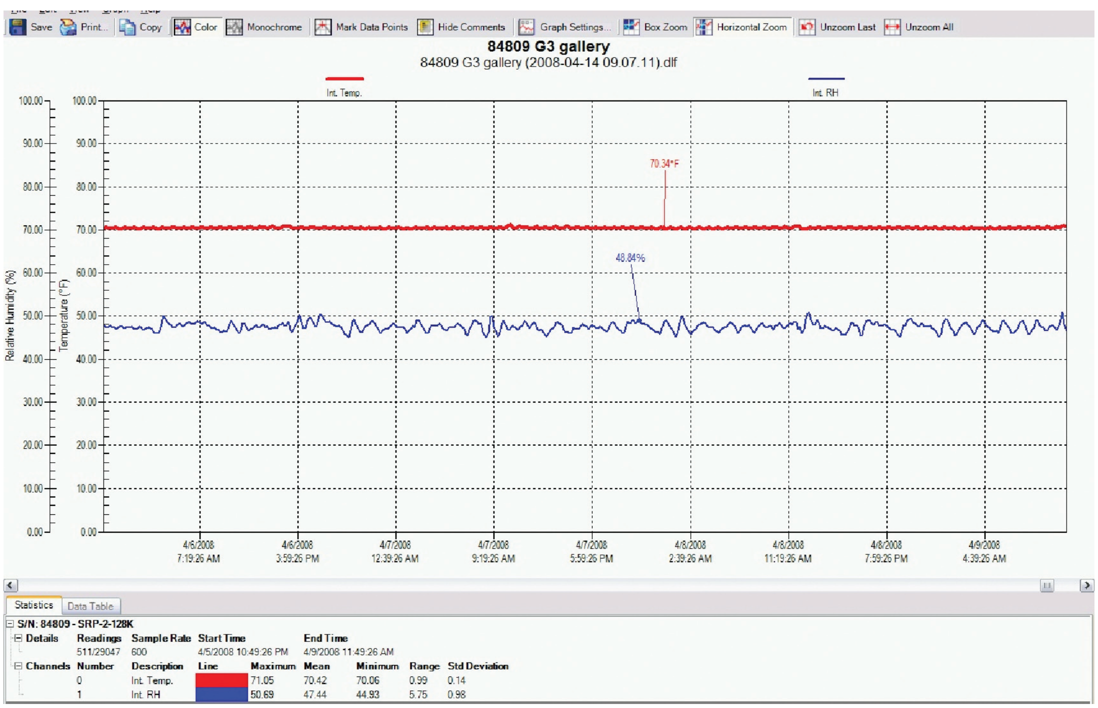


Fig. 2. You can download data from the loggers at anytime. The resulting graphs are easy to customize, print, and e-mail. Also data can easily be exported to Climate Notebook or other programs

Networking ACR Loggers

- A server device transfers data to the network. We use one box per gallery or storage space. Up to ten loggers can be connected to one device. The server device requires a power source and a network jack.
- The loggers are connected to the server box and each other with a series of adaptors and Telco cables. The cables can be long so that loggers can be far apart and you can separate the first logger in the chain from server box. This way the "messy" wires, adaptors and server boxes can be hidden behind gallery walls or in adjoining spaces, with only the logger or probe visible in the space itself.

TrendReader 2 Software—Networked Loggers

- At AMNH we currently have 6 server boxes in place with 1–2 loggers attached to each. Five are in galleries on-site, one is an off-site storage location.
- All of the loggers can easily be checked from any other networked computer in the museum that is set-up to access them.
- The software allows you to leave "real time windows" open on your desktop, to monitor conditions throughout the day as necessary.

(See figs. 1–2)

Calibration

- RH sensors can drift over time and have a limited lifetime. It is very important that the accuracy of RH sensors be checked on a regular basis. Since the companies charge significant fees for recalibration it pays to be able to check them yourself before sending them in for regular servicing.
- Salt chambers are easy and inexpensive to set up.
- Salt chambers are used at AMNH to check loggers over time and also when they first arrive to make sure they are functioning properly before they are used.
- The chambers are reported to have limited accuracy but if you run several loggers and logger types at once for cross comparison, it can be a very reliable tool.
- This is the simple system used at AMNH.
  - Saturated salt solutions that hold specific RH levels are placed in small well sealed plastic containers. The lids of the containers are fitted with a Gortex window that allows vapor exchange but prevents liquid spills and salt migration.
  - This small container is then placed in a larger container that can hold several loggers.
- Data from salt chambers can be used to check accuracy of any type of logger and can be used to recalibrate ACR loggers.
  - The calculated high and low values are entered into the ACR software to calibrate the logger.

Even if you are not going to calibrate loggers yourself the salt chambers are a simple and inexpensive way to periodically check logger accuracy.

JANE BOYD AND BARBARA BROWN

ENVIRONMENTAL MONITORING EXPERIENCES AT THE HARRY RANSOM CENTER UNIVERSITY OF TEXAS AT AUSTIN

Types of environmental monitors (loggers) used:

- HOBO model H08–004–02–20 currently in use
  - Source: Onset Computer Corporation
- PEM (Preservation Environmental Monitor)—5 units in use
  - Source: Image Permanence Institute

Strategic plan: locations of the monitors are mapped on floor plans of building to help us track conditions in the four vertical quadrants of building (each served by one air handler); although all four quadrants are not necessarily covered on each of the floors. We are monitoring collection storage areas as well as gallery spaces.

HOBOs

- Smaller sized monitors
  - Allow for flexibility of placement
  - Unobtrusive
    - Exhibit Galleries
    - Special Collections Rooms
    - Display Cases
    - Back-up units
      - Can easily be used to replace other units that are temporarily out for repair.

Monitoring the Nitrate Vault

- Exterior of the vault (which has is own air handling system)
  - Recording Hygrothermograph which includes a digital readout of the temperature and Relative Humidity levels.
- Interior of the vault
  - A HOBO is mounted inside on the interior wall.

Downloading Data

- HOBO Shuttle
  - A cable links the HOBO Shuttle to the logger.
  - When the download is complete the green "successful" light shines on.
- Download Complete
  - Once disconnected from the logger, the Shuttle lights will indicate the status of the battery life.
- Save File
  - Each HOBO data file is saved as a .txt file and then imported into the appropriate Climate Notebook

Software (CNB) file. (PEM data is downloaded directly into Climate Notebook.)

- Climate Notebook
  - Several Report options are available from CNB.
  - The Engineer's Report is useful.
    - Graphically illustrates when the temperature and Relative humidity levels are within range.
    - Provides the percentage of time that the temperature and relative humidity levels are within tolerance.

Systems Pros

- Both Allow
  - Custom setting of data collection intervals.
    - Custom setting amount of time during which data can be collected (e.g. 3 months or more).
- CNB Software
  - Data management and evaluation capabilities.
  - Ability to track and compare indoor and outdoor data.
  - Useful graphic presentation of information.
- Good Technical Support Services
  - Image Permanence Institute for PEMs and CNB.
  - Onset for HOBOs.

System Cons

- Report printing problems
  - Charts may not print properly.
  - May be due to incompatibility of equipment (an in-house issue most likely: occasional computer / printer program communication glitches).
- Not email friendly. (Since the time of the presentation, we have learned much more, and this is no longer a problem. The charts can be easily saved as .pdf files and sent as attachments to an email.)

Lessons Learned

- PEM
  - Track battery changes and other maintenance information.
  - Track move dates and locations.
- CNB
  - Keep hard copies of charts and notes for each location/monitoring device.
- Organizing Data
  - Organize by location or area monitored then include device name or number.
  - Organize files on your computer by year to make it easier to find.
- Paper Log Book
  - Download dates
  - By Whom
  - Action
    - Location/Device
    - Collect data
    - Chart made /date
    - Chart published /date
    - Notes (e.g., maintenance information)

JOAN M. BRINK
ENVIRONMENTAL MONITORING AT CORNELL UNIVERSITY

Cornell has one storage facility. The temperature range is 65–68° F and the Relative Humidity range is 35–45%.

Hygrothermographs used by Cornell from 1985 until the late 1990s

- Maintenance costs were high.
- Hygrothermographs are made by various companies but all work on the same basis, the temperature and relative humidity levels are marked on charts by the hour and the day. The charts needed to be replaced on a weekly basis.
- Parts such as hair bundles and pens also need frequent changes, and could cause record keeping problems.
- Sling psychrometers were needed to calibrate the hygrothermographs on a continuing basis.

Dataloggers

- Availability of electronic sensors to replace the hygrothermographs.
- Cornell chose the ACR Dataloggers, supplied by the Cascade Group, Oyster Bay, NY.
- In 1992 a datalogger with internal electronic sensors was produced which enclosed the humidity probe within the unit.
- A laptop computer was used to download information in the field, which is then transferred onto a desktop computer. Charts are edited using ACR software, converted for uniformity and then distributed curators, and other appropriate staff.

Internet Dataloggers

- ACR Dataloggers were time consuming.
- Did not provide real time data.
- Cornell began investigating web-based dataloggers.
- Pinnacle Technology was willing to built a prototype, once successful, Pinnacle moved into production.
- Six Pinnacle, Internet Datalogger/THR units were successfully used at Cornell.
- "Original" Internet Datalogger/TRH is no longer available as some of its parts are now outdated.
- Telnet—If you wish to test a telnet session with the online ID/TRH, call Jim at Pinnacle Technology (785–832–8866) for a login name and password.

- Pinnacle is currently redesigning the unit, and they expect release to be September 2008. No price change is anticipated. The base price is currently $675, or $750 with extra sensors.
  - No special software is needed.
  - Accessible from anywhere in the world via the Internet.
  - Works in real time.
  - Visible digital display of readings.
  - Visual online graphing.
  - Easy downloads.
  - Compatible with Excel for graphs.
  - Email alarms.
  - Machine generated "trouble tickets" sent via email using predetermined notification list which is setup individually for each unit.

Internet Alarms

The alarm setup, in fact all other setups, can be individualized to suit your individual needs. This is the setup screen as seen through Tera Term (a free software system).

ID/TRH login: user
ID/TRH password:
ID/TRH /> alarms
1) Upper temp limit: 75 deg. F
2) Lower temp limit: 50 deg. F
3) Maximum temp change: 10 deg. F
4) Upper RH limit: 65%
5) Lower RH limit: 25%
6) Maximum RH change: 10%
7) Aux. Sensor Alarm: Off
8) Aux. Sensor String: No Sensor
9) Alarm Hold Time: 5 min
10) Alarm Repeat Time: 0 min
11) Email for alarm: jmb7, beb1,
12) Exit

Sample Report: MailDumps

ID/TRH /> maildump
Samples are available from 2/3/07 to 4/9/08
Enter the latest date required [4/9/08] 3/31/08
How many days would you like to dump? [all] 1
Enter the email address: jmb7@cornell.edu
Sending samples to jmb7@cornell.edu...
Connecting to appsmtp.mail.cornell.edu:25...
Connected to mailserver - Press enter <cr> to cancel

Comes through email as:
Date: Fri, 4 Apr 2008 11:36:47 –0400 (EDT)
From: CLStest@cornell.edu
Subject: CLStest data dump

Timestamp,Date,Time,Temp,RH,Flag:
04338690,03/31/08,23:30,074,027,0
04338660,03/31/08,23:00,075,026,0
04338630,03/31/08,22:30,076,026,0
04338600,03/31/08,22:00,075,026,0

Data is compatible with Microsoft Excel. Simply open Excel and then open your text file using Microsoft Excel. Microsoft Excel enables you to produce a chart or file. According to IPI (Image Permanence Institute), RIT, Rochester, NY, this data is also compatible with Climate Notebook.

(See figs. 3–4)

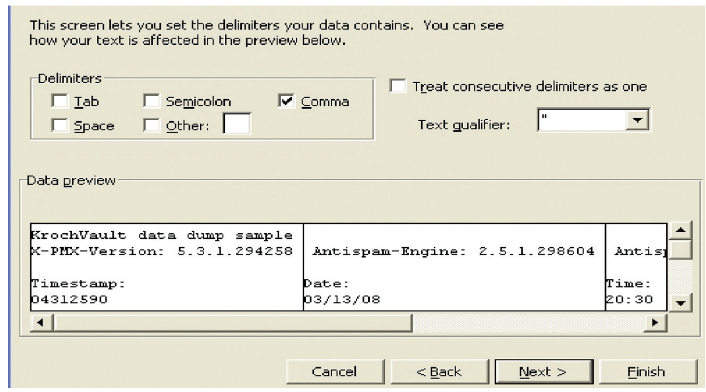


Fig. 3.

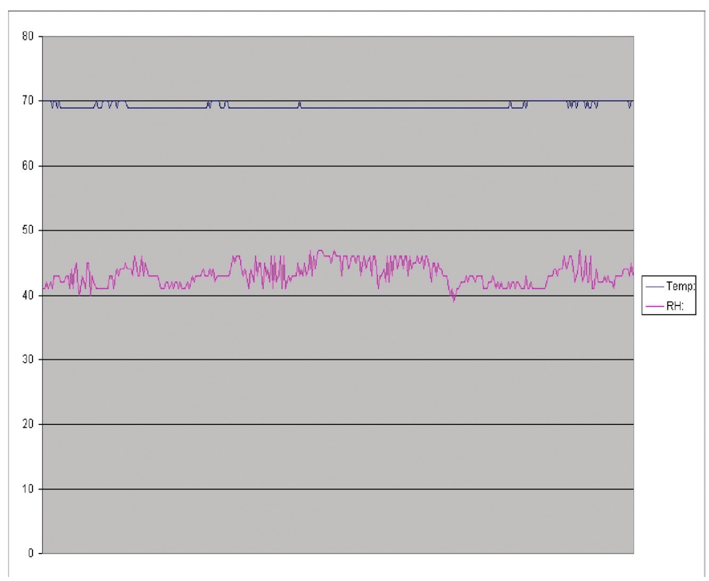


Fig. 4.

ELIZA GILLIGAN

SMITHSONIAN INSTITUTION LIBRARIES; HYBRID APPROACH TO ENVIRONMENTAL MONITORING

Monitoring locations

- We monitor temp/RH in our special collections storage areas on a weekly download basis (4 locations in DC, and 1 in NYC).
- We monitor other locations on an as-needed basis.
  - Exhibit cases (1).
  - Areas affected by National Museum of American History renovation (2).

Our Needs

- Collect accurate temperature and Relative Humidity data.
- Need both remote and on demand access.
- Ability to retain data.
- Ability to share data with library and facilities staff throughout the Institution.

Loggers We had Tried…

- ACR dataloggers, which worked but were over 10 years old and used a DOS operating system.
- Hanwell, tried but it did not work in NHB
- Climate Notebook & PEM's
  - Software great; monitors require ram card download.

Developing the Hybrid Approach

- Use Climate Notebook (CNB) for all data graphing and presentations.
  - Superior graphics, very easy to email to facilities staff as a .PDF file.
- ACR data uploaded to Excel (in order to convert data to .csv format), then CNB to produce graphs.

Replacing the ACR

- Heard about the web based Pinnaclebeing used by Cornell University at the American Library Association meeting.
- Looked on website www.dataloggerstore.com and found some other options including Newport iTHX-M.

Pinnacle vs. Newport

- Pinnacle was easy to install and use, had good tech support, was developed for the library community, but had no battery back-up.
- Newport- not developed for the museum, library, archives community, was much more complex to configure, but included more functionality (such as a battery back-up, email alarms, and use of a flash memory card).
  - Ethernet connection.
  - Flash memory card slot.
  - Can be wall mounted.
  - Probe comes in different lengths.
  - LCD display of data.
  - AC power cord.

(See figs. 5–7)

NANCY LEV-ALEXANDER

ENVIRONMENTAL MONITORING AND MANAGEMENT AT THE LIBRARY OF CONGRESS

Monitoring Objectives—A successful monitoring program begins with clear objectives

- What's Possible
  - Determine best possible storage/exhibit climates based on collection need, mechanical system capability and collateral factors such as human comfort where relevant.
- What's Wrong
  - Collect and analyze data to locate the source of mechanical problems.
- What Needs Attention
  - Analyze data to assess collection risk and to prioritize preservation actions and resources.

Equipment Used

We do not rely on the fixed building sensors as their maintenance is not under our control nor is the data easily uploaded in batches into Climate Notebook.

- Preservation Environmental Monitor (PEM)
  - 120 PEMs deployed in 3 Capitol Hill Buildings and 3 offsite locations.
  - (Architect of the Capitol manages over 100 fixed sensor sites throughout 5 Library buildings).
- Climate Notebook ®Analysis Software
- MyClimateData: The Collections Storage System
  - Web-based application created to collect, organize, analyze risk and share many types of collection information including environmental data, floor plans, photographs, notes.
  - www.imagepermanenceinstitute.org
  - Myclimatedata is a new application that IPI created for the Library which we intend to launch towards the end of this summer 2008.

Benefits

Our facility is large but onsite manual downloading is still very feasible. We use the CNB compare notebooks feature frequently to look at an indoor climate in relation to outdoor conditions. We also compare current data to past performance in the same space or spaces with theoretically similar mechanical capabilities.

Fig. 5. Online availability of data, either real time or archived graph

Fig. 6.

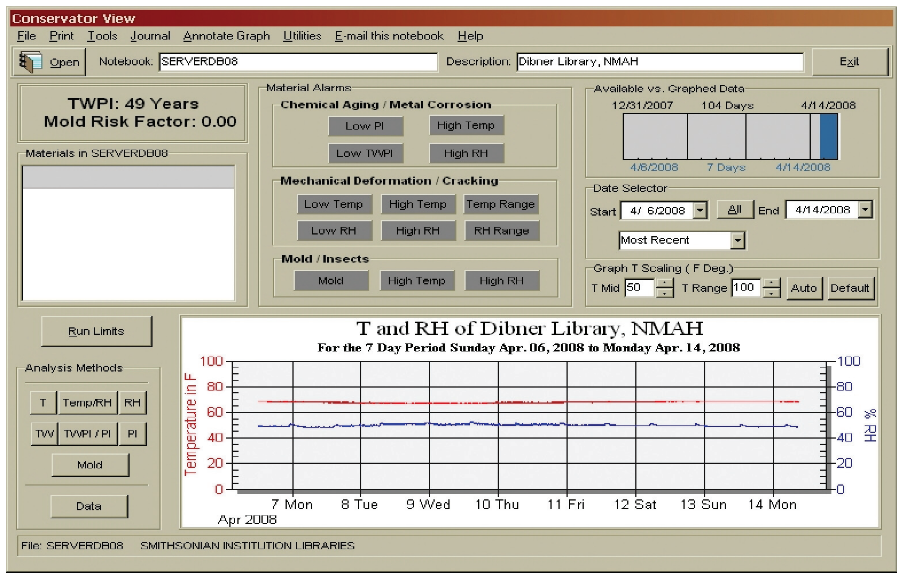


Fig. 7. Climate Notebook Conservator's View

- PEMs
  - Easy to install and operate.
  - Portable therefore flexible.
  - Accurate / IPI performs will calibrate units.
  - Easy to remedy problems without losing data.
  - Requires regular site visit to collection spaces for downloads.
- Climate Notebook®
  - Allows data to be manipulated in many ways.
  - Allows spaces to be compared including outdoor data.
  - Analyzes and displays data by temp, RH, dew point, Preservation Index, Equilibrium Moisture Content.

