

# THE TEXTILE SPECIALTY GROUP POSTPRINTS

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American Institute for Conservation  
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## PREFACE

The twentieth volume of POSTPRINTS contains papers presented at the Textile Specialty Group (TSG) session of the annual meeting of the American Institute for Conservation of Historic & Artistic Works (AIC), in Milwaukee, Wisconsin from May 11-14, 2010.

TSG POSTPRINTS is a non-juried publication. Submission of these papers to juried publications, such as the *Journal of the American Institute for Conservation*, is encouraged. The papers, chosen from abstracts submitted to the Meeting Chair, Denise Migdail, Textile Specialty Group Vice Chair for 2009-2010, are published as submitted by the authors. Editing of papers was done according to the *Journal of American Institute of Conservation's* Guidelines for Authors and AIC's best practices guidelines for print and electronic publications. Materials and methods presented within the papers should not be considered official statements of either the Textile Specialty Group or of the American Institute for Conservation of Historic & Artistic Works.

The Editors wish to thank the contributors to this publication for their cooperation and timeliness. Without their enthusiasm and hard work this publication would not have been possible. Special thanks are extended to Translation Services USA, LLC, for translating the abstracts into Spanish. Thanks also are due to Joel Thompson, who laid out the volume using Adobe Indesign.

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# CONSERVATION OF A FELT SCULPTURE

ERIN ESLINGER

**ABSTRACT** – A 1968 untitled felt sculpture by Richard Morris was treated to correct holes, tears, and misshaping from hanging. The sculpture consists of eight large layered rectangular panels of wool felt with horizontal slits, with the top corner of each panel fitted with grommets to permit the panels to be hung in a large swag effect. Treatment was carried out by the author at the Midwest Art Conservation Center in the summer of 2009. Distorted areas of the felt were reshaped and a needle felting technique was used to reinforce and repair the weakened and damaged areas. The metal grommets were removed and replaced. The treatment successfully allowed the sculpture to be safely displayed with minimal visibility of the repair.

**CONSERVACIÓN DE UNA ESCULTURA EN TELA: RESUMEN** – Se trató una escultura sin título de 1968 realizada por Richard Morris para corregir perforaciones, rasgones y deformaciones debido al colgado. La escultura consta de ocho grandes paneles de tela de lana rectangulares dispuestos en capas con aberturas horizontales, con ojales en el extremo superior de cada panel para poder colgarlos creando un gran efecto de festón. El tratamiento fue realizado por el autor en Midwest Art Conservation Center en verano de 2009. Las áreas distorsionadas de la tela fueron remodeladas y se utilizó una técnica de fieltro con aguja para reforzar y reparar las áreas débiles y dañadas. Se extrajeron y reemplazaron los ojales metálicos. El tratamiento posibilitó exitosamente que la escultura fuera exhibida con seguridad y la visibilidad de la reparación fue mínima.

## 1. INTRODUCTION

The artist Richard Morris, known for his minimalist style in many mediums, intended his 1968 untitled sculpture (fig. 1) to change with time and environment in ways that he did not want to control or predict. This approach, he wrote, "...results in forms which were not projected in advance. . . . Chance is accepted and indeterminacy is implied" (Morris 1968, 35). While the owning institution wanted to retain the functionality of the piece in so far as it should be able to continue to be displayed, the artist's intent was considered and no other changes to the piece were addressed.

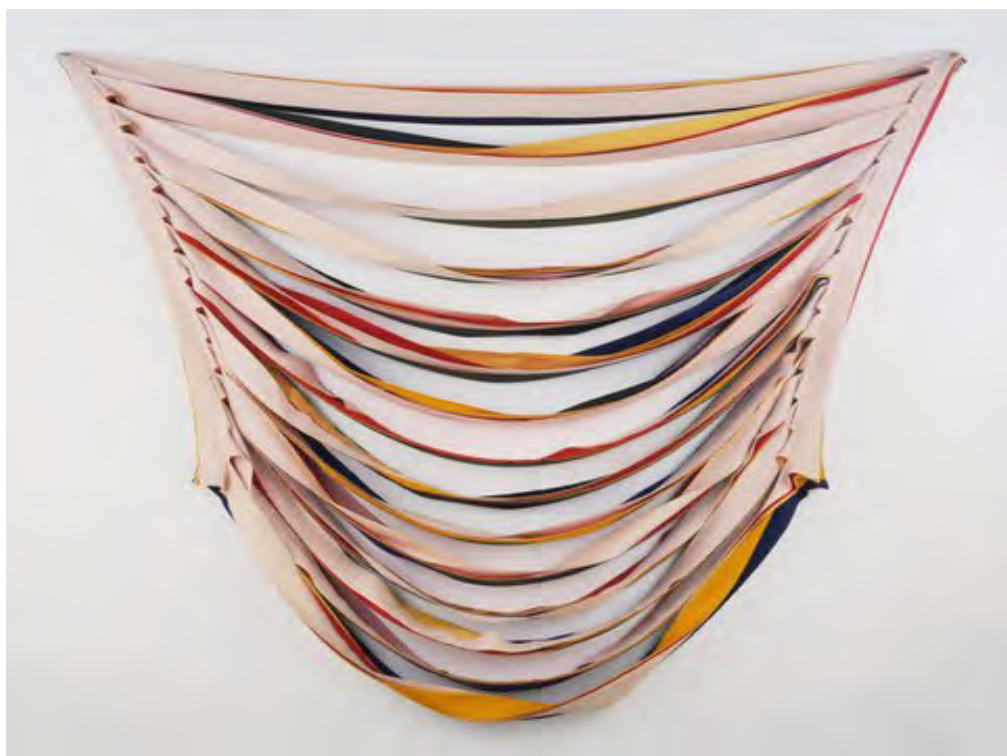


Figure 1. The piece on display prior to treatment.

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The sculpture (80 x 142 in. when flat) consists of eight rectangular panels of commercially produced, 100% wool felt. The pieces are layered, one on top of another, each with fourteen matched, evenly spaced horizontal slits and is displayed in a loose manner, creating a large swag effect. The felt panels appear in color order from front to back: off-white, red, yellow, yellow-orange, dark blue, pink, black, and dark green, each approximately 2mm thick (fig. 2). Each panel has two fastened grommets, one in each upper corner for display. The weight of the felt has created holes, tears, and misshaping in the areas surrounding these grommets. Over time, a few grommets pulled free of the felt. The original display grommets were 15/16 in. diameter, although the sculpture had been repaired previously in 1986, in four corners, as evidenced by larger replacement grommets, stitching, and patching.



Figure 2. Composite photo of all panels (proper left side at top).

The sculpture was sent to the Midwest Art Conservation Center (MACC) for treatment. The goal of the treatment was to stabilize the piece so that it could continue to be displayed and therefore continuing to function as preferred by the owning institution, the Walker Art Center. Only the stress and damage surrounding the grommets were treated. Those areas were then reinforced to prevent future damage. The project was completed by the author during the summer of 2009 at MACC under the supervision of senior textile conservator Beth McLaughlin.

### 2. TREATMENT

The Walker Art Center provided copies of previous treatment reports in which a conservator proposed use of adhesive and support fabric to improve the distortions to the felt.

A previous treatment in 1986 was evidenced by larger grommets and mesh facing material applied by hand stitching which, at present, appeared to have little to no impact on the continuing degradation of the felt. In each instance, the pieces of damaged felt were clamped under grommet washers and could not be accessed unless the grommets were removed. To do so without damaging the felt, the grommets had to be manipulated to such a degree that they could not be replaced in the sculpture. After consulting with the owning institution, it was determined that a complete replacement of all of the grommets would be an acceptable treatment. The MACC

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senior textile conservator examined the sculpture and, after researching several possible treatments such as supports applied by hand-stitching or adhesives, proposed to treat the piece by aligning the tears and stretching around the grommets with heat and humidification while supporting the surrounding area via needle felted support patches, an approach found to be the least invasive and most reversible of those considered.

### 2.1 GROMMET REMOVAL

Tests showed that the delicate felt could not withstand the stress of unrolling the grommet flange. Research did not find any tool or accepted method for removing grommets. When inspecting the piece, it was found that, for the most part, the flanges of the grommets were not cutting into the felt. It was only the pressure of the flange on the washer that secured the grommet. This meant that the flange itself could be cut to be removed. Cutting the washer was also considered.

After first testing several ways to remove the washer, focus then moved to ways to remove or alter the flange. First, an attempt was made to cut off the flange parallel to the felt surface with a jeweler's saw. Though this was somewhat effective, it was very time consuming and would potentially cause a great deal of stress on the weakest parts of the felt. The next test involved pinching the top of the flange with pliers with the intent that the washer could then just be lifted off over it. Though this was also somewhat successful, it was incredibly difficult to manipulate the flange manually and it seemed this also had the potential to be stressful to the piece. These approaches were then combined. While pressing down securely on the sides of the grommet so that it would not shift and stress the felt, a small wire cutter was used to snip through the flange four times at a perpendicular angle to the grommet (fig. 3). It was not difficult then to use pliers to pinch to flange sides inward. The washer was then easily removed and the flange could be pulled from the fabric from the other side. Although the areas of felt around the grommets were the most delicate, this approach to removing the grommets seemed to have little to no impact on the felt. The small wire cutters used were the size of jeweler's wire cutters but with a high hardness cutting blade. Both lineman (flat-nosed) pliers and needle-nose pliers were utilized depending on the size of the flange.



Figure 3. Steps of grommet removal showing snipped flange, pinched flange, and removed grommet.

### 2.2 FELT REPAIR

After removing the facing applied in the previous treatment to provide better access to the weakened areas, the next step was to consolidate the distorted felt directly around the grommets (fig. 4). It was thought that correcting these tears prior to attaching the new support material would increase stability. This was done by



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humidification and low heat treatment combined with manual manipulation (fig. 5). Testing showed that the material did not discolor or shrink when exposed to this treatment.