(See figs. 8–10)

Drawbacks

Even the new PEM II costs a few hundred dollars which can be prohibitive, although well worth the expense. Anyone in the conservation/preservation profession should be capable of mastering Climate Notebook but its complexity may not be suitable for a small cultural institution particularly.

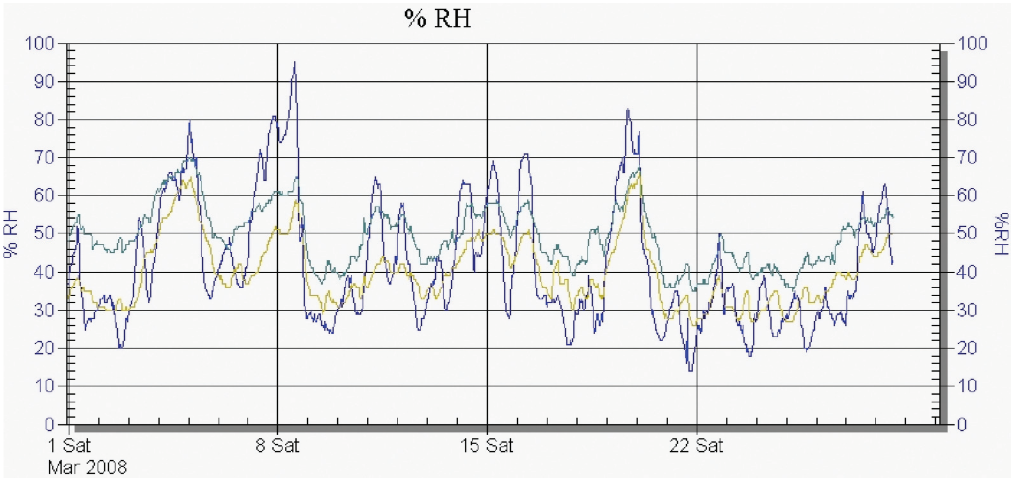


Fig. 8.

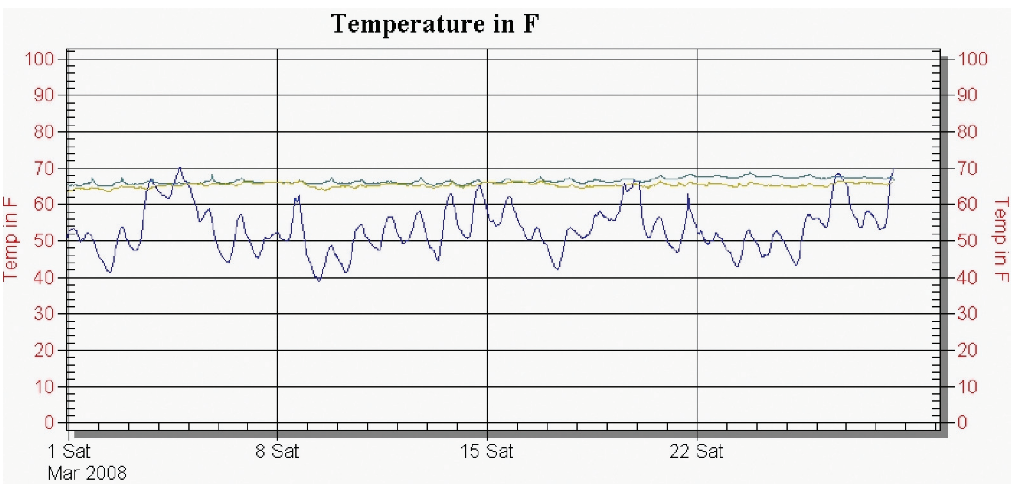


Fig. 9.

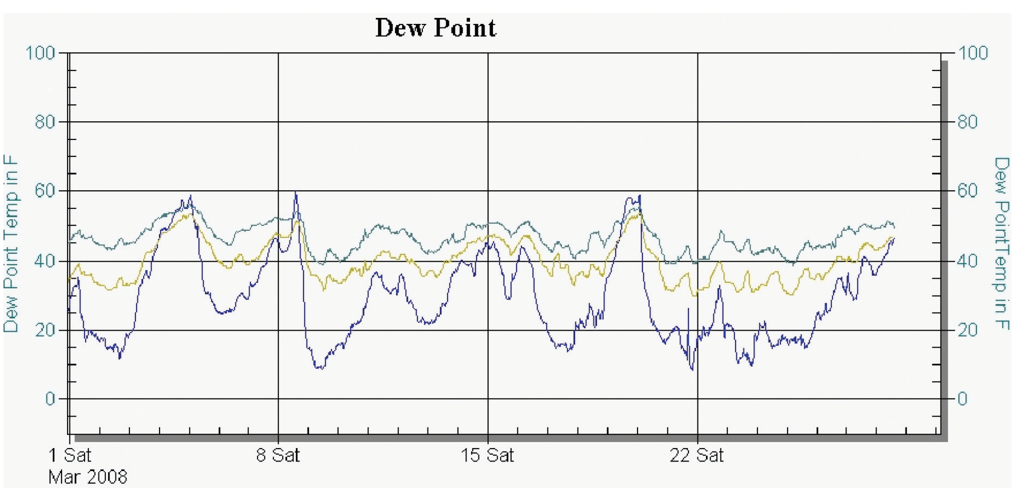


Fig. 10.

- PEMs
  - – Not inexpensive.
  - – PEM I SRAM Cards have limited memory and require card reader.
  - – (PEM II uses standard flash drive to collect data).
  - – Requires onsite downloads.
- Climate Notebook®
  - – Requires time and attention to learn software.

Lessons Learned

We have several vaults and exhibit cases with independent HVAC equipment that if malfunctioning can produce heat without cooling. These spaces can become very warm—above 80F—within a day. I believe that built in equipment shutoffs are more immediately reliable than alarms but your monitoring strategy should reflect specialized concerns. In a larger strategic sense we are focused on the long term both in our investigations and in our approach to remedy problems. Like most institutions LC facility staff has many balls to juggle including life safety concerns which always take priority. Every mechanical deficiency cannot be addressed at once. Conservation/preservation staff need to understand the resources and expertise available in facility departments, to prioritize, and bring forward problems with this in mind.

- Understand your objectives and priorities.
- Short term and urgent.
  - – Protect specialized climates that can quickly change such as insulated vaults or cases with independent HVAC equipment through frequent and/or constant monitoring.
- Long term
  - – Focus on careful investigation that leads to sustained improvements rather than quick fixes.
  - – Think about how the location of monitors or sensors influences data.
  - – Collect and analyze data strategically by location, season or event.
- Work collaboratively with facilities and collections colleagues.
  - – You'll need to have a good relationship with facility technicians, mechanics or engineers unless you can single-handedly run your building.
  - – Collection managers and staff can be the most persuasive advocates for preservation.
- Do not use environmental data as a cudgel.
  - – Even well-intentioned sharing of environmental data can be taken as " I know more than you do."

Special Applications

- Monitoring conditioned exhibit case versus unconditioned case to determine effectiveness of silica gel.
- Comparing data collected from monitors in storage space against data collected from data loggers placed in return air ducts.
- Verifying effects of known mechanical adjustments such as planned shut downs or announced changes in chilled water temperature.

VASARE RASTONIS

ENVIRONMENTAL MONITORING SYSTEMS AT COLUMBIA UNIVERSITY

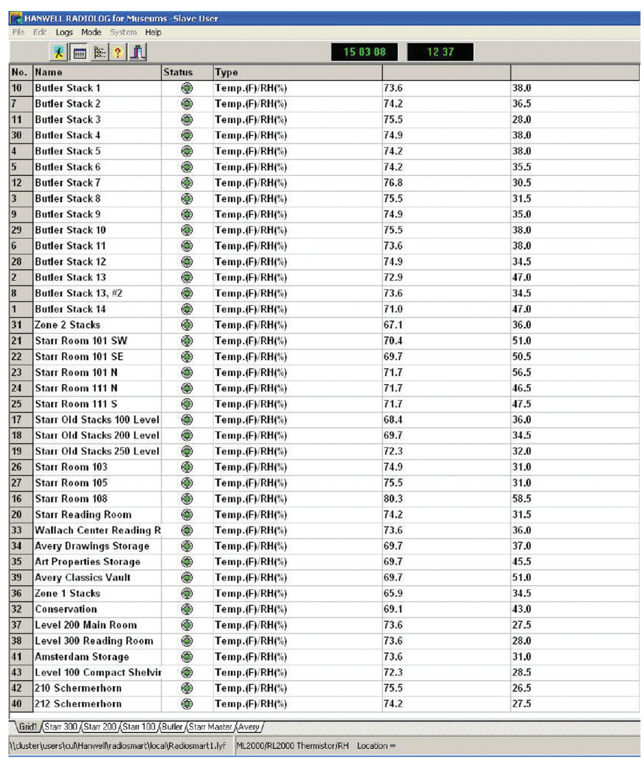
Dataloggers

- 14 ACR Smart Readers
- 41 Hanwell RL–2100 sensors
- 7 PEMs & 5 PEM2s

How Hanwell Works

- 41 sensors in 3 libraries collect data using Vaisala sensors.
- Data is sent in set intervals to 4 Smart receivers in the 3 libraries via radio telemetry.
- Hanwell software polls the Smart receivers for stored data.
- Data is transferred to the server at Butler Library over the network.
- Environmental data can be accessed by 15 PCs but can only be controlled by 1 PC in the conservation lab at Butler Library.

(See fig. 11)



No.	Name	Status	Type		
10	Butler Stack 1		Temp.(F)/RH(%)	73.6	38.0
7	Butler Stack 2		Temp.(F)/RH(%)	74.2	36.5
11	Butler Stack 3		Temp.(F)/RH(%)	75.5	28.0
30	Butler Stack 4		Temp.(F)/RH(%)	74.9	38.0
4	Butler Stack 5		Temp.(F)/RH(%)	74.2	38.0
5	Butler Stack 6		Temp.(F)/RH(%)	74.2	35.5
12	Butler Stack 7		Temp.(F)/RH(%)	76.8	30.5
3	Butler Stack 8		Temp.(F)/RH(%)	75.5	31.5
9	Butler Stack 9		Temp.(F)/RH(%)	74.9	35.0
29	Butler Stack 10		Temp.(F)/RH(%)	75.5	38.0
6	Butler Stack 11		Temp.(F)/RH(%)	73.6	38.0
28	Butler Stack 12		Temp.(F)/RH(%)	74.9	34.5
2	Butler Stack 13		Temp.(F)/RH(%)	72.9	47.0
8	Butler Stack 13, #2		Temp.(F)/RH(%)	73.6	34.5
1	Butler Stack 14		Temp.(F)/RH(%)	71.0	47.0
31	Zone 2 Stacks		Temp.(F)/RH(%)	67.1	36.0
21	Starr Room 101 SW		Temp.(F)/RH(%)	70.4	51.0
22	Starr Room 101 SE		Temp.(F)/RH(%)	69.7	50.5
23	Starr Room 101 N		Temp.(F)/RH(%)	71.7	56.5
24	Starr Room 111 N		Temp.(F)/RH(%)	71.7	46.5
25	Starr Room 111 S		Temp.(F)/RH(%)	71.7	47.5
17	Starr Old Stacks 100 Level		Temp.(F)/RH(%)	68.4	36.0
18	Starr Old Stacks 200 Level		Temp.(F)/RH(%)	69.7	34.5
19	Starr Old Stacks 250 Level		Temp.(F)/RH(%)	72.3	32.0
26	Starr Room 103		Temp.(F)/RH(%)	74.9	31.0
27	Starr Room 105		Temp.(F)/RH(%)	75.5	31.0
16	Starr Room 108		Temp.(F)/RH(%)	80.3	58.5
20	Starr Reading Room		Temp.(F)/RH(%)	74.2	31.5
33	Wallach Center Reading R		Temp.(F)/RH(%)	73.6	36.0
34	Avery Drawings Storage		Temp.(F)/RH(%)	69.7	37.0
35	Art Properties Storage		Temp.(F)/RH(%)	69.7	45.5
39	Avery Classics Vault		Temp.(F)/RH(%)	69.7	51.0
36	Zone 1 Stacks		Temp.(F)/RH(%)	65.9	34.5
32	Conservation		Temp.(F)/RH(%)	69.1	43.0
37	Level 200 Main Room		Temp.(F)/RH(%)	73.6	27.5
38	Level 300 Reading Room		Temp.(F)/RH(%)	73.6	28.0
41	Amsterdam Storage		Temp.(F)/RH(%)	73.6	31.0
43	Level 100 Compact Shelvir		Temp.(F)/RH(%)	72.3	28.5
42	210 Schermerhorn		Temp.(F)/RH(%)	75.5	26.5
40	212 Schermerhorn		Temp.(F)/RH(%)	74.2	27.5

Grid1 / Starr 300 / Starr 200 / Starr 100 / Butler / Starr Master / Avery

\\cluster\users\cul\Hanwell\radiosmart\local\Radiosmart1.lyf ML2000/RL2000 Thermistor/RH Location =

Fig. 11. "Text" view for all 41 radiologgers/sensors

Pros

- Convenient monitoring of current environmental conditions from a PC or Mac with Windows.
- Environmental data can be batch collected and backed up as .csv files—especially time saving with 41 monitored locations.
- Temperature and RH can be recorded at varying intervals (once every 5 seconds to once every 12 hours).
- Sensors can either stand freely or be mounted to a surface using Velcro or high security metal brackets.
- Sensors general properties, calibration, filters and alarms can be adjusted as needed.

Cons

- Sensors run on 9v batteries which require replacement approximately every 7–8 months for sensors with display screens and 9–10 months for sensors without display screens.
- The Conservation department does not receive support from our IT department for Hanwell software.
- With the availability of real time data, 1–2 hours a week can be spent checking the conditions and reporting to curators and facilities when problems occur.
- The sensors with display screens show temperature in degrees Celsius.
- Poor radio frequency causes alarms to show in the "text" view and spikes in data to appear in the "graph view."

EMILY KAPLAN

NATIONAL MUSEUM OF THE AMERICAN INDIAN (NMAI): HANWELL SYSTEM

NMAI has three facilities, one in New York, one in Suitland, Maryland and one on the National Mall in Washington DC. They use the Hanwell system at the Suitland and Washington facilities and Hobos at the New York facility. What follows is a summary of experiences with the Hanwell system at the Maryland and Washington facilities.

The NMAI Cultural Resources Center in Suitland, MD, which opened in 1999, is the NMAI storage and research facility. Hanwell Environmental Monitoring System (EMS) software, an Architect controller with receiver and one repeater, and eleven relative humidity/temperature radio telemetry sensors with auxiliary battery packs are used in the Suitland facility. The sensors are placed in three levels of collections storage (approximately 48,600 cubic feet), and in all collections processing rooms including conservation laboratories. Collections Management staff are responsible for monitoring the system, tracking and turning off alarms, printing out reports, and reporting any problematic environment changes to the Smithsonian Office of Facilities, Engineering, and Operations. Collections staff also compare data collected from the Hanwell system to the building HVAC system reports. This has been particularly useful when addressing unacceptable swings in relative humidity.

NMAI uses a dedicated PC in the collections storage area with an Uninterruptible Power Supply because the building has a history of power outages, which can affect data collection. Several staff members have access to the Hanwell software from their desktops using a Windows Remote Desktop Connection. NMAI also uses hygrothermographs in some areas for backup and comparison. The challenge at this time is to decide whether to invest in a system upgrade (most of our components were purchased in 1999) to attain consistency in environmental monitoring methods with our two other facilities. The EMS software has been superseded by a new software system and cannot be upgraded, which makes IT support problematic. NMAI currently does not have a service contract with the vendor. So options are being evaluated.

At the NMAI exhibit facility on the Mall in Washington DC which opened in 2004, we use a more recent version of the Hanwell software and sensors; including Radiolog software, an Architect Host Computer AR510 base station/receiver, and twenty relative humidity/temperature radio telemetry sensors with auxiliary battery packs. Some sensors are equipped with external probes. Sensors are installed in galleries, some exhibit cases, and the collections workroom. Since the sensors have probes, the sensors themselves easily can be hidden in the galleries, inside cases, and under case decks. There is no dedicated PC for this Hanwell system, it is accessible only from the Collections Manager's desktop and from a PC in the central server room that can only be accessed by the IT staff.

NMAI has had some challenges with the Hanwell system. As the museum was being prepared to open, the initial installation of hardware and software did not perform reliably for several months due to unexpected radio signal interference caused by the building structure. Although the vendor visited on site when the building was a shell to test radio reception from various floors to an internal antenna, the signals did not transmit continuously from distant corners of the galleries after the walls and exhibit cases were in place. NMAI also experienced problems with the Architect base station crashing due to initial building power outages and other problems that still sporadically happen. An additional "Bermuda Triangle" effect occurred in one display case that contained plasma screens-the Hanwell engineers have never determine why the screens interrupted the radio signal. So NMAI gave up after several months and reverted to a recording hygrothermograph inside that case.

The system is currently running with a new version of the software and two repeaters, one on each gallery floor. The main drawback, in addition to the Architect crashing, is the labor-intensive interface. The alarms require manual

data entry and authorization each time a sensor experiences a reading outside of parameter that lasts for more than 10 minutes. (The 10 minute elapsed time alarm was especially frustrating when units were reporting sporadically due to signal loss.) Another consideration is battery replacement—considerable labor and frequent access to exhibit cases is needed to change the 9 volt batteries needed by the unit. Auxiliary battery packs with 4 AA batteries are useful because they can extend the working time of the sensor, but they are awkward and bulky in part because they need electrical tape to secure the battery pack to the sensor unit. The auxiliary battery pack is not a problem in collection storage areas but can be a problem in exhibit cases due to space restrictions and aesthetic concerns.