Figure 4. Example of distorted and torn area of felt around grommet hole before and after reshaping.

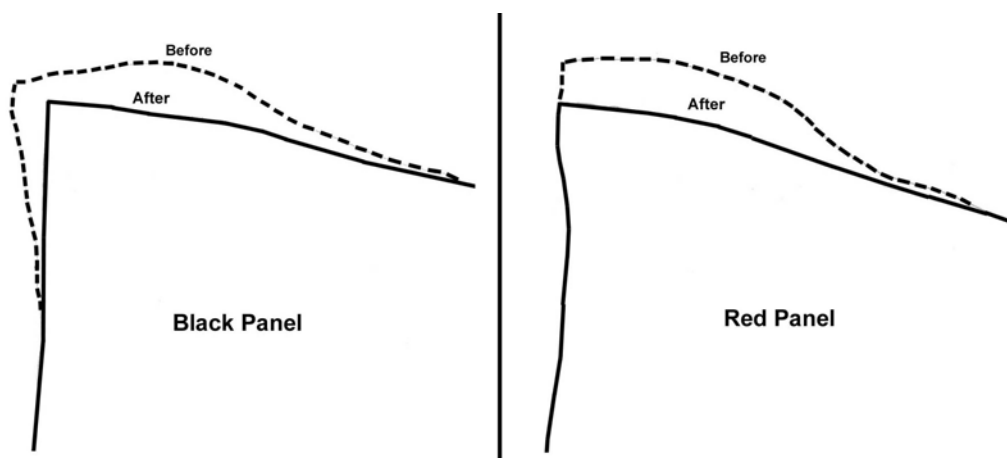


Figure 5. Examples of outside edges before and after being treated. Similar results were seen with all of the panels.

To attach the support material needle felting was used. Needle felting, commonly used in crafts, is essentially a technique used to attach one piece of wool to wool, or protein fibers to other fibers. A thin, barbed metal needle is pushed through pieces of material layered on top of each other (fig. 6).

Locating suitable felt for the support material proved to be challenging. Local textile retailers provided several types of wool blends and synthetic wool, all of which were tested. The highest wool to synthetic blend available locally was 40/60. This did not needle felt well and was available in limited colors. One-hundred percent wool felt was available locally in limited colors and was not the correct thickness or density to be a suitable support. Color matching was important, as the support felt could possibly be visible after the needle felting process. Finally, factory and wholesale producers of wool felt were contacted, one of which was Aetna Wool Corporation of Allentown, Pennsylvania. Upon request they provided 2 x 3 in. sample pieces of all available colors (fig. 7). The colors matched and the thickness and density were suitable. They were selected as the source for the support material.

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Figure 6. Needle felting in process.



Figure 7. Color samples from Aetna Wool Corporation.

In the needle felting technique, as the barbed needles are pushed through the felt they pull some of the material from the top layer down, through to the reverse of the bottom layer. A small amount of the bottom material is also pulled back up. The wool texture secures the two layers together. However, when the pieces are peeled from each other they separate with relative ease. The fibers remain attached to their original felt piece and can be reincorporated with manual pressure, heat, and humidification.

The required support material size was large enough to necessitate larger scale tools to facilitate the attachment. A large bristled brush measuring 3 1/4 x 5 in. with a hard plastic back, specifically made to be placed underneath the pieces of felt being attached, was used. The brush enables the needles to be pushed all the way down; the bristles allow the needles to pass through while the plastic back stops them and protects the surface below. A commercially available handheld punch made to hold five felting needles was used (fig. 8). Although felting can be done with only one needle and punches accommodating up to 12 needles are available, a punch with five needles covered an area of the piece large enough to work efficiently but still allowed for a measure of control over what was felted. This particular punch also had a retracting plastic guard which, while protecting the delicate needles, also insured that all the needles were horizontally aligned before being inserted. Although the needles leave small puncture marks, to minimize the effect, the smallest gauge of needles was used, 42 gauge.



Figure 8. Needle felting process, showing felting punch and brush support.

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Figure 9. Black and red panels with support material, before felting.

Two layers of support material were attached (fig. 9). The main support is a larger piece matching and starting at the two edges of the sculpture closest to the grommet (originally a right angle but deformed over time) which expanded beyond the weakened grommet area into fingers of fabric horizontally tapering inward and downward. The purpose of this shape was twofold. First, it was important not to effect the natural draping of the piece. Secondly, any continuous straight edges would have greater visibility. A second, small round piece of felt, slightly larger than the grommet width was placed between the artwork and the main support acting as a felt washer. Once the grommets were attached this became a ring, giving further support at the source of the stress on the piece. To create a stronger attachment, felting began from the reverse. After covering an approximately 4 in. square area with 10 insertions, the piece was turned and insertions repeated but increased to 20 to 30 insertions per section. Most of the felting was done with the artwork above and the support below as this process creates a small amount of visible tufting on the surface of the bottom layer.

### 2.3 GROMMET REPLACEMENT

Once the support material had been attached, the grommet die was used to cut a new hole in the support material to accommodate the new grommet. The grommets were then attached manually, using a grommet-setting tool (fig. 10).