The Collections Manager, monitors data from her desktop and can print out charts for the units in the 20–25 different locations in the galleries, storage, and cases. This is a useful tool for accountability and to use when communicating with building engineers and maintenance staff. For example, if there are unusual spikes on the charts that set off the alarm, the system notes the precise date and time which helps the engineers diagnose the HVAC malfunction. If the system goes out of parameter and is not reported by engineering night shifts, it is possible to determine who was on duty at the hour of malfunction that went undetected.

NMAI has Hanwell sensors in some cases, Arten sensors in others, and a recording hygrothermograph in one case. The Collections Manager visually monitors the displays during periodic gallery walkthroughs. NMAI also uses HOBOs in some cases for a light monitoring project, these are downloaded monthly.

LINDA BLASER

ENVIRONMENTAL MONITORING: PEM AND CLIMATE NOTEBOOK IN THE REGIONS

My experience working at both the National Archives and Records Administration and National Park Service there were several types of environments to monitor—cold storage for acetate film, cool storage for electronic media, archival storage, preaccessioned permanent records storage, and temporary records storage. Each type of record is controlled by a different set of regulations and therefore has different set points and goals. In both situations I've used PEMs to monitor those environments. PEMs are used to certify the environment in new buildings, alert staff to problems, as a basis for discussions with facility managers, used to compare microclimates and stratification within a storage space, and used to verify compliance with regulations.

Climate Notebook software provides easy to interpret reports that can be used when discussing environmental conditions with the building engineers, and the collections managers.

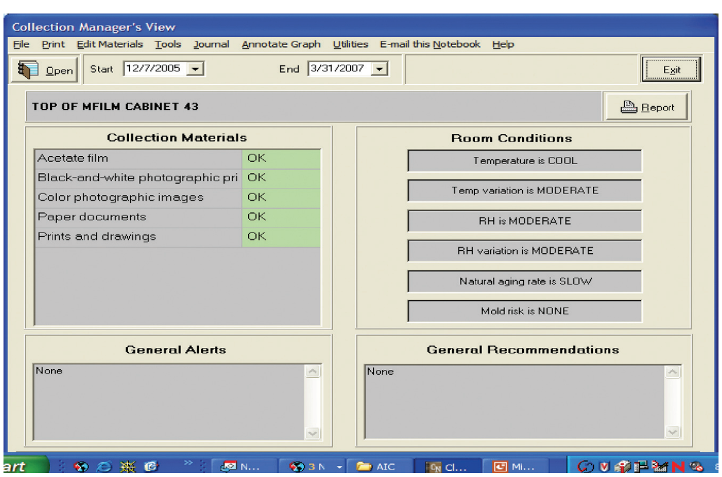
(See figs. 12–13)

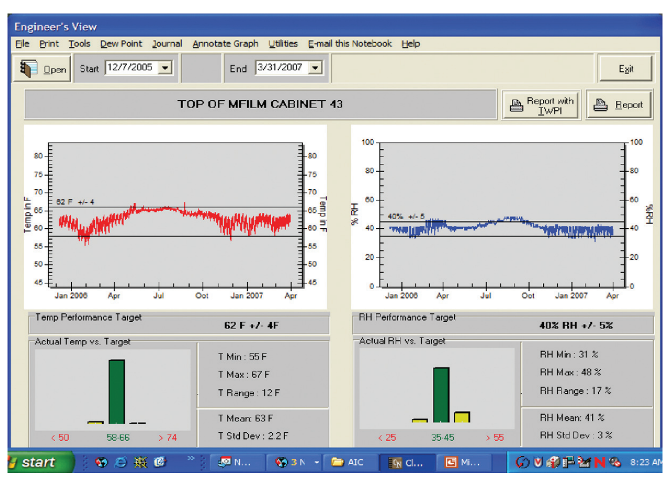
Prior to the April 2008 Archives Discussion Group, we asked several conservators who were unable to attend to contribute his or her opinions about data loggers.

ADG DISCUSSION COMMENTS AND QUESTIONS:

Contributor 1

One participant uses HOBO's because of the significantly lower price-tag and small size (easy to put in traveling exhibit cases, easy to hide). Besides having monitors placed in permanent monitoring position, additional monitors are often needed for short term projects. Having a HOBO "back-up





Figs. 12–13.

stash" fulfills those types of needs. HOBOs need more sensor and battery changes. The data from HOBOs can be are difficult to export into the Climate Notebook. At this institution there is a dedicated computer for all the environmental software and records to eliminate potential problems caused by multiple and different software systems and multiple peoples having access to the system. Those problems include lost data, slowness, and misplaced files. They have found that HOBOS to be less accurate and are less reliable over the long haul than the PEMs. If you need pin-point precision with your data, you may want a PEM. Accuracy of the ACR system is somewhere in between HOBOs and PEMs. Deciding which to purchase depends on what you need to do.

Resistance to monitoring and the need for it are common complaints among staff, especially since people can be too overly tweaked by small nuances like cycling or the converse, not knowing how to interpret the information (raw data or graph form). An additional problem is the perception that all of the data from the various types of monitoring equipment data needs to match EXACTLY, which is very unlikely.

Contributor 2

One participant could not recommend the SmartReader II. In this conservator's opinion, the SmartReader took most of a day to download and had batteries in them that require proprietary replacement by the company (i.e. costs upwards of $200–$300 to change the battery). Additionally, one could consider updating to a new model instead for a little more money when the batteries run low. However, be aware that once the batteries begin to run low, the humidity meter goes awry, thus disrupting the saved data.

Contributor 3

Although there are other considerations such as long term reliability, warranties, calibration, sensor replacement, flexibility and readability of downloaded data, the accuracy of moderately priced dataloggers are entirely adequate for describing daily fluctuations and seasonal change patterns, and are acceptable for a wide range of collection materials. Patterns of change are as important as refinement of the numbers. Of course, you will have to produce data that is credible, especially if it becomes a question of "who has the right numbers?" between facilities maintenance and conservation staff. Be prepared to bring your own testing equipment to confirm the conditions you are presenting. If cost is a concern, try the lowest priced instrument that can provide comparable performance to recommended brands (a HOBO, for example). Check the manufacturer's specifications—in particular, the "plus or minus" accuracy figures over which Relative Humidity and temperature range. Some units come with software; for others, it is an additional one-time cost. Make sure you are getting an 'apples to apples' comparison. See if you can work with the system on a trial basis before committing to the purchase. Although an added cost, use a good quality digital psychrometer to test readings of dataloggers, and to use to spot test the environment. Specialized scientific equipment suppliers may offer lower prices than general archival suppliers. Check out battery-powered, mechanical hygrothermographs, because they can provide the same useful data, are reliable, accurate if maintained properly, can be user-calibrated and the information is always immediately available to view. The downside is that you will have to buy charts and pens, which are getting pricey.

As far as convincing administrators of the importance of the collections' environment: after gathering the environmental records you hope to provide, present your concerns using a Risk Management approach. Prioritize your collections in terms of vulnerability and sensitivity to environmental change and extremes, and other potential hazards to your collections. Show examples of environmentally deteriorated collection objects and be well-informed of current information and research on the subject, and speak about with predicted rates of deterioration over time at varying relative humidity and temperature levels. Arrange visits for your superiors to institutions with superior environmental control as an incentive which could lead a better environment for your collections.

Contributor 4

My favorite data logger is the Preservation Environmental Monitor developed especially for use in Museums by the Image Permanence Institute at the Rochester Institute of Technology. Many different data loggers can gather T and RH data and present it in a graph. What sets the PEM above the others is the Climate Notebook software that was also developed by IPI. Climate Notebook performs numerous analysis functions, including comparing T and RH in different buildings or from different galleries. It generates several different reports that are not only easy to read, but easy to understand by allied museum professionals such as collections managers, climate control engineers, and directors. Climate Notebook will also accept data from other dataloggers such as Hobo.

We have 5 PEMs that we have moved around to 12 different buildings, gathering a year or two of data on each building and characterizing conditions to justify environmental upgrades. We use the reports as supporting data for NEH and IMLS grants. Once the grant project is complete, we submit Climate Notebook reports to show the improvement in the collections environment. IPI has recently updated the PEM and is embarking on an 18-month field test of the new and improved product. Each PEM runs for 5 years without a battery change and stores all the cumulative information. It can be downloaded to a data card and transferred into Climate Notebook on a PC. IPI provides excellent support for their product. PEMs are more expensive that Hobo's but I have found that they are certainly worth the cost.

Contributor 5

One contributor uses Hanwell radiologgers purchased through Greg Basso of Cascade Group. She states, "we have some ACR Smartreaders (dataloggers) that are approx. 10yrs. old that we use in some storage areas, crates and exhibition cases. Spaces can be monitored remotely from the desktop computer". Besides conservation staff, the registrars and the facilities engineers understand how the radiologgers work. A total of 2 or 3 of 60 staff members are charged with environmental monitoring. The space is a museum collection. In the galleries the loggers are placed in appropriate locations agreed upon by the designers and conservators. There is one logger per gallery and one per storage space. Monitors are also used in the conservation lab. The equipment has not been calibrated to date, as they have had the equipment for just 1½ yrs and haven't had to deal with calibration yet. The vendors claims the calibration is very stable and the loggers can be calibrated with the software. Purchasing this system was related to cost: they received an internal grant to acquire the system otherwise they could not have purchased it. The loggers are approx. $1000 ea. And the equipment to run them can be another $2500–5000 or more depending on the type of building/structure, size and distance of all the spaces that one wishes to monitor.

One of her positive points includes getting real-time readings and weekly and /or monthly charts for current or past months. The new system helped the institution revisit and establish guidelines for temperature and RH in the museum working with the facilities staff. They are currently monitoring a few storage areas, the conservation lab and about fourteen galleries. Soon, they will be increasing the number of gallery spaces with 10 more loggers. A unique application includes using a radio logger to monitor the interior of an exhibition case. The dataloggers are a little large to put in a case and require a special case design. The designers like the loggers better than hygrothermographs because they are smaller and less noticeable in the galleries.

On the negative side, the institution does not have sole control. They must rely on the vendor to make adjustments in the system when problems arise with access or the system is not working properly. One of the lessons learned includes "…as a government agency we cannot hold the FCC license needed for the system so the vendor holds the license. That could be a problem in the future if something should happen to the vendor."

Contributor 6

One of our contributors, Mark McCormick-Goodhart of Aardenburg Imaging & Archives, conducts image permanence research on modern digital printing technologies. One of his research projects includes a print monitoring program which tracks the aging process of prints in real-world (RW) settings via special picture frames that are embedded with two environmental data loggers and a light sensor. To read about this research, please see http://www.aardenburg-imaging.com/realworldprintmonitoring.html.

Contributor 7

This contributor used ACRs for long time, as they aged and were no longer viable, this same contributor sought and received an NEH grant to purchase all new PEM dataloggers and Climate Notebook software. The dataloggers were rolled into the grant proposal as part of exhibition. Private practice conservators who work with small collection might also try to roll environmental monitors and their corresponding software into grants they may write on behalf of those small institutions.

Contributor 8

For that matter, environmental monitoring equipment and software can also be included when developing Capital Campaign requests.

Contributor 9

The Rotronix datalogger system is also quite useful. It is easy to calibrate in-house using salt solutions. Once calibrated other dataloggers can be compared to the calibrated Rotronix datalogger to determine the accuracy of the other brand datalogger. Unlike dataloggers that must be recalibrated at the factory, those institutions with Rotronix dataloggers will never experience an extended downtime for recalibration.

Aircuity dataloggers measures temperature, relative humidity, and pollutants. However, they do not work well in cold storage environments. The Acuity datalogger's allowable pollutant levels are much higher than what would be considered acceptable in a museum environment. While this system may work well for office spaces, it is not suited for museum spaces.

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Library Collections Conservation Discussion Group 2008: Digitization Project Case Studies

ABSTRACT

The Library Collections Conservation Discussion Group (LCCDG) of the Book and Paper Group was pleased to host a panel discussion on "Digitization Project Case Studies" at the 2008 AIC meeting held in Denver, Colorado. This topic was conceived following the lively brainstorming session held during the joint Electronic Media Group (EMG)/LCCDG discussion group at the 2007 AIC annual meeting in Richmond, VA. In preparation for the 2008 discussion group, the LCCDG co-chairs Sarah Reidell and Laura McCann recruited book and paper conservators to present short, informal case studies of digitization projects that incorporate conservation workflows. The five panelists selected represented a full range of digital imaging projects, from cooperative efforts with large corporations to in-house reformatting efforts. Each panelist shared a short presentation on a digitization project from their institution; described the size and scope of the project, funding source(s), staffing, project workflows, selection criteria, conservation treatment workflows, and treatments; and concluded with analyses of lessons learned and recommendations to colleagues. After presentations, the moderators led a question-and-answer session between the enthusiastic crowd and the five panelists.

PANEL PRESENTATIONS

Priscilla Anderson, collections conservator in Baker Library Historical Collections at the Harvard Business School, shared details of Baker Library's in-house subject-based digitization project, "The Development of American Capitalism," which produced a web-based virtual collection of approximately 1300 special collection items including unbound sheets, photographs, and bound volumes. Anderson described how digitization projects vie for the time and attention of the Baker Conservation staff as they review material, determine whether each item needs pre-scan or post-scan treatment (including what level of treatment), rehouse each item, and/or define special handling requirements during scanning. Pre-imaging assessment decisions represent difficult and often significant compromises but in this case were required to meet tight timeframes for digital imaging and were critical to achieving department goals. Collection materials returned for post-scanning assessment and treatment are often considered differently than the regular workflow because the existence of the high-quality, easily accessible scan presumably reduces the likelihood of a patron wanting to use the original item.

Heather Hendry, paper conservator in the Harvard University Library, Weissman Preservation Center (WPC), discussed her experience as a conservator dedicated solely to digital imaging projects. Harvard University's cooperative efforts to manage simultaneous, special collections digitization projects have provided the WPC with an opportunity to refine the conservation component of these projects over time. Each project builds upon the experience from previous projects, especially in developing flexibility in work spaces, tools, techniques, and staffing. These cumulative experiences have helped to establish relationships between conservation, special collections staff, and the digitization department. Efficient management of time and work enables treatments to be tailored to the object's needs and project time requirements. Treatment to prepare objects for digitization ranges from surface cleaning to more complex and extensive conservation. Tight deadlines for treatments are met by using a combination of conservators, technicians, and student assistants, as the complexity of the treatment requires.

Mary Oey shared her experience as conservator of music manuscripts at the Morgan Library and Museum in New York, which in 2007 received a donation to conserve and digitize the library's music manuscript collection. Her presentation

This open discussion took place on April 24, 2008, during the AIC 36th Annual Meeting, Denver, CO. The moderators organized the panelists, led the discussion, and recorded notes. Readers are reminded that the moderators do not necessarily endorse all the comments recorded and that although every effort was made to record proceedings accurately, further evaluation or research is advised before putting treatment observations into practice.

covered the planning and beginning stages of implementing a conservation and digitization project led by the conservation department. The project goals were not only to increase access to the collection via the World Wide Web and improve condition of collection, but also to advance professional standards of best practices for photographic digitization and to provide a working model for similar endeavors. Conservation treatment aimed specifically at both ensuring physical stability of manuscripts during imaging and improving the visual suitability of content for online publication. Commonly performed treatments included, tape removal, removal of old mends, aqueous treatment, and mending. Less frequent treatments were stain reductions and binding treatments.

Shannon Zachary, head of conservation services of the University Library at the University of Michigan, and Holly Robertson, head of preservation services at the University of Virginia Library, both spoke about cooperative mass digitization ventures with Google, Inc. The Google partnerships vary among institutions, but generally Google provides the equipment, space, and staffing for scanning as well as legal costs. The partner libraries are responsible for planning, publicity, public-relations, work-flow supervision, preparation of volumes, and supplying cataloging data. According to the partnership agreements, Google partner libraries are not permitted to disclose how many books have been scanned, where the books are scanned, or how the books are scanned, but all other information about the project can be shared. Google partner libraries, while not permitted to discuss the methodology of the digitization, are able to visit the facilities and inspect the operations.

The University of Michigan was one of the five original institutions to partner with Google and plans to digitize the entire print collection of the University Library. Conservation staff from all five early partners were involved with the project from the beginning stages, working with Google staff on the cradle design and developing handling policies. Zachary observed that overall there was less impact on the conservation, book repair, and bindery preparations units than anticipated. This was attributed to the fact that Google staff rejects material in poor condition, such as brittle books. These rejected volumes are sent to either a commercial bindery or the conservation lab for simple treatment (e.g., board reattachment using dyed Japanese paper) and then resubmitted for imaging by Google when possible. Plans exist to digitize the remaining volumes, mostly brittle books, independently of the Google project. Zachary commented on the irony that this new mass reformatting project systematically rejected precisely those volumes that the preservation and conservation community would judge most in need of reformatting.

The University of Virginia (UVA) partnered with Google soon after developing a preservation program. As UVA's first preservation officer Holly Robertson spoke on her experiences navigating the challenges of working on a high-profile, mass-digitization project. The physical conditions of the library collections prompted the additional allocation of preservation funding, particularly for commercial binding, since due to the specific UVA-Google contract all volumes must be bound and in good condition to be digitized by Google. Volumes requiring more than two hours of conservation treatment and brittle books were returned to the stacks. Other volumes were either treated in- house by preservation staff or sent to the commercial bindery. Robertson emphasized the need to visit scanning facilities, work closely with the partner staff/library administration to ensure proper handling of the volumes, and to communicate with other conservation professions involved in similar projects.

DISCUSSION SESSION

The second part of the LCCDG session was a half-hour discussion with questions from the audience and led by co-moderators Sarah Reidell and Laura McCann. Two major themes emerged in the discussion: the impact of digitization projects on conservation/preservation departments and the ethical implications of changes in treatment decision-making.

A common theme from the panelists was the ethical issue of adapting and redesigning conservation treatment to facilitate scanning. Panelists noted a shift from stabilization treatments for handling and use in a reading room towards treatments concerned with the requirements of imaging systems. Structural reinforcements and stabilization treatments were utilized with less frequency in contrast to humidification and flattening of materials for imaging. An example of a scanning-oriented treatment includes removing old repairs that obscure text. Another subset of questions raised along this theme was the weighted pre-selection of materials slated for treatment based on their ability to maintain the demands of a digitization workflow. Several of the case-study projects noted that objects requiring more intensive treatment were often excluded from the conservation queue so as not to slow down the imaging system. Another of the ethical implications raised was a greater elevation of aesthetic over physical characteristics, a by-product of the increased and rapid sophistication of imaging equipment and software. The issue of treatment documentation was addressed by all the presenters. The Baker Library at Harvard Business School uses an adapted short paper form to record treatment for its digitization project. Heather Henry and Mary Oey described database documentation systems used at their institutions. Michigan maintains dated information sheets that describe repair techniques and materials. The limited treatments currently carried out at the University of Virginia are statistically recorded in ARL fields.

The impact of digitization projects on existing conservation workflows and staffing was discussed. At the University of Virginia the partnership with Google has resulted in

departmental expansion. Similarly, other institutions report creating new positions or hiring contract conservation staff specifically to meet digitization demands. When new staff hires are not possible and the digitization projects represent additional workloads Anderson emphasized the importance of using time-management strategies such as time-blocks or percentage allocations.

SUMMARY

Overall, the implementation of digitization projects provides an opportunity to recalibrate conservation and preservation efforts within the library and museum community. One point made clear by these presentations and the resulting discussion is that the conservation community gains much by sharing and cooperating within and outside of itself. Misperceptions about non-disclosure agreements often unnecessarily isolate institutions and those working on digitization projects. Focused and project-based employment is increasingly driving hiring strategies and serves as a challenging platform for conservators at all stages in their careers. Communicating our collective accumulated knowledge through conferences, listservs, formal and informal articles, and personal communication benefits the projects, the health of our cultural collections, and our profession.

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Alternative Fabric Supports for the Dacron Lining Technique for Paper Objects

ABSTRACT

The Dacron technique for lining paper objects was described in the conservation literature in the first volume of the *Book and Paper Group Annual*. Dacron lining is one of a number of methods used to line paper objects and dry them under tension. An advantage of Dacron lining is its suitability for large paper objects such as wall maps. The size limitations depend on the dimensions of the Dacron available and that of the table/rigid support. The method can be used where extra care is needed to keep tear edges aligned. It works well when lining an artifact with losses where uneven pressure during drying can be problematic. Artifacts lined in this way become particularly flat; therefore this must be the desired effect.

In the past few years, it has been noted that the Dacron that is offered in supply catalogs differs from the original product used when this technique was first described. The original Dacron had a smooth surface that readily released from the Japanese paper lining once drying was complete. The new Dacron has more tooth and can cause damage to the lining paper during release. For this research project, the efficacy of different fabrics was tested in order to find an alternative to the original Dacron. A summary of the technique, its advantages and disadvantages are presented. A survey of paper conservators and textile suppliers determined which fabrics to test. Examination and testing included adherence to the rigid support and lining paper and subsequent ease of release from the lining paper. Finding an alternative fabric will ensure that this valuable lining method does not disappear from the conservator's repertoire of techniques.

INTRODUCTION

The Dacron lining technique had been successfully used by the authors on numerous occasions, primarily in the lining of oversize maps. However, attempts to use this technique with the new version of Dacron were found to be unsuccessful. The lining paper stuck too firmly to the Dacron such that removal proved potentially dangerous to the object being lined. Alternative fabric sources for this useful technique were investigated. Literature and internet searches were done to investigate the technique and variations. The technique was first described by Gary Albright and T.K, McClintock in the *Book and Paper Group Annual*, 1982. It was then listed as a possible lining technique in the *Paper Conservation Catalog*, Chapter 29. A few discussions on the Conservation DistList mention the difficulties in finding the "Original" Dacron. Suggestions for alternatives included using the "New" Dacron with a Hollytex intermediary or using a filament polyester taffeta.

Seven fabrics were chosen to test the Dacron lining method. The qualities needed to replicate the "Original" Dacron were as follows:

- good adherence to the rigid support to retain tension while drying
- good adherence to the lining paper
- easy removal of lining paper from fabric
- upon removal, fabric should not impart a texture/pattern to the lining paper

Two samples of the "Original" Dacron that had been used successfully for many years were used as the controls. The newer version of Dacron, purchased through Testfabrics, Inc. was tested alone and with the use of Hollytex as an intermediary layer between the "New" Dacron and the lining paper. Three additional fabrics were chosen from the Testfabrics, Inc. catalogue that had similar characteristics to the "Original" Dacron, Filament Polyester Oxford Weave (Style 749), Polyester Taffeta (Style 738) and Baumann Unilargo 100% Polyester plain weave.

Two different Japanese papers were used for the linings, Hiromi Sekishu R-014 Extra thin and Paper Nao RK-27. The two papers were chosen to replicate a lining of a small

Poster presented at the AIC 36th Annual Meeting, April 21–24, 2008, Denver, Colorado.

TOP TO BOTTOM, LEFT TO RIGHT

Fig. 1. Paste applied to a sanded piece of Plexiglas

Fig. 2. Paste applied to the surface of the fabric

Fig. 3. Wet lining paper, on Mylar support, placed onto fabric

Fig. 4. Paste applied to lining paper

Fig. 5. Wet/damp object, on Mylar support, placed onto lining paper

Fig. 6. Mylar rolled off surface of object

Fig. 7. Completed lining left to dry

paper artifact and an oversized artifact, respectively. Four poster-weight papers were cut to 50 x 34 cm pieces to be lined. Linings were all done on sanded Plexiglas boards using Aytex-P wheat starch paste. The fabrics were tested twice with each Japanese paper. The most successful fabrics were tested a third time.

THE DACRON LINING PROCESS

Below is a brief description of the technique as it was performed for this test. The method was based on that described in the *Paper Conservation Catalog*, Chapter 29.

Materials:

- Heavy Plexiglas sheet (sanded)
- Japanese paste brush
- Japanese smoothing brush and/or roller
- “Dacron” or an alternative release fabric, dampened and rung out
- Japanese paper
- Wheat starch paste. The paste is usually thinned to a consistency similar to whole milk. A loaded brush should glide easily over the fabric and Japanese paper.

1. Spray out the artifact to be lined and apply it face down to a Mylar sheet then set it aside. Alternatively, place the artifact in a water bath and remove on a Mylar sheet.
2. Using the Japanese brush, apply an even layer of paste to the Plexiglas (fig. 1).
3. Spread the Dacron sheet out over the paste layer. Smooth out wrinkles with a smoothing brush.
4. Apply an even layer of paste to the Dacron (fig. 2).
5. Apply the Japanese paper to the Dacron surface. One edge of the Japanese paper is placed in contact with the Dacron surface. The remainder is held by one person and incrementally lowered to the Dacron surface while another person smoothes the paper down with a smoothing brush (fig. 3).
6. Paste out the Japanese paper (fig. 4).
7. Apply the artifact to the Japanese paper. Apply one edge of the Mylar support first and lower the artifact down, smoothing it into place through the Mylar (fig. 5).
8. Roll back and remove the Mylar (fig. 6).
9. Allow the artifact and lining to dry (fig. 7).
10. When dry, release the Dacron using a large spatula.
11. Release the Japanese paper from the Dacron in a similar manner. Release all edges first, then the body of the lined artifact. The Dacron can also be carefully pulled away from the Japanese paper lining once the edges have been released.

Fig. 8. Removal difficulty and skinning using “Original” Dacron pink

Fig. 9. Release of Japanese paper from Baumann fabric

RESULTS AND CONCLUSION

The fabrics tested varied in their efficacy as lining supports. They varied in terms of adherence during drying and release after drying was complete.

Adherence

While all of the fabrics adhered well to the Plexiglas drying board, some did not adhere well to the Japanese lining papers. The Baumann fabric, for example, did not adhere to the Japanese paper (fig. 8). The lined item released from the Baumann fabric and became severely cockled. Such a lining could potentially cause serious damage to an artifact. The Polyester Taffeta adhered well to the heavier, RK 27 lining paper, but the thinner Sekishu released and cockled slightly.

Release

Some fabrics could not be safely removed from the lining paper. When the fabric was separated from the Japanese paper, using a large Teflon spatula, the paper was severely skinned. The "New" Dacron, as well as the "Original" Dacron, pink, behaved in this way (fig. 9).

Recommended Fabrics

Three fabrics performed well both in terms of adherence and release. They adhered well to the Plexiglas board during drying but released with careful use of the Teflon spatula. These fabrics can be recommended for use. The second and third fabrics listed can be purchased from Testfabrics, Inc.

- "Original" Dacron, white—This fabric is no longer available for purchase or is difficult to find.
- "New" Dacron with Hollytex—Please note that without the Hollytex, this fabric actually *damaged* the Japanese lining paper.
- Polyester Oxford Weave

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FABRICS SOURCE

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ROSEMARY FALLON AND NORA LOCKSHIN

Which Cracked First: The Inkin' or the Egg? Analysis and Treatment of Ink Deterioration in the William Bache Silhouette Album

BACKGROUND

William Bache arrived in Philadelphia from England in 1793 with no apparent training as a silhouettist. He began his career in Baltimore in 1803 along with two partners: Augustus Day, who was a Philadelphia carver and gilder, and Isaac Todd. The partners were granted a patent on June 15, 1803 for a physiognotrace, a device for tracing a profile and reducing it by means of a pantograph. The National Portrait Gallery (NPG) album was created by Mr. Bache in New Orleans, between 1803 and 1809, as a record book of silhouettes. The album is notable for the diverse community represented ranging from the prominent families to freed slaves. A partial index of names appears in the back. The album was selected for treatment to appear in the NPG exhibition, *Legacy: Spain and the United States in the Age of Independence 1763–1848.*

Treatment

A prior proposal for this book had been delivered to the National Portrait Gallery (NPG) by Nora Lockshin, pursuant to a rehousing project and grant request. Rosemary Fallon re-examined the book with curators Wendy Wick Reaves and Anne Goodyear and recommended reopening the project with Nora Lockshin at the Smithsonian Center for Archives Conservation. In a joint meeting, the binding treatment was revised and agreed upon; focus shifted to the leaves to be shown in the exhibition. Reaves commented on a reddish-brown powdery substance on the silhouettes and asked if it could be treated or minimized in some way. The black silhouettes were quite glossy in some areas and showed a spotty, uneven, rusty brown appearance across the volume. Lockshin proposed analysis in conjunction with the Museum Conservation Institute (MCI) to augment the conservation treatment and the body of knowledge on Bache's materials and techniques.

Poster presented at the AIC 36th Annual Meeting, April 21–24, 2008, Denver, Colorado.

CONDITION

The brown spots of deterioration appear rusty and powdery, and are extremely friable. The circular areas are not localized in any obvious way, but it is also evident that the powdery and opacifying rusty appearance coincides with high and flex points, such as at the folded-over details, clueing us to abrasion, either from facing leaves or flexion over time. A visual effect of browning and cracking suggested iron gall deterioration, but the material seemed an illogical choice for the artist's intent and the time period. Observation under ultraviolet radiation did not signal iron-gall fluorescence (usually yellow or green); the silhouettes did reflect very weakly in the dark blue-violet range. The fluorescence did not match naturally aged samples of shellacs, ruling out India ink. Another consideration was based on prior research on another artist's silhouettes (Smith 1995; Knipe 2002), which identified the presence of Prussian blue in the black medium. Our hypothesis was that if Prussian blue were present it might be following the same deterioration path of a ferric cation and it would also complex the indicating paper. However, basic iron-gall tests came back negative over several samples.

Due to the fairly quick exhibition and research turnaround, the challenge of finding a suitable consolidant was left for future research. A simple treatment for the exhibition leaves only was proposed and carried out. Removal of brown deterioration product was tested by gently rolling a water-dampened, blotter-drained swab over the deterioration area and the whole silhouette, which was allowed to air-dry. Gloss remained unaffected, except for perhaps being slightly brighter in areas that had fine powder and dust over the smooth surface. Saliva cleaning was also tested and it did not seem to affect gloss of non-deteriorated areas, but it was not more effective than deionized water, and also presented the risk of enzymatic deterioration of the less deteriorated gloss coating. Each silhouette on the exhibition leaves was cleaned with a new swab and air dried. The amount of water present in the swab allowed for quick surface evaporation and blotter and weights were not applied. The album pages were

interleaved with sheets of silicone release paper. Currently, the item is seen as a hazardous object (see Analysis section) and HEPA–filtration vacuuming mitigation with personal protective equipment and individual health monitoring is an envisioned next step.

TECHNICAL STUDY AND ANALYSIS

Technique

Differences that point to technique can be seen across the many silhouettes, such as original variation in thickness, gloss, presence of detailed highlights, retouched losses, and even some accidental inclusions of gilding metals. The ink varies in thickness and gloss through album, especially when looking at pages 38 and 39, in which the silhouettes appear respectively matte and glossy. There is no strong evidence for a machine-manufactured, prepared, commercial silhouette paper. The character of the silhouette appears usually to be a thin wove paper, and the artist numbered the back of the silhouettes to match the index in the preparation of this album. Evidence of slow, evaporative drying can be seen in thicker areas at high magnification. There are air bubbles and craquelure, highly textured surfaces, and embedded dust. The black colorant appears even overall except where deteriorated, without washiness or pooling of black colorant. Extra silhouettes by the same artist also found in the collections provide valuable clues to the artist's technique (inked brushwork visible at the edges of a hollow cut, fully inked and highlighted, but not glossy.)

Analysis

Testing was undertaken with a team from MCI. To identify organics, both Walter Hopwood and Lockshin performed Fourier transform infrared spectroscopy (FTIR), and pyrolysis-gas chromatography/mass spectroscopy (py-GC/MS) on a minimum of acceptable samples, leading to no definitive conclusion but providing some clues that suggested resins and albumin. Lynn Brostoff used a handheld X-ray fluorescence (XRF) spectrometer on pages 38 and 39—the pages with matte and glossy silhouettes—to determine the presence of metals. Only trace amounts of iron and calcium were identified, along with significant levels of sulfur in glossy areas, and lead and/or arsenic in a few samples. As some arsenic signals overlap with those of lead, the arsenic was thought during initial analysis to be a trace element. Due to time constraints, further investigation was deferred until after the exhibition. A handling warning was issued for return of the object; more thorough XRF testing was performed, confirming the presence of arsenic in some form throughout the volume on all representative surfaces and swab wipes.

To further identify and localize the metal concentrations, Judy Watson performed scanning electron microscopy with energy dispersive spectrometry (SEM-EDS). The SEM-EDS was extremely useful as we were able to zoom in location and depth with great precision on fragments and microsamples on stubs, from black area to rusty area, including sampled rusty powder only to create elemental maps. The elemental map for sulfur alone shows a lack of sulfur at the topographically high point. The sample of rusty powder scraped from the surface of a deterioration spot was identified as containing sulfur only. Elemental mapping suggests that 1) the ink is carbon-based, 2) the coating contains sulfur, 3) the high points of the silhouettes have worn down due to pressure and abrasion of facing pages over time, and 4) the brown powder is a byproduct of this abrasion. An elemental map for iron was generated after the other analyses had taken place; it was present in amounts lower than calcium and silicon.

The object was returned after exhibition for more rigorous arsenic testing via XRF and x-ray diffraction (XRD). The analytical method XRF is not directly quantitative, but results can be compared with reference materials, also referred to as standards, of known composition. Protocols for XRF identification and quantification of arsenic-containing pesticides have been under development by scientists at MCI, using pressed pellets of microcrystalline cellulose containing embedded known quantities of arsenic trioxide as reference standards. By comparison of sample spectra to these reference standard spectra, it is possible to extrapolate that each page in the book may contain between 200–1000 ppm. Attempts to speciate the arsenic's compound form are underway. The object's container and wrapper are now labeled with a hazard warning in accordance with best practices.

COLLABORATIONS, CONCLUSIONS, AND FUTURE RESEARCH

To answer our original question (which cracked first: the inkin' or the egg?) from the evidence in front of us: the slow drying, the terpenes, the albumin, the gold and silver foil, the thickness, the available silhouettes that are not in the album that appear matte, we propose that it may be Bache's own formulation applied as a coating to the finished brush and lampblack or bone-black ink drawings, something volatile, and minimally aqueous, that would not solvate the fine brush work of the silhouette. When terpenes were identified, Lockshin began to think "outside the watercolorist's box," as it were, and started thinking about painter's supplies, like dammar. That, coupled with knowing that Bache's partner was gilding frames for the silhouettes, gives a source of egg and furniture coatings. Don Williams, furniture conservator, suggested "signpainter's glaire," which is a mixture of isinglass and egg mixed with spirits of wine.

Future work, as mentioned in the Treatment section, may involve residue mitigation or technical studies by interns or fellows. Further study options include: testing coating mixtures for application; artificial aging and comparison;

close-up examination of silhouette edges (are they scissor- or knife-cut?); consolidation trials and identification of consolidant; and developing a protocol for ongoing treatment by future interns.

Conclusion

This project has certainly added to the body of knowledge on the work of William Bache's portrait silhouettes for conservators, curators, collectors, and the general public. The treatment was greatly facilitated by a fertile environment for inquiry and communication. Having access to and sharing curators' notes and prior scientific research done in the subject area, and holding open meetings with curators, conservators, and scientists, allowed MCI to reconnect to NPG's needs. It also provided a chance for MCI to test new, non-destructive instrumentation detection limits on paper-based material.

Unexpectedly, it has also served to promote awareness of potential hazardous material in book and paper collections where there were no warning flags. Due to the history of collections management at the Smithsonian, and in no small part due to the efforts by Smithsonian and external colleagues to raise awareness of hazards in collections, paper and book conservators now know to regard to objects with relationships of taxidermy, ethnologic, botany, or treatment history of silking as suspect. Unfortunately, this object had no signaling relationship to any of these disciplines, nor had it been part of a collection with an historic treatment protocol. There was no visible indication that might alert a conservator that the surface dirt was not just accumulated dirt and dust of two hundred years, but in fact the residue of intervention with a heavy metal pesticide. On the basis of this object alone, Lockshin is revisiting her lab policy to suggest all surface cleaning on unique materials to be conducted wearing gloves and/or with other HEPA personal protective equipment.

Without a climate that supports conservation research beyond exhibit treatment, and the support of technical scientific staff, it is unlikely that this object would ever have been identified as a case study in hazardous collections management. The authors look forward to continuing research on questions raised by this object.

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Reconsidering the Classification of Foxing through Photographic and Historic Analysis and Presenting Two Case Studies of the Conservation Treatment of Foxed Paper

ABSTRACT

This poster was presented at the AIC meeting of 2008. It summarized the results of my PhD thesis paper for the Tokyo University of the Arts, which reconsiders the C. E. Cain and B. A. Miller classification of foxing and describes conservation treatments of foxed paper. The goals of the paper were to evaluate and characterize the forms of foxing defined and classified by Cain and Miller in their 1984 article, "Proposed Classification of Foxing", published in the Preprints of the American Institute for Conservation 10th Annual Meeting, and also to report on two different conservation treatments of artworks on foxed papers from the collections of the Library of Congress done during my internship year there in 2006–2007.