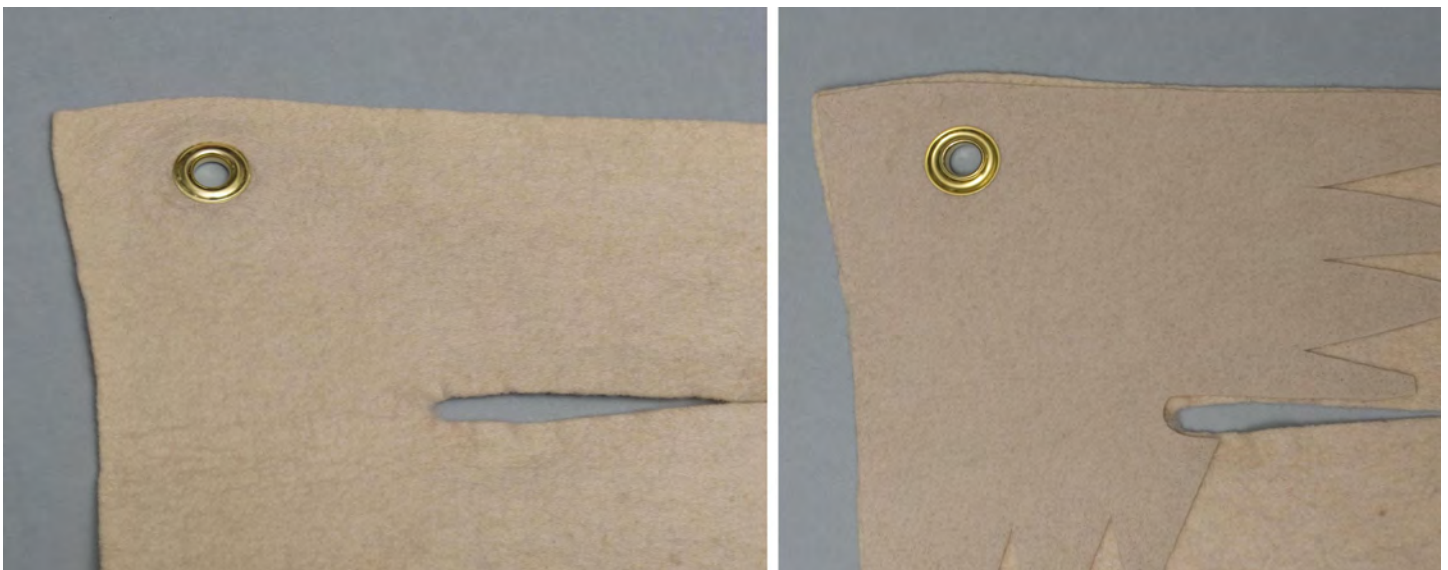


Figure 10. White panel, front and back, after new grommet is attached.



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### 3. CONCLUSION

Once the treatment was completed, the previously visible torn and gaping damaged areas were no longer evident. The weakened areas were stabilized and the addition of support material would lend much needed strength to the most taxed areas of the sculpture. The support material could be removed manually without the use of chemicals or other invasive approaches, needle felting being highly reversible. One concern with this treatment was that the thickened sections might be visible and cause the piece to hang stiff or awkwardly. Once hung however, the piece did drape in a natural manner and the new supports were not easily visible (figs. 11, 12).



Figure 11. Detail of proper left corner on display after treatment.



Figure 12. Sculpture after treatment, on display at the Walker Art Center.

## CONSERVATION OF A FELT SCULPTURE

### ACKNOWLEDGEMENTS

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### REFERENCES

Morris, R. 1968. Anti-Form. *Artforum* 6(8) (April): 33-35.

### SOURCE OF MATERIAL

Aetna Felt Corporation  
2401 W. Emaus Avenue  
Allentown, PA 18103  
1-800-526-4451

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# EVALUATION OF THE FORMS SUPPORTING ICONIC COSTUMES AT THE NATIONAL MUSEUM OF AMERICAN HISTORY: WASHINGTON, FRANKLIN, LINCOLN & THE FIRST LADIES

SUNAE PARK EVANS

**ABSTRACT** - The supporting forms used to display the museum's iconic costume objects at The National Museum of American History (NMAH) have changed over time, with varying impact on the objects. The author examines three suits and one collection of dresses, which have been exhibited repeatedly over a long time span. The investigation provides insights into the improved methods to display costumes as a part of the museum's preventive conservation approach. As the exhibition history at NMAH shows, the mannequins, mounting materials, and the methods have been improved over time as better knowledge and materials became available. In retrospect, it is obvious that problems arose from once-current display techniques used in the past. By observing damage from the stress and strain to costumes from previous mounting, by selecting archival materials, and through a better understanding as to how the costume would have been worn on the accurate body shape of the period, it is possible to create a new form that is archivally sound and provides superior support. The importance of collaboration and the sharing of expertise and knowledge between the various museum disciplines are also recognized.