Cain and Miller's classification remains remarkably useful to discussions of foxing. I hope that my contribution will augment their classification through photographic documentation and analysis. The poster showed photographs including images produced under normal and UV light. The analysis presented showed that some foxing appears to elude classification under Cain and Miller's categories or may represent subcategories. The poster also illustrated foxing on Western type paper made in Japan including some papers made in the Meiji era (starting in 1868). These findings resulted from the examination and consideration of the history of some papers from the eighteenth-twentieth century. These papers included Western paper; Western type paper made in Japan; and Japanese paper. The artworks examined included works by Western and Japanese artists. Examination was done at four institutions: the Library of Congress; the Arthur M. Sackler Gallery and Freer Gallery of Art (the National Museums of Asian Art of the Smithsonian Institution); the Carnegie Museum of Art; and the University Art Museum—Tokyo National University of Fine Arts and Music.

The eighteenth-century Japanese print (*ukiyo-e*) "Back View of a Noblewoman" by Chobunsai Eishi (1756–1829) and the sixteenth-century engraving "Music Motet" by Jan Sadeler I were selected for treatment from the Library of Congress collections. These prints had foxing and were treated with different methods which were described in detail on the poster. With regard to the Japanese print, it was inferred from analysis with Scanning Electron Microscopy (SEM) and copper test strips that the cause of foxing on the *ukiyo-e* was copper from the artificial gold paper to which it was adhered. After careful testing, chelating agents were used to remove the staining. It was presumed that the cause of foxing on the Music Motet engraving was water damage and the effects of two backing papers. Sun bleaching of the print in an alkaline solution under a UV filtering Plexiglas was used to remove the staining. Among other sources, these treatments were informed by the articles "The use of chelating agents in conservation treatments" by Helen Burgess (The Paper Conservator volume 15 1991 36–44) and "Alternatives to conservation methods of art on paper" by Keiko Mizushima Keyes (Preprints, International Conference on the Conservation of Library and Archive Materials and the Graphic Arts, Cambridge; England: IPC. 166–170). The positive treatment results confirm the efficacy of the strategies described in the articles.

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Developing Guidelines for Iron-Gall Ink Treatment at the Library of Congress

The Library of Congress Conservation Division formed a working group to establish protocols for iron-gall ink treatment as part of a multi-year commitment by the Preservation Directorate to address the conservation and preservation of iron-gall ink. The group's goal was to evaluate existing Conservation Division practices together with recent research and produce a set of guidelines for staff to use in the examination and treatment of iron-gall ink on paper.

Iron-gall ink is well represented in collections at the Library of Congress. The Manuscript Division in particular holds many important documents written in iron-gall ink by the founders of the United States. In addition, iron-gall ink is abundantly represented in maps and atlases in the Geography and Map Division; art and architectural drawings in the Prints and Photographs Division; scores by famous composers in the Music Division; and ancient manuscripts in the African and Middle Eastern Division.

Various treatments have been utilized to combat the damaging effects of iron-gall ink corrosion on works in the Library's collection. From the late-nineteenth century through the mid-twentieth century, treatments, such as lining, silking and lamination with cellulose acetate, largely focused on reinforcing paper weakened by iron-gall ink corrosion. However well intended, these treatments did not address corrosion of the ink itself; in fact, they often accelerated the deterioration of the ink and paper.

In the last ten to fifteen years, researchers in Europe have elucidated the deterioration mechanisms associated with iron-gall ink and have developed new examination tools and treatment options for its stabilization (Banik and Webber 1999; Brown 2000; Kolar and Strlič 2006). In 2001, the Library of Congress initiated its own research project and established the Iron-Gall Ink Corrosion Group to investigate the efficacy of existing treatments conducted by the Library's conservation staff alongside recently developed European treatments.

In 2005, when the Iron-Gall Ink Corrosion Group had completed its work, a second group was formed to develop a unified approach toward preserving Library collections incorporating iron-gall ink. The Protocols for Iron-Gall Ink Treatment (PIT) Group developed a set of written guidelines for the examination, documentation and treatment of iron-gall ink on paper. This was accomplished by integrating the Library of Congress study (Connelly-Ryan et al. 2007) and published research with findings documented in internal treatment records, anecdotal observations and experiences of staff conservators, and discussions with colleagues outside the Library. The guidelines were evaluated and refined through a series of practical demonstrations and in dialogue with conservation staff.

The effort highlighted the need for further research to verify and build upon existing studies; in particular, to evaluate the long-term effects of ethanol-modified treatments; magnesium-based complexing and alkaline treatments; and different types of sizing agents on iron-gall ink.

The documents reproduced in the following pages represent a comprehensive effort to guide the conservator through myriad options for the preservation and conservation of iron-gall ink on paper. While these guidelines are specifically designed for objects at the Library of Congress that reside in optimal storage and environmental conditions, the approach may be customized to suit the particular needs of diverse collections and institutions. The guidelines comprise nineteen documents: a detailed examination form designed specifically for iron-gall ink on paper to supplement the primary record of treatment; a glossary that standardizes the terminology used in the examination form; recommendations for micro-chemical and solubility testing; a system of flow charts, or "treatment trees", to guide the decision-making process based on results obtained through examination and testing; and explanatory notes on the treatment options presented. New research and information will be incorporated into the guidelines in the future as the opportunity arises.

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The documents are presented here as a contribution to the national and international dialogue on the treatment of iron-gall ink. A detailed explanation of the treatment trees is given in the postprints of the International Institute of Paper Conservation/Institute of Conservation conference held in Edinburgh in July 2006 (Biggs et al. 2007). The practical application of the guidelines to the complex treatment of three important Library of Congress objects is presented in the succeeding article, "Iron-Gall Ink Treatment at The Library of Congress: Old Manuscripts—New Tools", by Claire Dekle and Mary Elizabeth Haude.

GUIDELINE DOCUMENTS FOR THE EXAMINATION AND TREATMENT OF IRON-GALL INK ON PAPER

On the following pages find these documents

Examination and Testing (5 documents)
- Record of Examination of Iron-Gall Ink on Paper (fig. 1)
- Additional Testing (fig. 2)
- Glossary for Record of Examination of Iron-Gall Ink on Paper (fig. 3)
- Chemical Testing (fig. 4)
- Solubility Testing (fig. 5)

Treatment Trees (2 charts)
- Washing Treatment Trees (fig. 6)
- Alkaline & Complexing Treatment Trees (fig. 7)

Washing and Drying Treatments (6 documents)
- Conditioning / Pre-Wetting (fig. 8)
- Water Type (fig. 9)
- Water Temperature (fig. 10)
- Washing Methods (fig. 11)
- Ethanol-Modified Washing (fig. 12)
- Drying (fig. 13)

Alkaline and Complexing Treatments (6 documents)
- Bookkeeper ® Spray System (fig. 14)
- Calcium Bicarbonate (fig. 15)
- Calcium Phytate / Calcium Bicarbonate (fig. 16)
- Ethanol-Modified Calcium Phytate / Calcium Bicarbonate (fig. 17)
- Magnesium Bicarbonate (fig. 18)
- Ethanol-Modified Magnesium Bicarbonate (fig. 19)

Sizing (1 document) (fig. 20)

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FIG. 1.1

RECORD of EXAMINATION of IRON-GALL INK on PAPER **project number**
Library of Congress – Conservation Division
examination date

author / artist / maker

title

date

description of object **conservator**

APPEARANCE of INK

Color warm / cool pale / dark
[describe - hue, etc.] ______

Intensity light / medium / strong / other ______

Application quantity uniform / variable
quality soft / sharp / feathered / wash / smeared

Penetration none / slight / moderate / severe / cannot determine

Surface characteristics shiny / dull
particulate no / yes [describe] ______
deposits [describe] ______

Other

CONDITION of INK and PAPER (Note: numerals correspond to Treatment Trees)

VISIBLE LIGHT

1 Physical damage to inked paper
cracks none / some / many
losses none / some / many
delamination none / slight / moderate / severe
other [describe] ______

2 Discoloration surrounding ink none / overall / localized [describe] ______
slight / moderate / severe

Adhesion / Cohesion
friability none / overall / localized [describe] ______
slight / moderate / severe
cupping none / overall / localized [describe] ______
slight / moderate / severe
cracking none / overall / localized [describe] ______
slight / moderate / severe
flaking none / overall / localized [describe] ______
slight / moderate / severe

3 Burn-through none / minor / moderate / severe

Transfer of discoloration no / yes [location, describe] ______

ULTRAVIOLET LIGHT (longwave, 364-365 nm)

Absorption none / overall / localized [describe] ______

4 Fluorescence none / overall / localized [describe] ______
location [describe] ______ color [describe] ______

Other

CHARACTERISTICS of PAPER

Opacity translucent-------------------------opaque

Thickness __________ millimeters

Surface texture smooth-------------------------------rough

Degree of sizing not sized----------------------------heavily sized

Other relevant observations

FIG. 1.2

CHARACTERISTICS of ATTACHMENTS / ASSOCIATED MATERIALS **(e.g. seals, ephemera)**

locations(s)

[describe]

Appearance in ultraviolet light (longwave, 364 – 365 nm)

Sensitive? water ____________

pH ____________

TESTING Record locations, duration and results of testing. Possible results may include

- bleeding
- sinking
- surface change
- color change
- color separation
- transfer / offsetting

	location	BEFORE	DURING	AFTER
CHEMICAL Iron (II) ion				
pH of paper surface [test mfr.] ____________ other (e.g. iron (III) ion, copper)				
RATE of ABSORPTION by PAPER **SOLUBILITY** H_2O filtered / deionized alkalized w/ ____________ to pH ______ Ethanol				
Ethanol & deionized H_2O solution alkalized w/ ____________ to pH ______ 50% / 50% ____ / ____				
Alkaline or complexing solutions ________________________ ________________________				

SUMMARY

FIG. 2

RECORD of EXAMINATION of IRON-GALL INK on PAPER
Library of Congress – Conservation Division

project number

examination date

ADDITIONAL TESTING	Record locations, duration and results of testing. Possible results may include: bleeding, feathering, sinking, surface change, color change, color separation or transfer of ink components to test material			
	LOCATION	BEFORE	DURING	AFTER
CHEMICAL Iron (II) ion				
pH of paper surface [test mfr.] ______________				
other (e.g. iron (III) ion, Cu) **RATE of ABSORPTION by PAPER**				
SOLUBILITY $H_2$0 filtered / deionized alkalinized w/ _________ to pH ______				
Ethanol				
Ethanol & deionized $H_2$0 solution alkalized w/ __________ to pH ______ _50% / 50%_				
____ / ____ ____ / ____ Alkaline or complexing solutions				
_________________________ _________________________				

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 3.1**
Library of Congress – Conservation Division

GLOSSARY for RECORD of EXAMINATION of IRON-GALL INK on PAPER

The glossary defines and elaborates terms used in the "Record of Examination of Iron-Gall Ink on Paper"

APPEARANCE of INK This section records observations about the visual character of the ink.

Color Describes the hue of the ink and whether it is **warm** or **cool, pale** or **dark**.

Intensity Describes the strength or opacity of the ink, judged by its ability to obscure the paper.

Application Describes observations of the method(s) used to deposit ink on the paper.

Quantity Describes the amount of ink deposited by the tool used to apply the ink. For example, the quantity of ink applied with a quill pen is likely to be **variable** as the pen is used and recharged. A fountain pen is likely to produce a more **uniform** line as ink is continuously released from the ink reservoir.

Quality Describes characteristics imparted to the ink during its application.

Soft and **sharp** describes the edge definition of an ink line.
Feathered ink is the result of ink moving laterally through the paper.
Wash refers to application by brush, often indicated by the presence of large areas of ink and a softer, wider line than could be achieved with a writing instrument.
Smeared refers to inadvertent movement of ink before it is completely dry.

Penetration Refers to the degree to which the ink moved into the paper upon application. Characteristics of both the ink and the paper affect the penetration, such as the dye-like qualities of the ink, the amount of binder in the ink, and the porosity of the paper.

Surface characteristics **Shiny or dull** refers to the appearance of the ink as a function of its ability to reflect or scatter light. The assessment is best judged with magnification. The degree of reflectance or scatter is influenced by the binding medium, the penetration of ink into the paper, and the presence or absence of particulates.
Particulate describes the presence of colored, opaque solids, generally formed by oxidation of the ink before drying.
Deposits refer to substances found on the surface of the ink but not integral to it, such as crystals or exudates. These deposits are the products of chemical reactions in the ink film; they are not to be confused with sand or other particles applied to help dry the ink.

CONDITION of INK and PAPER This section records observations related to the degradation of ink.

Physical damage to inked paper Describes physical damage to the paper as a direct result of ink corrosion.
Cracks are breaks through the ink and paper.
Losses are holes in inked areas of paper.
Delamination describes an inked layer of paper splitting or peeling away from the main body of the paper.

Discoloration surrounding ink Describes diffuse, darkened areas of paper surrounding ink applications.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 3.2**
Library of Congress – Conservation Division

GLOSSARY for RECORD of EXAMINATION of IRON-GALL INK on PAPER

Adhesion/ Cohesion
Adhesion refers to the degree to which the ink holds onto the paper.
Cohesion refers to the degree to which components of the ink hold together.

Friability describes the loss or deterioration of the ink binder, sometimes indicated by the transfer of a fine particulate to adjacent areas. Evaluated with a microscope, ink is considered friable if particles are readily moved with the light touch of a brush or feathered blotter edge.
Cupping describes severe cracking that indicates physical stresses in the ink layer. It is usually visible as "islands" of ink, with lifted edges.
Cracking describes the formation of fissures in the ink layer, not in the paper.
Flaking describes detachment of ink from the paper.

Burn-through Refers to the darkening on the verso of an inked area caused by ink corrosion rather than ink penetration. Other physical damage to the paper may be associated with burn-through, especially if it is severe. Sometimes referred to as "strike-through", a term borrowed from printing.

Transfer of discoloration Indicates localized darkening of paper in contact with the inked paper. The discoloration is a mirror image of the original inked area, generated through chemical reactions. The phenomenon may be apparent as fluorescence in ultraviolet (UV) radiation, as well as discoloration in visible light.

Absorption Indicates the presence of iron based on its characteristic absorption of UV wavelengths. Absorption is a useful indicator, rather than an absolute identifier for iron, as other metals also absorb UV. UV enhances the visibility of iron dispersed in paper that might not be apparent in visible light.

Fluorescence Indicates paper degradation visible around the inked area or in paper in contact with the ink. May be a precursor to **discoloration**. Fluorescence is often more apparent on the verso rather than the recto of paper.

CHARACTERISTICS of PAPER This section records paper characteristics that particularly affect the deposition and appearance of the ink.

Opacity An estimation of the ability of light to pass through paper. Mark the dotted line of the scale between **translucent** and **opaque**. Tracing paper is an example of translucent paper; thick blotting paper is an example of opaque paper.

Thickness A measurement of the paper in cross-section, made with a micrometer.

Surface texture A description of the visual or tactile qualities of the paper. Mark the dotted line of the scale between **smooth** and **rough**. An example of **smooth** paper is a hot pressed or calendared sheet; an example of **rough** paper is a heavily textured watercolor paper.

Degree of sizing An assessment of the deposition of the paper size. Mark the dotted line of the scale between **not sized** and **heavily sized**.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 4**
Library of Congress – Conservation Division

CHEMICAL TESTING

Iron (II) Ion

Iron (II) ions catalyze oxidative degradation of cellulose, one of the primary destructive reactions associated with iron-gall ink on paper.

An indicator paper developed by the Netherlands Institute for Cultural Heritage may be used to test for the presence of iron (II) ions. The test paper is made of Whatman® filter paper impregnated with an iron (II) sensitive compound, bathophenanthroline. When moistened with deionized water and placed in direct contact with iron gall ink, the indicator paper turns magenta or pinkish-red in response to iron (II) ions. The color may be evaluated semi-quantitatively to determine the presence of iron (II) ions in the ink and paper before and after treatment.

Iron (III) Ion

If the iron (II) test is negative, a test for the presence of iron (III) ions should be performed. Iron (III) ions can be reduced to iron (II) ions through redox reactions and cause oxidative degradation of cellulose.

The test paper from the iron (II) test kit is moistened with de-ionized water and placed in direct contact with iron-gall ink. After the test paper is removed from the object, a drop of 1% aqueous ascorbic acid solution is applied to the test paper. As the ascorbic acid reduces iron (III) ions to iron (II) ions, the indicator paper will turn magenta or pinkish-red.

pH

Although surface pH is only an approximate measurement of the true pH of the paper, it is a useful indicator of the efficacy of treatment. Surface pH can be measured using non-bleeding pH indicator strips and surface-electrode pH meters. pH strips are preferable to pH meters for use on objects because they require less moisture. Reducing the amount of moisture reduces the risk of ink movement, iron ion migration, tidelines, and paper distortion.

pH strips are composed of paper impregnated with a color-sensitive acid-base indicator designed to respond within a discrete pH range. Since the pH measurements of iron-gall ink are generally between 1.0 and 4.0, it may be helpful to start testing with a pH strip for that range. To further reduce the amount of moisture applied to the object and to conserve resources, a pH strip may be cut into several, more narrow strips.

SOURCES CONSULTED

Biggs, Julie L. 2006. The conservation of iron-gall ink on paper. *Working paper*. FAIC Samuel H. Kress Conservation Publication Fellowship.

Neevel, Johan G., and Birgit Reißland. 2005. Bathophenanthroline indicator paper development of a new test for iron ions. *PapierRestaurierung* 6 (1): 28-36.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 5.1**
Library of Congress – Conservation Division

SOLUBILITY TESTING

Test Objectives

- To predict ink solubility in proposed treatment solutions. Since solubility parameters of inks treated with partially aqueous solutions might change, retesting of water-sensitive inks is recommended between treatment steps.
- To predict potential for color change in ink and paper
- To predict potential for movement of ink to verso (sinking) and lateral spread (bleeding)

Test Site Selection and Documentation

- Test each type of ink apparent throughout the object. Indications that different inks may have been used include variations in handwriting, the use of correction or deletion marks, the presence of annotations, addresses or signatures, or if the object has many pages or spans many years. The most sensitive or soluble ink will determine the treatment approach.
- Test inks that exhibit evidence of differential aging, whether due to discrete variations in storage conditions or local treatment. Indications of such variation may be more apparent in ultraviolet or infrared wavelengths.
- Perform tests in an inconspicuous area where possible
- Test in an uninked area of paper and compare with ink results to determine the degree to which any discoloration is contributed by the paper
- Become familiar with the appearance of the recto and verso of areas just before testing
- Annotate/mark blotters or other testing materials during treatment to refer to until treatment is completed.
- Make a photocopy of the object, sleeved in polyester film, to note locations of testing sites. Note type/method of test performed. If photocopying is not advisable, note locations on a polyester template using indelible marker.