**EVALUACIÓN DE LAS FORMAS DE APOYO DE EXHIBICIÓN DE TRAJES REPRESENTATIVOS EN EL MUSEO NACIONAL DE HISTORIA ESTADOUNIDENSE: GEORGE WASHINGTON, BENJAMIN FRANKLIN, ABRAHAM LINCOLN Y LAS PRIMERAS DAMAS: RESUMEN** - Las formas de apoyo que se utilizan para exhibir los trajes representativos del museo en el Museo Nacional de Historia Estadounidense (NMAH, por sus siglas en inglés) cambiaron con el correr del tiempo, lo cual produjo diversos impactos en los objetos. El autor examina tres trajes y una colección de vestidos que se exhibieron en reiteradas ocasiones durante un prolongado lapso de tiempo. La investigación brinda una perspectiva sobre los métodos mejorados para exhibir trajes como parte de la estrategia de conservación preventiva del museo. Tal como lo indica la historia de exhibiciones del NMAH, los maniqués, los materiales de montaje y los métodos mejoraron con el correr del tiempo a medida que surgieron mejores conocimientos y materiales. En retrospectiva, es obvio que las técnicas de exhibición pasadas que en su momento eran actuales causaron problemas. Al observar los daños que la presión y la tensión de los montajes anteriores causaron a los trajes, seleccionar materiales de archivo y mediante un mejor entendimiento de la manera en que el traje se habría usado en la forma corporal precisa del periodo, es posible crear una nueva forma acertada desde el punto de vista de la archivística y que brinde un soporte superior. También se reconoce la importancia de colaborar y compartir la experiencia y los conocimientos entre las diversas disciplinas del museo.

## 1. INTRODUCTION

About three million objects in various materials, shapes, and sizes are kept at the National Museum of American History (NMAH), but only three-percent of them are on exhibit. Among them, a few high iconic garments have been displayed repeatedly over time at the Smithsonian Institution since the public always expects to view these objects whenever visiting the museum. Although the overall condition for these objects are still fairly sound, they are often distorted and worn with certain areas that are stressed due to improper support, mounting materials, and handling over the years. While it is likely that past supporting methods and mounting materials were up to the current standards and knowledge of conservation practices at the time, in retrospect, it is obvious that problems arose from some of these display techniques. This paper examines how the supporting forms used to display the museum's iconic costume objects at NMAH have changed over time and how this has impacted the objects. This investigation will provide insights into the improved methods to display costumes as a part of our museum's preventive conservation approach. The research was heavily dependent on previous photo

## EVALUATION OF THE FORMS SUPPORTING ICONIC COSTUMES AT THE NATIONAL MUSEUM OF AMERICAN HISTORY: WASHINGTON, FRANKLIN, LINCOLN & THE FIRST LADIES

documentation, museum records, and colleagues recollections since many of the exhibitions do not exist anymore.

### 2. BENJAMIN FRANKLIN'S THREE-PIECE SUIT

The purple ribbed silk suit worn by Benjamin Franklin consists of a matching waistcoat, breeches, and coat. This simple three-piece suit symbolized the new American republic look during the War of Independence when Franklin wore it in 1778.



Figure 1. Benjamin Franklin's suit displayed horizontally without any support in *Growth to the United States*, 1964 to 1974. Courtesy of the National Museum of American History (NMAH), Division of Home and Community Life.

Elkanah Watson of New York received the suit from Franklin in Paris in February of 1778. He then gave the suit to the Massachusetts Historical Society in December or January of 1802-3. There was an agreement on a long-term loan (1963 to the present) from the Massachusetts Historical Society (MHS) to the National Museum of History and Technology (NMHT), now called the National Museum of American History (NMAH). This agreement stated that the suit would be exhibited in a new exhibit titled *Growth of the United States* and that the suit would be properly cared for and stored under the NMAH's facilities and expertise. This first exhibition, from 1964 to 1974, displayed the suit horizontally without any support (fig.1). It was placed with the pieces of the suit overlapping each other. The lights were filtered using the methods available at the time. It was discovered during the closing of the exhibit in 1974 that the construction of the suit was stable, but the fabric's dye condition on the surface was extremely fragile and unstable. The dye would come off whenever the suit was touched. Also, there were faded areas on the suit where the pieces overlapped, caused by light exposure during the exhibition. At that time, it was recommended not to exhibit the suit under any circumstances, but only to house it safely in storage as a study piece (NMAH Accession File).

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In 1982 the suit was dressed on a fiberglass mannequin to photograph for a publication (fig. 2). The front curve of the suit looked unnatural and showed a big gap between the waistcoat and the breeches. In addition, the proportion of the suit looked awkward. This lack of fit resulted because the fiberglass mannequin that was available was incorrectly shaped in the approved eighteenth century posture and did not support the suit precisely.