Test Solutions and Sequencing

- It is advisable to perform treatment as soon as possible after testing
- Initial tests should be very small, using the aid of a magnifier or microscope to assess change
- Where possible, use test solutions and methods that will mimic proposed treatment conditions. This may include adjustments to pH, choice of treatment solutions, temperature, duration, or method of application (such as using a suction table).
- Placing a moisture barrier below the test site encourages movement of the solution upward or laterally. Placing a blotter beneath the test site encourages downward movement of the solution.
- Test with a 100% aqueous solution and 100% ethanol. If an ink is soluble in one solvent but not the other, test with varying proportions of ethanol and water to determine the solubility parameter.
- Begin testing with a droplet of solution followed by immediate blotting
- Test with alkaline and/or complexing solutions after washing and drying. If the condition of the object precludes an intermediate drying step, test with washing, alkaline and/or complexing solutions in a continuous series to mimic the proposed treatment protocol.
- As confidence grows that the ink is stable, a timed exposure may be performed by dampening the ink with repeated brush applications, wicks of cotton, or by using tiny blotter squares covered with a moisture barrier.
- Test solutions should be applied for a minimum of 12 minutes. Some changes may not be immediately visible, but may appear after 5 or 10 minutes.
- Drying may include air drying, or blotting with filter paper or blotter, using finger pressure or weight. Note that air drying, or prolonged exposure to a solution without blotting, may produce tidelines that can become stubborn stains upon aging.
- To avoid leaving visible tidelines in the paper, use methods to diffuse the edges of the tideline

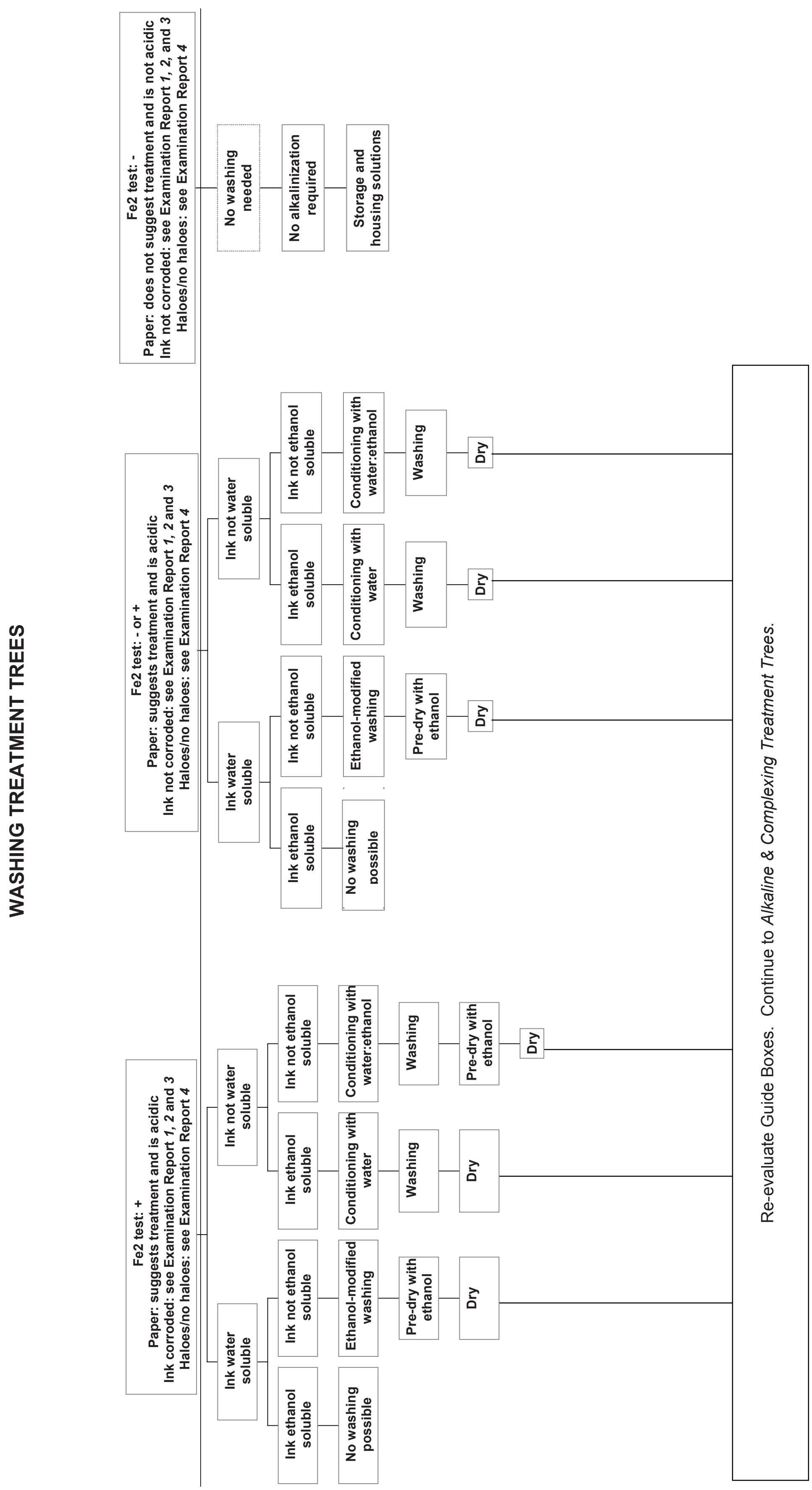
PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 5.2**
Library of Congress – Conservation Division

SOLUBILITY TESTING

Test Observations

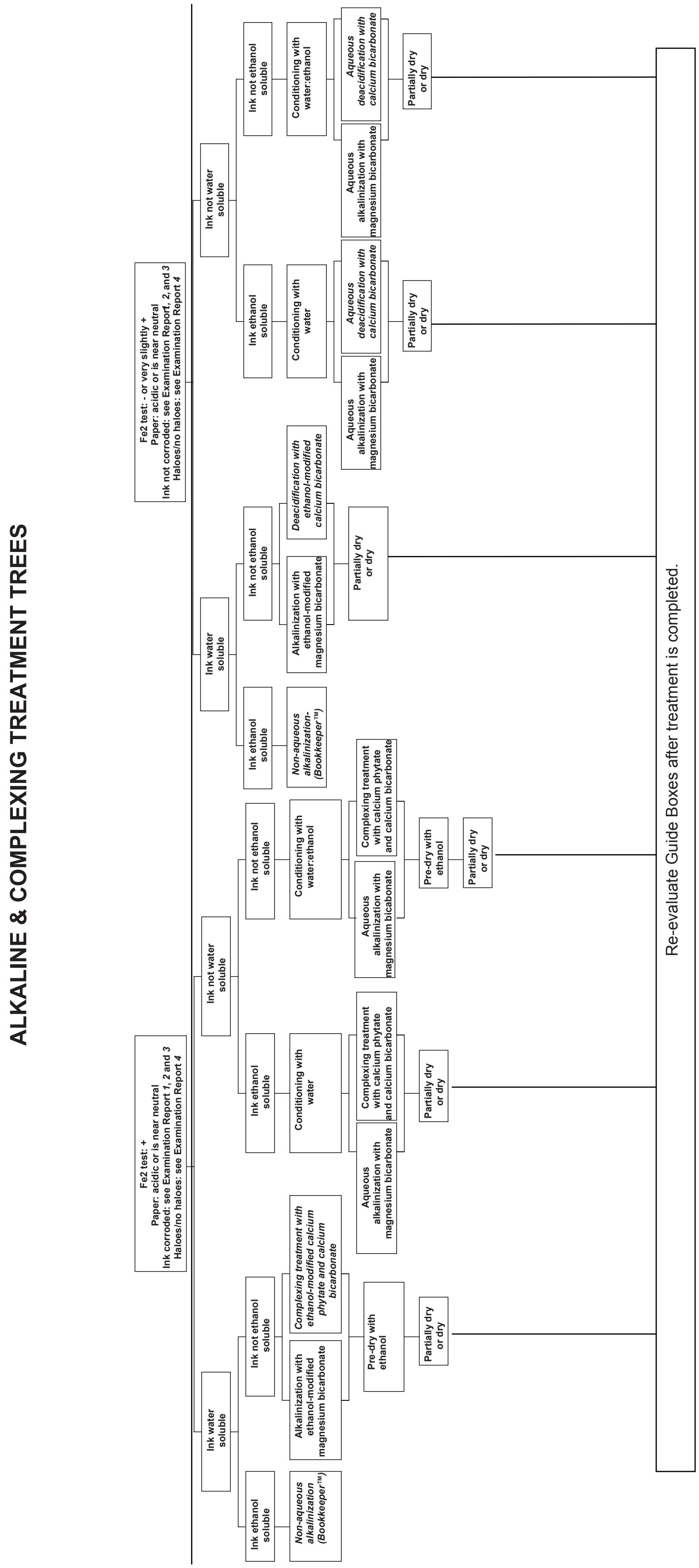
- Evaluate test sites in visible light and ultraviolet radiation, and with magnification
- Note changes in ink color, texture, or intensity
- Note any changes in paper color or texture
- Look for any movement of ink to the verso (sinking)
- Note any lateral movement of ink, such as bleeding
- Compare the appearance of the test site with the surrounding paper
- Note any transfer of colored components from ink and/or paper onto blotter or wicks

FIG. 6



Library of Congress PIT Group 2006

FIG. 7



Library of Congress PIT Group 2006

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 8.1**
Library of Congress – Conservation Division

CONDITIONING / PRE-WETTING

Conditioning / Pre-wetting, general

Advantages

- Helps ensure that the ink-inscribed paper takes up moisture uniformly and does not distort during treatment
- Allows the paper fibers to swell gradually with moisture

Disadvantages

- Ink components may sink or migrate into the paper. The probability for migration may be predicted through careful testing.

Ethanol or ethanol and water solutions

Advantages

- Reduces differences in moisture absorption rates often associated with degraded sizing, or damage induced by mold or degraded ink
- Encourages the gradual replacement of ethanol with water, resulting in less distortion of paper

Disadvantages

- Ink components may sink or migrate into the paper. The probability for migration may be predicted through careful testing.
- Using ethanol requires additional precautions for health and safety

Application methods for ethanol or ethanol and water solutions

Spray

Advantages

- Ease of application
- Minimizes physical contact with the ink and/or paper
- Allows for gradual introduction of the conditioning solution

Disadvantages

- Repeated spraying may be necessary if the solution evaporates faster than the paper can absorb it

Brush

Advantages

- Ease of application
- Quickly saturates the paper with the conditioning solution. Polyester web may be used as a barrier to minimize disruption of fragile ink areas.

Disadvantages

- Use of polyester web obscures ink behavior

Bath

Advantages

- Completely and evenly saturates the paper, promoting uniform uptake of the treatment solution

Disadvantages

- Ink components may sink or migrate into the paper. The probability for migration may be predicted through careful testing.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 8.2**
Library of Congress – Conservation Division

CONDITIONING / PRE-WETTING

Aqueous conditioning (suitable for inks that are ethanol-soluble, as ethanol-water solutions are preferred for all other conditioning/pre-wetting)

Advantages

- Reduces differences in moisture absorption rates often associated with degraded sizing, or damage induced by mold or degraded ink

Disadvantages

- Ink components may sink or migrate into the paper. The probability for migration may be predicted through careful testing.
- Hydrophobic areas of paper respond more slowly to aqueous conditioning, and may not wet up at all

Application methods for aqueous conditioning

Spray

Advantages

- Ease of application

Disadvantages

- Repeated spraying may be necessary if areas of the paper resist uptake of moisture

Humidification (damp pack or humidity chamber)

Advantages

- Allows for gradual introduction of moisture into paper. Reduces differences in moisture absorption rates often associated with degraded sizing, or damage induced by degraded ink or mold.

Disadvantages

- Ink components may sink or migrate into the paper. The probability for migration cannot be predicted, even with careful testing.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 9**
Library of Congress – Conservation Division

WATER TYPE

Washing, general

Advantages

- Aqueous washing treatments improve the strength, flexibility, and brightness of paper
- Aqueous washing treatments remove iron (II) ions, acids, and other water-soluble degradation products

Disadvantages

- No aqueous washing treatment will prevent ink corrosion from re-occurring in documents that contain iron-gall ink. Additional treatment, such as complexing and alkalinization, is needed for long-term protection.
- May affect the appearance of the ink (fading, bleeding, sinking, color change, potential dissolving of ink binder)

Tap water

Advantages

- Readily available

Disadvantages

- The chemical composition of tap water varies. Tap water may require treatment to be suitable for conservation purposes.

Deionized water (~pH 6)

Advantages

- Metal ions, chlorine, and organic impurities are removed

Disadvantages

- Absence of all metal ions results in an aggressive washing solution that may remove beneficial ions from the paper and adversely affect its long-term stability
- Water quality varies over time. Monitoring the water produced by the deionizing system is recommended.
- Washing in this type of water may cause components of ink to bleed

Calcium hydroxide-adjusted deionized water (pH 7 – 8.5)

Advantages

- Calcium hydroxide ($Ca(OH)_2$) adjustment reduces the risk of removing beneficial ions from the paper
- Promotes removal of acidic degradation products from the ink and paper

Disadvantages

- If used in spray applications, calcium particles may clog the sprayer

Ammonium hydroxide-adjusted deionized water (pH 7 – 8.5)

Advantages

- Removes dirt and discoloration from paper more effectively than water alone or $Ca(OH)_2$-adjusted deionized water
- Can be used in spray applications without clogging the sprayer

Disadvantages

- May cause graying of paper
- May cause unwanted changes to colorants in paper
- The pH of the wash bath can be difficult to maintain as ammonium hydroxide (NH_4OH) is volatile and evaporates quickly
- Using NH_4OH requires additional precautions for health and safety

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 10**
Library of Congress – Conservation Division

WATER TEMPERATURE

Temperature of water (approximate)

	Fahrenheit	**Celsius**
"**Room**"	68ºF	20ºC
Tepid	80ºF	~27ºC
Warm	90ºF or >	~32ºC or >
Hot	120ºF or >	~49ºC or >
Simmering	<212ºF	<100ºC

Washing in all temperatures of water

Advantages

- Aqueous washing treatments improve the strength, brightness, and flexibility of the paper
- Aqueous washing treatments remove iron (II) ions, acids, and other water-soluble degradation products from the ink and paper

Disadvantages

- No aqueous washing treatments prevent ink corrosion from re-occurring in documents that contain iron-gall ink. Additional treatment, such as complexing and alkalinization, is needed for long-term protection.
- May affect the appearance of the ink (fading, bleeding, sinking, color change, potential dissolving of ink binder)

Increasing water temperature for washing

Advantages

- May improve the brightness of the paper
- May accelerate and enhance the removal of iron (II) ions, acids, degraded size, and other water-soluble degradation products from the ink and paper. May also shorten the duration of washing treatment.

Disadvantages

- May affect the appearance of the ink (fading, bleeding, sinking, color change, potential dissolving of ink binder)
- May cause color change in the paper, possibly over-whitening it or imparting a gray cast
- May increase swelling of paper fibers and cause visual changes to the ink and paper
- Higher temperatures may cause undesirable alteration or removal of sizing, colorants, and other components of paper manufacture

Simmering water treatment

Advantages

- Improves the brightness of the paper
- Very efficient at removing iron (II) ions, acids, degraded size, and other water-soluble degradation products from the ink and paper. Can significantly shorten the duration of washing treatment.
- May increase the flexibility of the paper

Disadvantages

- May affect the appearance of the ink (fading, bleeding, sinking, color change, potential dissolving of ink binder)
- May cause color change in the paper, possibly over-whitening it or imparting a gray cast
- May cause the paper to shrink
- May cause physical damage to ink-corroded paper (cracks, breaks, losses)
- Probability of unwanted changes occurring to ink and/or paper cannot be predicted through testing
- An aggressive treatment that has a limited application

SOURCES CONSULTED

Biggs, Julie L. 2006. The conservation of iron-gall ink on paper. *Working paper*. FAIC Samuel H. Kress Conservation Publication Fellowship.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 11.1**
Library of Congress – Conservation Division

WASHING METHODS

Immersion (placing object in a bath of solution)

Advantages

- Unrestricted access of water to the object makes it an effective procedure for washing
- Easiest method of washing

Disadvantages

- Least controllable of the aqueous washing procedures

Suction table (spraying or misting object on suction table at low setting)

Advantages

- Less aggressive than immersion, so it is less likely to cause changes to the ink
- Restricts movement of the paper during treatment
- Allows control of the solution amount, location, and duration of application

Disadvantages

- Washing may be incomplete, leaving degradation products and iron ions in the paper (immersion is more likely to move the components out of the paper)
- May promote lateral migration of ions and degradation products within the paper
- Suction may cause sinking of ink
- Uneven drying, distortion, and dimensional changes in the paper are possible
- Preferable for one-sided documents

Screen washing (placing object on a screen in a bath of solution)

Advantages

- Provides support for the object while allowing complete contact between the solution and the paper

Disadvantages

- Requires careful monitoring to ensure effective washing

Fluxion, blotter, and other capillary washing

- Generally not recommended for iron-gall ink on paper as capillary action may cause unwanted movement of ink components

Increased number of applications (repeating procedure)

Advantages

- Fresh solutions encourage more effective washing
- Offers an alternative to increased duration of washing and may achieve similar results

Disadvantages

- Requires more solution

Increased duration of application (extending the length of time of the procedure)

Advantages

- May result in more effective removal of degradation products, iron ions, and acidic components

Disadvantages

- Difficult to replicate conditions of prolonged treatment when performing solubility tests

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG.11.2**
Library of Congress – Conservation Division

WASHING METHODS

Series of varied applications (combining different application methods for one object)

Advantages

- Allows for customized treatment to meet specific needs of the object

Disadvantages

- Requires more planning to execute effectively

Agitation (physically moving water across the surface, either overall or locally)

Advantages

- Periodic movement of water across the surface of the paper increases the transfer of degradation products from the paper into the bath
- Agitation above a discrete stain may remove chromophoric degradation products from that area

Disadvantages

- May lead to the loss or movement of ink into the bath as the water moves across the surface of the paper.