On January 17, 2006, when NMAH exhibited the suit to honor Franklin's 300<sup>th</sup> birthday, it had been stored for about three decades. After a current condition survey was completed, the suit was found to be structurally sound and capable of being displayed. Various museum experts from the fields of art, science, costume history, and conservation concluded that approved environmental factors, a monitored lower light level, and the construction of a archivally safe display form could minimize further damage to the suit. The decision was made to display the suit for a maximum period of three months under a light level of 1.5 foot-candles (NMAH 2005).

The use of a muslin pattern of the suit constructed by an eighteenth-century costume reproduction specialist limited the handling of the historical suit while constructing a display form. Chemically stable Ethafoam plank was used to build a form from scratch. It was based on the measurements of the suit and an accurate eighteenth century stance and pose that did not create any undue stress on the suit. The fit was refined by using polyester batting to add to the necessary part of the body. Polyester stockinette was then used to cover the form to provide a finished product (fig. 3) (NMAH 2006).



Figure 2 (left). Benjamin Franklin's suit dressed on a fiberglass mannequin for a publication in 1982.  
Figure 3 (right). Benjamin Franklin's suit displayed on a custom-made Ethafoam form in Benjamin Franklin's Suit in 2006. Photos courtesy of the NMAH, Division of Home and Community Life.



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The decision to exhibit the Benjamin Franklin suit provided a great opportunity to study and analyze it, particularly its fabric dye, in a way that had not been possible previously. Although it had long been established that the purple dye on the suit was unstable, a more intense study helped to understand more completely the nature of this problem and how advanced and accelerated the damage had actually become.

A senior research textile conservator on the Smithsonian staff joined in to monitor any color and fading during the exhibition using a non-destructive tool, a Minolta-Konica CR300 tristimulus colorimeter, calibrated to a white tile at D65 (Ballard 2005). Initially planned research to analyze the dye pigment and any other residue on the suit and to stabilize the dye condition has still been pending because of the lack of the staff resources and time limit.

### 3. GEORGE WASHINGTON'S UNIFORM

The three-piece buff wool uniform consists of a coat, waistcoat, and a pair of breeches that were actually worn by General Washington, but were from different time periods and were not worn together. The waistcoat and breeches were from the period of the Revolutionary War, but the uniform coat was from around 1789, after he had resigned from the Continental Army to become the nation's commander-in-chief. This conclusion was reached after study of the proportions and construction details of the uniform pieces. The uniform was held by the Columbian Institute and the National Institute and subsequently housed in the Patent Office before arriving at the Smithsonian in 1883. During the war years of 1942-1944, the Smithsonian packed up many of its treasured artifacts and sent them to the Shenandoah Valley for safekeeping. Otherwise, the uniform has become one of the iconic museum objects, and it has been on display almost continuously since 1944 (NMAH 2004).

Photo documentation of Washington's uniform on display at the Smithsonian started in May 1888 when Mr. John Noah modeled wearing the uniform and holding a sword (fig. 4). In 1944, the uniform was exhibited on a hanger without any padding (fig. 5), and later in the Arts and Industries building before moving to NMHT once it opened in 1964. It was typically displayed on a succession of mannequins with a head resembling the general. They were often made of clay or fiberglass with realistic faces, hairstyles, and hands (fig. 6). As most costumes on view at NMAH belong to someone who is well recognized, visitors often try to relate the real person to the detail of the mannequin's face and hairstyle rather than focusing on the costume. When the new exhibition *The American Presidency* was planned to open in 2000, the project team including curators, designers, educators, conservators, and other experts well understood this point. In order to discourage this tendency, the majority of costumes for this exhibition were displayed on forms made of Ethafoam without heads, hands, and any other exposed body parts.

The latest mannequin used to display the uniform until 2000 was made of clay over a steel armature, which was heavy and had a hard and rigid surface. The mannequin was padded with cotton batting using duct tape to hold it in the place. Joints such as the wrist, neck, and hips were stabilized with duct tape. The steel armature gradually became bent and crooked due to the heavy weight of the mannequin over time. It was apparent that the clay was not an easy material to carve, cut, or add to in order to achieve the proper eighteenth-century posture. Improper mounting materials and the incorrect body shape of the inflexible clay mannequin caused the stress and strain on certain areas of the uniform, including the near upper shoulders of the coat and the upper thigh of the breeches.

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Figure 4 (top left). George Washington's uniform modeled by a museum staff member in 1888. Figure 5 (top right). Washington's uniform displayed on a hanger in 1944. Figure 6 (bottom left). Washington's uniform displayed on a fiberglass mannequin until 1999. Figure 7 (bottom right). Washington's uniform displayed on a custom-made Ethafoam form in 'American Presidency' in 2000. Photos courtesy of the NMAH, Division of Armed Forces History.



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For the American Presidents exhibition in 2000, the collaborative efforts of the curators from Military history and Costume along with the costume conservator led to a support form made from a carved Ethafoam plank that presented the eighteenth-century general's uniform more accurately (fig. 7). The Ethafoam form was carved precisely to create the dropped and backward shoulder position that was typical of eighteenth century men's posture. It helped to eliminate the pressure on the front chest and upper back of the coat so it smoothly fit on the body. Also, there were wrinkles caused from the short length of the thigh support on the upper front areas of the breeches, which was corrected with a new mounted form and with an accurate posture of the eighteenth century gentleman. In addition, a pair of reproduction boots based on George Washington's reference record was commissioned from a eighteenth century boot reproduction specialist in order to provide increased advantage to the form's appearance and pose.

### 4. ABRAHAM LINCOLN'S THREE-PIECE OFFICE SUIT

The Smithsonian received a black silk office suit consisting of vest, trousers, and coat worn by Lincoln from the widow of Mr. William Morris Hunt in 1894. Hunt was a Boston artist who painted Lincoln's posthumous portrait in 1865. Thomas Pendel was the White House doorkeeper who delivered the Lincoln suit to Hunt upon the request of Mary Lincoln. Pendel was about the same size as Lincoln and posed in the suit for the artist. The portrait was eventually destroyed in a fire, but Hunt's sketch done at the time still survives (Rubenstein 2009).

Lincoln's suit had been stored for a couple of decades in the Smithsonian Castle storage until 1920 when it was displayed on a hanger without any support for a short time (fig. 8). In 1959, the 150<sup>th</sup> anniversary of his birth, the Smithsonian started an exhibit on Lincoln (Rubenstein 2009). The suit was displayed on a fiberglass mannequin with styled hair and realistic face and hands a couple of times in the Arts and Industries building before NMHT opened in 1964 (fig. 9). In 2000, only the coat without the other two pieces was chosen to be displayed for the exhibition *American Presidency*. The overall construction condition of the suit was stable and fair, but the silk surface was unstable. Whenever the suit was handled, the black fibers came off from the degradation. Also, the weighted silk lining of the coat was severely degraded and split all over. Therefore, the entire lining was overlaid with Stabiltex to stabilize the splits.



Figure 8. Lincoln's office suit displayed on a hanger, circa 1920s. Courtesy of the NMAH, Division of Political History.



Figure 9 (left). Lincoln's office suit displayed on a fiberglass mannequin before 1964. Figure 10 (right). Lincoln's office suit displayed on a commercially purchased Ethafoam mannequin in 'Abraham Lincoln: an Extraordinary Life' in 2009. Photos courtesy of the NMAH, Division of Political History.

The coat skirt both at the front and the back has a permanent distortion diagonally because the coat has been displayed before 2000 without closing the buttons at the front opening. Also the fiberglass mannequin did not adequately support the coat at the shoulder area, so the coat had hung loosely. In 2000, a commercially purchased Ethafoam mannequin was customized to create a realistic nineteenth-century body shape by modifying the shoulder areas to drop and pull backwards and by adding polyester batting to make the upper chest thicker and more curved. A muslin underskirt was made to support the coat skirt. In order to celebrate Lincoln's 200th birthday, the latest exhibition *Abraham Lincoln: An Extra Ordinary Life* opened in spring 2009. This is the biggest display yet at NMAH focusing on Lincoln and his office suit, and the form created for the 2000 exhibition was reconfigured to display the entire suit (fig.10).

## 5. FIRST LADIES' DRESSES

Cassie Mason Myers Julian-James, a leader of Washington social society, established a costume collection for the Smithsonian Institution in 1912. She collaborated with Rose Gouverneur Hoes, a descendant of President James Monroe, to develop an exhibition of costumes of the ladies of the White House. By 1914, fifteen dresses were collected from the friends and families of former first ladies and, at the same year, the exhibition *The Collection of Period Costumes* was opened in the Smithsonian's Arts and Industries Building. The first ladies exhibition intended simply to show the dresses of the hostess of each presidential administration, but the collections kept growing and became the most popular and the longest running exhibition at the Smithsonian.



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By 1931, there were costumes representing a presidential wife or hostess for each past administration (fig. 11). In 1955, the *First Ladies Hall* exhibition featured the first ladies' gowns with appropriate historical backdrops in the form of popular period rooms. In 1964, when the new NMHT opened the exhibition, personal accessories and White House china and furnishings were added to the gowns (NMAH 2009) (fig. 12).



Figure 11. First ladies exhibition in the 1930s. Courtesy of the NMAH, Division of Political History.



Figure 12. First ladies exhibition in the 1970s. Courtesy of the NMAH, Division of Political History.

Starting in 1987 the first ladies exhibition was closed for five years to prepare a new exhibition. For the first time, a costume conservator was hired in the centralized Conservation Department (now Preservation Services)

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to prepare museum-wide exhibitions. A team of interns, technicians, and private contractors under the direction of the costume conservator prepared the new first ladies exhibition by treating the dresses and mounting them on a new set of mannequins. The condition of the many of the dresses was fragile, dirty, damaged, and degraded due to many years of displaying them in an uncontrolled environment and without adequately supportive and archivally sound mounting. With the beginning of the first ladies exhibition in 1914, the dresses were displayed on mannequins made of a clay torso with some type of wooden support.



Figure 13. First ladies exhibition in 1992. Courtesy of the NMAH, Division of Political History.