SOURCES CONSULTED

Biggs, Julie L. 2006. The conservation of iron-gall ink on paper. *Working paper*. FAIC Samuel H. Kress Conservation Publication Fellowship.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 12**
Library of Congress – Conservation Division

ETHANOL-MODIFIED WASHING

Ethanol and water solutions, general

Advantages

- Allows for treatment of most/many water-soluble inks
- Inclusion of ethanol in the solution can restrict the expansion of the paper, which may be desirable for paper with extensive physical damage
- May reduce the solubility of the ink in water, allowing for subsequent treatments with successively greater amounts of water

Disadvantages

- Ink components may sink or migrate into the paper
- Using ethanol requires additional precautions for health and safety

50% ethanol and 50% water

Advantages

- Most often selected for slightly water-soluble inks
- May help prevent losses and cracking of the ink and splitting of the paper

Disadvantages

- Less effective than 100% water in removing discoloration and acidic components
- Repeated baths or additional treatment may be needed to remove iron (II) ions
- The pH of the paper may not rise as much as it would with water alone
- May affect ethanol-sensitive compounds present in the ink and paper (the probability for change may be predicted through careful testing)

66.6% ethanol and 33.3% water

Advantages

- For inks that are exceedingly soluble in water, this solution may still allow some of the benefits of washing

Disadvantages

- The comments made for the 50% ethanol and 50% water solution apply, but with greater emphasis

10% ethanol and 90% water

Advantages

- Inclusion of a small amount of ethanol to the washing solution may help to wet out papers that are heavily sized or that would wet out unevenly due to damage caused by ink corrosion, mold, or other factors

Disadvantages

- May affect ethanol-sensitive compounds present in the ink and paper. The probability for change may be predicted through careful testing.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 13.1**
Library of Congress – Conservation Division

DRYING

Preliminary drying - Chemical

Ethanol immersion

Advantages

- Ethanol displaces water in paper, speeding drying while reducing contraction of paper
- Immersion ensures uniform saturation
- May reduce risk of bleeding of water-sensitive ink while drying

Disadvantages

- Not suitable for ethanol-sensitive inks
- Using ethanol requires additional precautions for health and safety

Ethanol spray

Advantages

- Ethanol displaces water in paper, speeding drying while reducing contraction of paper
- May reduce risk of bleeding of water-sensitive ink while drying
- Can be applied in smaller amounts than immersion and/or local application

Disadvantages

- Not suitable for ethanol-sensitive inks
- Using ethanol requires additional precautions for health and safety

Preliminary drying - Physical

Partial air drying
(removing object from bath and placing briefly on blotter or drying screen to expose paper to air before complete drying. Complete air drying not recommended for iron-gall inks on paper.)

Advantages

- Water evaporates from object more slowly than by other methods but is dependent on the ambient temperature, relative humidity, or air circulation
- Less contact with ink surface than with blotter or suction table techniques

Disadvantages

- None

Blotting
(placing object briefly between blotters to absorb excess moisture before complete drying)

Advantages

- Rapidly moves water away from paper surface

Disadvantages

- Contacts surface of ink, and is therefore not recommended for inks that are fragile or show transfer during testing. Can be mitigated by using a polyester web barrier.

Suction table
(placing object on blotter on suction table to draw out excess moisture before complete drying)

Advantages

- Helps to limit lateral movement of soluble ink components
- Rapidly moves water away from the paper

Disadvantages

- May cause the ink to sink into the paper
- May flatten or disrupt ink topography
- May cause paper to dry unevenly or at expanded dimensions, imparting physical stress to ink-inscribed paper

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 13.2**
Library of Congress – Conservation Division

DRYING

Drying

Between blotters only

Advantages

- Rapidly moves water away from paper surface

Disadvantages

- Ink transfer to blotter may occur
- Ink topography may be disrupted by rough surface of blotter
- Blotter may adhere to object
- Transfer of any optical brighteners in blotter more likely without a polyester web barrier

Between polyester web and blotters

Advantages

- Rapidly moves water away from paper surface
- Polyester web may prevent ink transfer onto blotter
- Smooth polyester web allows an object to move as it dries

Disadvantages

- Certain types of polyester web may snag ink-corroded paper
- Dense polyester web may inhibit transfer of moisture from the surface and slow drying

Between polyester web and wool felts

Advantages

- Inhibits transfer of moisture and promotes slow drying

Disadvantages

- Inhibits transfer of moisture and promotes slow drying
- Certain types of polyester web may snag ink-corroded paper

Directional drying (between combinations of polyester web, blotters, felts, or barrier layers)

Advantages

- Absorbent and hydrophobic materials can be used in various combinations to direct or control drying to reduce the risk of sinking or other changes to the ink

Disadvantages

- Requires experience and practice to achieve the desired results

Suction table

Advantages

- Helps limit lateral movement (bleeding) of soluble ink components

Disadvantages

- May cause the ink to sink into the paper
- May flatten or disrupt ink topography
- May cause paper to dry unevenly or at expanded dimensions, imparting physical stress to ink-inscribed paper

Restraint

Overall, heavy weight (using a press, clamped system or heavy weights)

Advantages

- Allows close surface contact with paper and drying materials to promote quick transfer of moisture to drying materials

Disadvantages

- May flatten ink or paper topography
- May cause the sheet to dry at expanded dimensions, imparting physical stress to ink-inscribed paper

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 13.3**
Library of Congress – Conservation Division

DRYING

Overall, light weight (using acrylic sheet or glass sheet without additional weight)

Advantages

- Does not flatten ink or paper topography

Disadvantages

- May not provide adequate surface contact between paper and drying materials, causing uneven drying or distortion

Weight applied to edges

Advantages

- In conjunction with felts, can hold object in place without flattening the ink

Disadvantages

- May place uneven stresses on paper and/or ink

Stretch drying (tensioned drying of object)

Advantages

- Drying is rapid
- No contact with ink surface

Disadvantages

- May stretch paper beyond original dimensions, imparting physical stress to ink-inscribed paper
- Not recommended for physically compromised objects

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 14**
Library of Congress – Conservation Division

BOOKKEEPER® SPRAY SYSTEM

Bookkeeper® is a dispersion of sub-micron-sized particles of magnesium oxide in perfluoroalkane with a surfactant (a proprietary perfluoropolyether derivative).

Advantages

- Imparts a significant alkaline reserve to paper. (The manufacturer, Preservation Technologies, states that the final pH after treatment ranges from pH 7-10 and deposits 1.5% calcium carbonate by weight to paper.)
- Can be used on inks that are soluble in water and ethanol
- Can be used on objects that cannot be treated with aqueous or ethanol-modified aqueous solutions

Disadvantages

- Does not remove acids or other water-soluble degradation products from the ink and paper
- The effect of Bookkeeper® on iron-gall ink has not been extensively analyzed
- Uneven deposition may occur
- May leave a fine powdery residue on the ink and paper
- Using Bookkeeper® requires additional precautions for health and safety

SOURCES CONSULTED

Boone, Terry, Lynn Kidder, and Susan Russick. 1998. Bookkeeper® for spray use in single item treatments. *AIC Book and Paper Group Annual*, 17:29-43.

Stauderman, Sarah D., Irene Brückle, and Judith J. Bischoff. 1996. Observations on the use of Bookkeeper® Deacidification Spray for the treatment of individual objects. *AIC Book and Paper Group Annual*, 15:11-19.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 15.1**
Library of Congress – Conservation Division

CALCIUM BICARBONATE

Advantages

- Provides an alternative treatment for ink and/or paper that is sensitive to alkaline pH and that may be visually altered by a magnesium-based alkaline treatment
- Can remove water-soluble acids from paper more effectively than washing alone
- Research conducted at the Library of Congress indicated that calcium bicarbonate treatment is effective according to the following criteria:
  - pH, alkaline reserve
    - Compared to no treatment or to washing only, resulted in a small increase of surface pH of inked and non-inked regions of sized rag paper
    - Provided some alkaline reserve
  - Paper brightness
    - Compared to no treatment or to washing only, resulted in a subtle increase in brightness of unsized and sized rag paper after artificial aging
  - Ink color
    - Did not significantly alter the color of the ink, consistent with other calcium-based treatments

Disadvantages

- Preparation of treatment solution is time-consuming. Advance chilling of water is necessary.
- Preparation requires additional precautions for health and safety
- Solution best used immediately after preparation. Storage requires airtight container and cool temperature.
- Research conducted at the Library of Congress indicated that calcium bicarbonate has drawbacks according to the following criteria:
  - pH, alkaline reserve
    - Low concentration of alkaline salts and small buffering capacity provide limited protection against future degradation of ink and paper
  - Burst testing
    Compared to magnesium bicarbonate treatment, or calcium phytate with calcium bicarbonate, is less effective at preserving paper strength and elasticity

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 15.2**
Library of Congress – Conservation Division

CALCIUM BICARBONATE

Preparation of calcium bicarbonate solution using compressed carbon dioxide (CO_2) gas

This method, modifying that of the Netherlands Institute for Cultural Heritage, was developed by the LC Iron-Gall Ink Corrosion Group in 2004.

volume of calcium bicarbonate solution produced	100 ml	500 ml	1 liter	4 liters	10 liters	40 liters
calcium carbonate, powdered	0.11 gm	0.55 gm	1.1 gm	4.4 gm	11 gm	44 gm
deionized water, chilled overnight	100 ml	500 ml	1 liter	4 liters	10 liters	40 liters
carbon dioxide gas	as needed					

- Fill container with chilled deionized water to the required amount
- Place container on a stirring plate with a stirring bar in center of base of container
- Attach a light weight to gas diffuser or nozzle to hold it near the base of the container for maximum dispersion of CO_2 gas
- Turn on stirrer. Adjust the speed as needed to produce rapid movement of the solution.
- Turn on gas. Adjust flow rate to produce vigorous bubbling of CO_2 gas through the solution.
- Add calcium carbonate powder gradually. Adjust stir rate and/or flow rate to prevent settling of the powder, as settled powder will not go into solution.
- Bubble CO_2 gas through mixture until the powder is dissolved. In a covered, unpressurized container, 10 liters may take up to 3 to 4 hours to make. Check the solution periodically to make sure the stirrer position remains at the center of the base of the container and that there is sufficient CO_2 gas in the tank.
- Solution is ready when all or nearly all the calcium bicarbonate powder is dissolved. Decanting may be necessary.
- To avoid formation of a gritty residue on trays or in spray nozzles, clean equipment immediately after use

The pH of the solution should be 5.8 to 5.9. The solution is most effective when used immediately after preparation, otherwise the equilibrium of the solution shifts as CO_2 diffuses out of it and the calcium bicarbonate precipitates out as calcium salts. If it is necessary to store the solution, an airtight container at cool temperature is recommended. Re-bubble with CO_2 gas before use if required.

Treatment

- Pour solution into tray
- Immerse the object in the solution and cover the surface with polyester film. Place the film directly in contact with the solution to slow the diffusion of CO_2 and the precipitation of calcium salts.
- After 20-30 minutes of immersion, remove the object and partially dry on a blotter
- Air dry the object briefly, then place it between felts and/or blotters to dry and flatten

Sources consulted

Biggs, Julie L. 2006. The conservation of iron-gall ink on paper. *Working paper*. FAIC Samuel H. Kress Conservation Publication Fellowship.

Connelly-Ryan, Cindy, et al. 2007. Optimizing ink corrosion treatment protocols at the Library of Congress. In *Edinburgh Conference Papers 2006*, ed. Shulla Jaques. London: Institute of Conservation, 195-202.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 16.1**
Library of Congress – Conservation Division

CALCIUM PHYTATE / CALCIUM BICARBONATE TREATMENT

Advantages

- Calcium phytate complexes, or binds, iron (II) ions in corroded inks to inhibit further corrosion. Calcium bicarbonate aids in the removal of water-soluble acidic degradation products and may deposit a small quantity of alkaline reserve in the paper.
- Provides an alternative treatment option for ink and paper that may be visually altered (ink color may shift) by magnesium-based alkaline treatments
- May be appropriate as a single aqueous treatment for extremely corroded ink and deteriorated paper that can sustain only brief treatment, i.e., the washing treatment is eliminated
- May result in increased brightness of the paper
- Research conducted at the Library of Congress indicated that calcium phytate/ calcium bicarbonate is effective according to the following criteria:
  - pH, alkaline reserve
    - Resulted in a smaller increase in pH of paper as compared to magnesium-based alkaline treatments
    - pH was higher than for both untreated and washed samples
    - After artificial aging, pH was higher than the untreated, washed, and calcium bicarbonate-only treated samples
    - Provided a higher alkaline reserve than calcium bicarbonate alone
  - Burst Testing
    - Rag papers treated with calcium phytate/calcium bicarbonate demonstrated a high peak load (tensile or breaking strength), degree of elongation (fiber stretch), and burst energy absorption (tensile energy absorption), comparable to papers treated with magnesium bicarbonate solutions
  - Iron (II) ion Testing
    - Most effective in preventing regeneration of iron (II) ions in unsized paper, and was as effective as other phytate protocols for sized papers
  - Paper Brightness
    - Remained the brightest in tone after artificial aging compared to other treatment methods
  - Ink Color
    - Did not significantly alter the color of the ink

Disadvantages

- Preparation of treatment solutions is a time-consuming, two-step process
- Preparation, use, and disposal require additional precautions for health and safety
- White phytate salt deposits may form on the surface of the ink and paper after drying
- May result in an undesirable degree of brightening of the paper

Preparation of calcium phytate solution

Calcium phytate treatment involves two separate treatment steps:

(1) Calcium phytate treatment
(2) Calcium bicarbonate treatment

Calcium bicarbonate is required to make the calcium phytate solution and the alkaline treatment solution. Begin by determining the amount of solution needed for treating the object(s). The amount will depend on the size of tray required for immersion or other application. Ensure that there is enough calcium bicarbonate solution for both treatment steps.

Preparing calcium phytate requires the storage and handling of phytic acid (myo inositol hexakisphosphate, frequently supplied as inositol hexaphosphoric acid). The treatment solution is acidic. Conservators should wear protective clothing: lab coat or equivalent, appropriate gloves, and eye protection.

Check the label to ensure that the phytic acid is within its shelf life (3 years from the date of opening). If opening the bottle for the first time, clearly mark the date on the label. Phytic acid is a clear or pale-yellow to amber color; if it is dark brown and/or contains solids, it should not be used.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 16. 2**
Library of Congress – Conservation Division

CALCIUM PHYTATE / CALCIUM BICARBONATE TREATMENT

volume of calcium phytate solution produced	**250 ml**	**500 ml**	**1 liter**	**10 liters**	**20 liters**
1. phytic acid solution, 40% *or* 2. phytic acid solution, 50%	0.72 gm 0.57 gm	1.44 gm 1.14 gm	2.88 gm 2.28 gm	28.8 gm 22.8 gm	57.6 g 45.6 gm
calcium bicarbonate solution	100 ml	200 ml	400 ml	4 liters	8 liters
deionized water	max. 250 ml	max. 500 ml	max. 1 liter	max. 10 liters	max. 20 liters
ammonium hydroxide, 3%	ca. 2 ml	ca. 5 ml	ca. 10 ml	ca. 100 ml	ca. 200 ml

Instructions are for a total volume of 1 liter calcium phytate
Using the table above, modify the instructions for the volume of calcium phytate solution needed

- Work in a chemical hood
- Check the label to see if the phytic acid solution is 40% or 50% and choose the appropriate amount from the table above
- Pour a few milliliters (ml) of concentrated phytic acid solution from the original bottle into a beaker.
- Using a glass pipette, transfer the needed weight (in grams) of solution into another beaker.
- Dilute the phytic acid with about 50 ml deionized water and pour the solution into a beaker with a volume of at least 1 liter
- While stirring, add 400 ml of calcium bicarbonate solution. Calcium bicarbonate should be prepared according to the instructions entitled "Calcium Bicarbonate."
- Fill with deionized water to a total volume of 950 ml. If making more than 1 liter, ensure that the mixing container can accommodate the addition of ammonium hydroxide, which may exceed the approximate amounts given in the table above.
- While stirring the liquid, gradually add ammonium hydroxide with a pipette until the solution turns slightly turbid (approximately 10 ml). Dark colored paper or card may be placed behind the beaker to observe the change to the solution. Check the pH, which should have reached a value of 5.5-6.0.
- Fill up the container with deionized water to a total volume of 1 liter. Ensure that the pH is still 5.5-6.0.

The solution has an approximate concentration of 1.75 mmol/l calcium phytate, equivalent to 0.116% phytic acid. The solution is most effective when used immediately after preparation. Calcium phytate solution can spoil if it is kept for an extended period. In addition, the equilibrium of the solution shifts as carbon dioxide (CO_2) diffuses out of it, causing calcium salts to precipitate.

If storing is necessary, prepare the calcium phytate but do not add ammonium hydroxide until immediately prior to use. Calcium phytate should be refrigerated in an airtight container for no longer than 48 hours.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 16.3**
Library of Congress – Conservation Division

CALCIUM PHYTATE / CALCIUM BICARBONATE TREATMENT

Treatment

Step 1

- Pour calcium phytate solution into tray
- Immediately immerse the object in the solution and cover the surface with polyester film. Place the film directly in contact with the solution to slow diffusion of CO_2 and precipitation of calcium salts
- After 20 minutes immersion, remove the object and blot excess treatment solution

Step 2

- Pour calcium bicarbonate solution into tray
- Immerse the object in the solution and cover the surface with polyester film. Place the film directly in contact with the solution to slow diffusion of CO_2 and precipitation of calcium salts.
- After 20-30 minutes immersion, remove the object and partially dry on a blotter
- Air dry the object briefly, then place it between felts and/or blotters to dry and flatten
- Waste solutions of calcium phytate or calcium bicarbonate that contain no ethanol may be disposed of in the sink

SOURCES CONSULTED

Biggs, Julie L. 2006. The conservation of iron-gall ink on paper. Working paper. FAIC Samuel H. Kress Conservation Publication Fellowship.

Connelly-Ryan, Cindy, et al. 2007. Optimizing ink corrosion treatment protocols at the Library of Congress. In *Edinburgh Conference Papers 2006*, ed. Shulla Jaques. London: Institute of Conservation, 195-202.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 17.1**
Library of Congress – Conservation Division

ETHANOL-MODIFIED CALCIUM PHYTATE / CALCIUM BICARBONATE TREATMENT

Advantages

- Ethanol-modified calcium phytate complexes, or binds, iron (II) ions in water-soluble corroded inks to inhibit further corrosion. Ethanol-modified calcium bicarbonate aids in the partial removal of acidic degradation products and may deposit a small quantity of alkaline reserve in the paper.
- Provides an alternative treatment option for ink and paper that may be visually altered (ink color may shift) by a magnesium-based alkaline treatment
- May be appropriate as a single aqueous treatment for extremely corroded ink and deteriorated paper that can sustain only brief treatment (i.e., the washing treatment is eliminated)
- May result in increased brightness of the paper

Disadvantages

- Preparation of treatment solutions is a time-consuming, two-step process. Advance chilling of solutions is necessary.
- Preparation, use, and disposal requires additional precautions for health and safety
- White phytate salt deposits may form on the surface of the ink and paper after drying
- Addition of ethanol to aqueous calcium phytate and calcium bicarbonate dilutes the solutions and results in some precipitation of salts, which may reduce the efficacy of the treatment. The long-term efficacy has not been extensively studied.

Preparation of calcium phytate solution

Ethanol-modified calcium phytate treatment involves two separate treatment steps:

(1) Ethanol-modified calcium phytate treatment
(2) Ethanol-modified calcium bicarbonate treatment

Making ethanol-modified calcium phytate and calcium bicarbonate solutions requires the preparation of aqueous calcium phytate and calcium bicarbonate solutions to which ethanol is then added.

Calcium bicarbonate is required for the calcium phytate solution and the alkaline treatment solution. Begin by determining the amount of solution needed for treating the object(s). The amount will depend on the size of tray required for immersion or other method of treatment application. Take into account that the solutions will be diluted with a proportion of ethanol. Ensure that there is enough calcium bicarbonate for both treatment steps.

Preparing calcium phytate requires the storage and handling of phytic acid
(myo inositol hexakisphosphate; frequently supplied as inositol hexaphosphoric acid).
The treatment solution is also acidic. Conservators should wear protective clothing: lab coat or equivalent, appropriate gloves, and eye protection.

Check the label to ensure that the phytic acid is within its shelf life (3 years from the date of opening). If opening the bottle for the first time, clearly mark the date on the label. The solution should be a clear or pale-yellow to amber color; if it is dark brown and/or contains solids, it should not be used.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 17.2**
Library of Congress – Conservation Division

ETHANOL-MODIFIED CALCIUM PHYTATE / CALCIUM BICARBONATE TREATMENT

volume of calcium phytate solution produced	**250 ml**	**500 ml**	**1 liter**	**10 liters**	**20 liters**
1. phytic acid solution, 40% *or* 2. phytic acid solution, 50%	0.72 gm 0.57 gm	1.44 gm 1.14 gm	2.88 gm 2.28 gm	28.8 gm 22.8 gm	57.6 gm 45.6 gm
calcium bicarbonate solution	100 ml	200 ml	400 ml	4 liters	8 liters
deionized water	max. 250 ml	max. 500 ml	max. 1 liter	max. 10 liters	max. 20 liters
ammonium hydroxide, 3%	ca. 2 ml	ca. 5 ml	ca. 10 ml	ca. 100 ml	ca. 200 ml

Instructions are for a total volume of 1 liter calcium phytate
Using the table above, modify the instructions for the volume of calcium phytate solution needed

- Work in a chemical hood
- Check the label to see if the phytic acid solution is 40% or 50% and choose the appropriate amount from the table above
- Pour a few milliliters (ml) of concentrated phytic acid solution from the original bottle into a beaker. Using a glass pipette, transfer the needed weight (in grams) of solution into another beaker.
- Dilute the phytic acid with about 50 ml deionized water and pour the solution into a beaker with a volume of at least 1 liter
- While stirring, add 400 ml of calcium bicarbonate solution. Calcium bicarbonate should be prepared according to the instructions entitled "Calcium Bicarbonate"
- Fill with deionized water to a total volume of 950 ml. If making more than 1 liter, ensure that the mixing container can accommodate the addition of ammonium hydroxide, which may exceed the approximate amounts given in the table above.
- While stirring the liquid, gradually add ammonium hydroxide with a pipette until the solution turns slightly turbid (approximately 10 ml). Dark colored paper or card may be placed behind the beaker to observe the change to the solution. Check the pH, which should have reached a value of 5.5-6.0.
- Fill with deionized water to a total volume of 1 liter. Ensure that the pH is still 5.5-6.0.

The solution has an approximate concentration of 1.75 mmol/l calcium phytate, equivalent to 0.116% phytic acid. The solution is most effective when used immediately after preparation. Calcium phytate solution can spoil if it is kept for an extended period. In addition, the equilibrium of the solution shifts as CO_2 diffuses out of it causing calcium salts to precipitate.

If storing is necessary, prepare the calcium phytate but do not add the ammonium hydroxide until immediately prior to use. Calcium phytate should be refrigerated in an airtight container for no longer than 48 hours.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 17.3**
Library of Congress – Conservation Division

ETHANOL-MODIFIED CALCIUM PHYTATE / CALCIUM BICARBONATE TREATMENT

Preparation of ethanol-modified calcium phytate and ethanol-modified calcium bicarbonate solutions

Common proportion options are:

25% ethanol / 75% calcium phytate and 25% ethanol / 75% calcium bicarbonate
33% ethanol / 66% calcium phytate and 33% ethanol / 66% calcium bicarbonate
50% ethanol / 50% calcium phytate and 50% ethanol / 50% calcium bicarbonate

NOTE: **Do not use more than 50% ethanol with each solution.**
The Netherlands Institute for Cultural Heritage recommends using solutions with no more than 50% ethanol. The addition of ethanol will reduce the efficacy of the aqueous solutions and causes the precipitation of calcium salts.

- Work in a chemical hood
- Wear labcoat, appropriate gloves, and approved eye protection
- Measure the ethanol needed for each of the two steps. Refrigerate overnight in a labeled, airtight container.
- Immediately before beginning the complexing treatment, add the ethanol to the calcium phytate and mix well
- Immediately before beginning the alkaline treatment, add the ethanol to the calcium bicarbonate and mix well

Treatment

Step 1

- Pour ethanol-modified calcium phytate solution into tray
- Immerse the object in the solution and cover the surface of the solution with polyester film. Place the film directly in contact with the surface of the solution to slow diffusion of CO_2 and precipitation of calcium salts.
- After 20 minutes immersion, remove the object and partially dry on a blotter

Step 2

- Pour ethanol-modified calcium bicarbonate solution into tray
- Immerse the artifact in the solution and cover the surface of the solution with polyester film. Place the film directly in contact with the surface of the solution to slow diffusion of CO_2 and precipitation of calcium salts.
- After 20-30 minutes immersion, remove the object and partially dry on a blotter
- Air dry the object briefly, then place it between felts and/or blotters to dry and flatten

SOURCES CONSULTED

Biggs, Julie L. 2006. The conservation of iron-gall ink on paper. Working paper. FAIC Samuel H. Kress Conservation Publication Fellowship.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 18.1**
Library of Congress – Conservation Division

MAGNESIUM BICARBONATE

Advantages

- Has undergone extensive analytical testing and has been observed to perform well over time
- Imparts a significant alkaline reserve to paper
- Research conducted at the Library of Congress indicated that magnesium bicarbonate is effective according to the following criteria:
    - pH, alkaline reserve
        - Elevated pH of both inked and non-inked areas
        - Imparted a higher alkaline reserve than for calcium-based alkaline treatments
    - Burst testing
        - Rag papers treated with magnesium bicarbonate demonstrated a high peak load (tensile or breaking strength), degree of elongation (fiber stretch), and burst energy absorption (tensile energy absorption), comparable to papers treated with phytate solutions
    - Iron (II) ion testing
        - Was effective in slowing the regeneration of iron (II) ions
    - Paper brightness
        - Retained brightness in comparison to untreated samples
    - Paper color
        - Pronounced yellowing of magnesium-treated papers seen in other studies not observed in rag papers

Disadvantages

- Preparation of treatment solution is time-consuming. Advanced chilling of water is necessary.
- Preparation requires additional precautions for health and safety
- May cause color shift in inks and pigmented seals.
- Research conducted at The Library of Congress indicated that magnesium bicarbonate has drawbacks according to the following criteria:
    - pH, alkaline reserve
        - pH may increase over time
    - Burst testing
        - Unsized sulfite papers demonstrated a lower peak load, elongation to break, and burst energy absorption than rag papers
    - Ink color
        - Can cause red shift in ink color, typical of treatments with magnesium compounds

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 18.2**
Library of Congress – Conservation Division

MAGNESIUM BICARBONATE

Preparation of magnesium bicarbonate solution using compressed carbon dioxide (CO_2) gas

The Conservation Division generally makes a 0.10M stock solution with magnesium hydroxide powder. The stock solution is diluted for use. Magnesium carbonate powder may also be used for the stock solution, but it requires a different measured amount and takes longer to go into solution.

volume of 0.10 M magnesium bicarbonate solution produced	**1 liter**	**14 liters**
1. magnesium hydroxide powder	5.7 gm	80 gm
or		
2. magnesium carbonate powder	8.5 gm	119 gm
deionized water, chilled	1 liter	14 liters
carbon dioxide gas	as needed	

- Fill container with chilled deionized water to the required amount
- Place container on a stirring plate and a stirring bar in center of base of container
- Attach a light weight to gas diffuser or nozzle to hold it near the base of the container for maximum dispersion of CO_2 gas
- Turn on stirrer. Adjust the speed as needed to produce rapid movement of the solution.
- Turn on gas. Adjust flow rate to produce vigorous bubbling of CO_2 gas through the solution.
- Bubble CO_2 gas through the mixture until the powder is dissolved. In an unpressurized container, 14 liters may take up to 3 hours to make. Check the solution periodically to make sure the stirrer position remains at the center of the base of the container and that there is sufficient CO_2 gas in the tank.
- After the powder has dissolved, allow the solution to settle for several hours before measuring the amount of effective carbonate in it, either by titration or by a proprietary method, such as the Taylor Hardness Kit

Treatment

- If the 0.10 M stock solution is not clear, filter before use
- Dilute the solution to 1 part magnesium bicarbonate to 4 parts deionized water. A more dilute solution may be desirable for a very lightweight paper.
- After 20-30 minutes immersion, remove document and partially dry on blotter
- Air dry briefly and place between felts and/or blotters to dry and flatten
- To avoid formation of a gritty residue on trays or in spray nozzles, clean equipment immediately after use

SOURCES CONSULTED

Biggs, Julie L. 2006. The conservation of iron-gall ink on paper. Working paper. FAIC Samuel H. Kress Conservation Publication Fellowship.

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Connelly-Ryan, Cindy, et al. 2007. Optimizing ink corrosion treatment protocols at the Library of Congress. In *Edinburgh Conference Papers 2006*, ed. Shulla Jaques. London: Institute of Conservation, 195-202.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 19.1**
Library of Congress – Conservation Division

ETHANOL-MODIFIED MAGNESIUM BICARBONATE

Advantages

- Imparts a significant alkaline reserve to paper
- Appropriate for inks that can sustain only brief or partially aqueous treatment
- Research conducted at the Library of Congress indicated that ethanol-modified magnesium bicarbonate (65% ethanol /10% water and 25% magnesium bicarbonate) is effective according to the following criteria:
    - pH, alkaline reserve
        - Elevated pH of inked and non-inked areas
        - Imparted a higher alkaline reserve than calcium-based alkaline treatments
        - Solutions absorbed more readily by sulfite and softwood papers than other aqueous alkaline treatments
    - Burst testing
        - Rag papers treated with ethanol-modified magnesium bicarbonate demonstrated a high peak load (tensile or breaking strength), degree of elongation (fiber stretch), and burst energy absorption (tensile energy absorption) comparable to papers treated with phytate solutions
    - Iron (II) ion testing
        - Was as effective as fully aqueous magnesium bicarbonate in slowing the regeneration of iron (II) ions
    - Paper brightness
        - Retained brightness in comparison to untreated samples
    - Paper color
        - Pronounced yellowing of magnesium-treated items seen in other studies not observed in rag or sulfite papers

Disadvantages

- Preparation of solution is time-consuming. Advance chilling of ethanol and water is necessary.
- Preparation, use, and disposal requires additional precautions for health and safety
- May cause color shift in inks and pigmented seals
- Not recommended for treating ligneous papers as magnesium bicarbonate can cause color change in the paper
- Research conducted at the Library of Congress indicated that ethanol-modified magnesium bicarbonate has drawbacks according to the following criteria:
    - Burst testing
        - Unsized rag and unsized sulfite papers demonstrated a lower peak load, degree of elongation, and burst energy absorption than rag papers
    - Ink color
        - Can cause a red shift in ink color, typical of treatments with magnesium compounds

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 19.2**
Library of Congress – Conservation Division

ETHANOL-MODIFIED MAGNESIUM BICARBONATE

Preparation of ethanol-modified magnesium bicarbonate solutions

Proportion options include:

65% ethanol / 10% water and 25% magnesium bicarbonate
50% ethanol / 25% water and 25% magnesium bicarbonate

Preparation of 65% ethanol / 10% water and 25% magnesium bicarbonate solution

- Work in a chemical hood
- Wear labcoat, appropriate gloves, and approved eye protection
- Measure ethanol and water needed and combine in a container. Refrigerate overnight in a labeled, airtight container.
- Place stirring bar at center of base of container and place container on stirring plate
- Attach a light weight to gas diffuser or nozzle to hold it near the base of the container for maximum dispersion of gas
- Turn on stirrer. Adjust the speed as needed to produce rapid movement of the solution.
- Turn on gas. Adjust flow rate to produce vigorous bubbling of gas through the solution.
- Cover the container to trap the CO_2
- Bubble carbon dioxide (CO_2) gas through solution for 20 minutes
- Slowly add the magnesium bicarbonate into the ethanol-water solution while the CO_2 gas is bubbled through
- Continue to bubble the CO_2 gas through the solution for 10-15 minutes or until solution is clear

Preparation of 50% ethanol / 25% water and 25% magnesium bicarbonate solution

- Work in a chemical hood
- Wear labcoat, appropriate gloves, and approved eye protection
- Measure the ethanol and deionized water needed. Combine and refrigerate overnight in a labeled, airtight container.
- Immediately before beginning the alkaline treatment, add the magnesium bicarbonate to the chilled ethanol-water solution and mix well

Treatment

- Pour the ethanol-modified magnesium bicarbonate solution into a tray
- Immerse the object in the solution and cover with polyester film. Place the film directly in contact with the surface to slow diffusion of CO_2 and precipitation of magnesium salts.
- After immersion for 20-30 minutes, remove the object and partially dry on a blotter
- Air dry the object briefly, then place it between felts and/or blotters to dry and flatten

SOURCES CONSULTED

Connelly-Ryan, Cindy, et al. 2007. Optimizing ink corrosion treatment protocols at the Library of Congress. In *Edinburgh Conference Papers 2006*, ed. Shulla Jaques. London: Institute of Conservation, 195-202.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 20.1**
Library of Congress – Conservation Division

SIZING

Proteinaceous sizes

Gelatin size

Advantages

- Has undergone extensive analytical testing and has been observed to perform well over time
- Improves mechanical strength of paper
- Improves water and abrasion resistance of paper
- May protect paper against fluctuations of humidity
- May offer some protection against iron-gall ink corrosion by binding transition metal ions
- May protect the paper and the ink against degradation caused by oxidation
- Similar to the original size historically used in the production of most Western handmade papers

Disadvantages

- In poor environmental conditions, gelatin-sized paper may be vulnerable to mold or insect attack
- May yellow, either through overheating during use or in natural aging
- Modification of solution or application method may be necessary for water-sensitive inks

Preparation and application of gelatin size

The Conservation Division generally uses 0.25%-2% aqueous solutions of laboratory grade gelatin powder (e.g. Fisher 275 Bloom). The percentage of the solution is determined by the thickness and porosity of the paper as well as by the sizing retained by the paper after treatment. A more dilute solution may be appropriate for more porous papers.

The solution is expressed as weight to volume, e.g. 1% is 1 gm gelatin powder per 100 ml water

- Measure the quantities of gelatin powder and deionized water needed
- Heat the water and slowly add the powder to it
- After the gelatin has dissolved, allow solution to cool slightly before applying to the object. Solution may be applied by brushing onto the object through polyester web or by immersing the object in it.
- Blot the object with a blotter, change the polyester web and dry the object between felts and/or blotters

Aqueous gelatin solution may be modified with ethanol for water-sensitive inks

Parchment size

Advantages

- Provides protective properties similar to gelatin
- Similar to the original size historically used in the production of most Western handmade papers

Disadvantages

- The origin and purity of parchment clippings varies widely. Determination of the precise origin and composition of clippings is recommended.
- In poor environmental conditions, parchment-sized paper may be vulnerable to mold or insect attack

The Conservation Division generally does not apply parchment size to iron-gall ink-inscribed paper because the degree of polymerization of the size cannot be determined quantitatively.

PROTOCOLS for IRON-GALL INK TREATMENT NOTES **FIG. 20.2**
Library of Congress – Conservation Division

SIZING

Cellulose ether sizes

Methyl cellulose size

Advantages

- Prepared solutions have a longer shelf life than proteinaceous sizes
- Less vulnerable than proteinaceous sizing to mold or insect attack

Disadvantages

- At lower concentrations, does not improve mechanical strength of paper to the same degree as gelatin

Preparation and application of methyl cellulose size

The Conservation Division generally uses 0.5%-1% aqueous solutions of low molecular weight, short polymer length powdered methyl cellulose (e.g. Dow Methocel™A15C) for sizing.

- Measure the quantities of methyl cellulose powder and de-ionized water needed for solution
- Chill two thirds of the water and reserve
- Heat one third of the water to just under the boiling point
- Add the methyl cellulose powder to the heated water, whisking the mixture to disperse the powder
- Allow the solution to cool to room temperature for several hours, until sufficiently thickened. (See product container for suggestions of manufacturer or supplier.)
- Add the chilled water to the thickened solution
- Brush the solution onto the object through polyester web
- Blot the object with a blotter, change the polyester web and dry the object between felts and/or blotters

Aqueous methyl cellulose solution may be modified with ethanol for water-sensitive inks

Hydroxypropyl cellulose size

Advantages

- Can be dissolved in ethanol for application to water-sensitive inks

Disadvantages

- Does not improve mechanical strength of paper to the same degree as gelatin
- Use of ethanol requires additional precautions for health and safety

Preparation and application of hydroxypropyl cellulose size

The Conservation Division generally uses 1%- 2% solutions of hydroxypropyl cellulose (e.g. Klucel G® / Klucel GF®) in ethanol for sizing.

- Measure the quantities of hydroxypropyl cellulose powder and ethanol needed for solution
- Working in a chemical hood, heat the ethanol on a hot plate
- Add the hydroxypropyl cellulose powder to the warm ethanol, whisking the mixture to disperse the powder
- Cover the solution and allow it to cool to room temperature
- Brush the solution onto the object through polyester web
- Blot the object with a blotter, change the polyester web and dry the object between felts and/or blotters

SOURCES CONSULTED

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Deadline

The deadline for submissions is July 1. Send submissions to:

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