In 1992 when the new exhibit *First Ladies: Political Role and Public Image* opened, the focus of the first ladies exhibition had been drastically changed by incorporating women's history scholarship and the roles and contributions of the first ladies (NMAH 2009) (fig. 13). The exhibition recognized the field of costume conservation and one small room was designed to display the scientific research and conservation treatment procedures performed on a selected dress. The design of the new exhibition gallery focused on controlling the environmental factors so the dresses could be displayed under a low light level reading below 3 foot-candles and in dust free cases. Fiberglass mannequins without the heads and hands were selected to display the dresses so that the public could focus on them without distraction from any other details of the body parts as previously when the hairstyles, faces, and hands were made to resemble the first lady. Each mannequin was mounted with conservationally sound materials and each dress was supported with the appropriate underpinnings. Furthermore it was decided as a part of a preventive conservation policy that the dresses would be rotated every six months to provide relief from continuous display. Because of the lack of the museum resources and the budgets however, the Smithsonian was not able to afford to change any of the dresses until 2006.

In the summer of 2006 the museum was closed to the public for a major building renovation. During this time, every object on display was packed away. In fall of 2008 the center part of the museum was reopened without the first ladies gallery. The permanent first ladies exhibit was not scheduled to reopen until the next phase of renovation was completed. Due to the strong demand from the public to see the dresses however, a temporary display entitled *First Ladies at the Smithsonian* was newly prepared and installed in the west wing.

When the museum closed in 2006, the dresses from the 1992 exhibition were evaluated to see which one could be reused for the new temporary exhibition that was to open in 2008. Even though the 1992 exhibition was prepared and supported by strong conservation effort, unfortunately the dresses were strained, stretched, and/or distorted because the fiberglass mannequins were rigid and the mounting did not precisely support the gowns for such a long duration on display. The dressed mannequins were heavy, but were supported with a one-half



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inch diameter rod. As a result, they gradually became bent and crooked over time. For the exhibition in 2008, the fiberglass mannequins were altogether abandoned and the new forms were constructed of Ethafoam without any heads or hands (fig. 14). Fortunately, the muslin patterns previously made were still available for the most of the dresses, so the handling of the fragile dresses was minimized for the new mounting process.



Figure 14. First ladies exhibition in 2009. Courtesy of the NMAH, Division of Political History.

The high popularity of this first ladies gallery led the museum to add one more gallery to feature first lady Michelle Obama's inauguration gown (fig. 15). The newly added exhibition *A First Lady's Debut* opened after Michelle Obama officially donated her inaugural dresses to the museum. The forms for this exhibition were constructed to match the previous 2008 exhibition (NMAH 2010).

### 6. CURRENT PRACTICES AND CONCLUSIONS

It is difficult to judge specifically how these historic costumes became damaged and distorted because it was a combination of the usage of improper materials, mounting method, storage, display, and environment. As many of these costumes continue to be on constant display, the best way to prevent further damage is to support them with inert materials in a controlled environment, while correctly interpreting the period body postures and mannerisms. NMAH either purchases commercially available Ethafoam (Dow polyethylene foam, 220 density) figures for more modern costumes or constructs custom forms from carved Ethafoam plank with an aluminum or steel support rod depending on the posture or gesture. Some merits of the mannequins made of Ethafoam are that the foam is lightweight, inert, and easy to adjust size and to handle. All museums aim to display the costumes in the proper manner and without causing further damage, yet the selection of the mannequins can be based on the museum's philosophy. NMAH is a history museum and its main purpose is to use mannequins which will unobtrusively display and support the historic costumes properly. Some museums, on the other hand, select mannequins that will be used to further interpret the costume.

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Figure 15. Display of Michelle Obama's inaugural dress in 2010. Courtesy of the NMAH, Division of Political History.

The exhibition history at NMAH shows that the mannequins, mounting materials, and the methods have been improved over time as better knowledge and materials became available. By understanding the correct body shape and stance for the time period, by selecting archival materials, and through a better understanding as to how the costume would have been worn, it is possible to create a new form that may provide adequate support for many years without causing further damage. Another critical factor is to collaborate and to utilize the expertise and knowledge from the various museum fields.

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WASHINGTON, FRANKLIN, LINCOLN & THE FIRST LADIES**

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**SOURCES OF MATERIALS**

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# **CULTURAL EXCHANGE PROGRAMS: SHARING CONSERVATION INFORMATION IN AZERBAIJAN**

**PATRICIA EWER**

**ABSTRACT** - Azerbaijan is a breakaway region of the former Soviet Union with a long history of textile and carpet traditions. Today the populace is trying to recapture its cultural heritage. Museum administrators are striving to provide best practices throughout the country addressing general museum issues balanced with collections' needs and the practice of conservation. Professional exchanges have been made through The Fund for Arts and Culture and US Government agencies. This author was invited by The Fund to share information about textile conservation and to determine future directions. Conservation workshops were provided for area museum professionals from the Restoration Center, Carpet Museum, Museum of History and Academy of Science. The author also consulted on the design of the new conservation laboratories at the Carpet Museum. Today many conservation professionals are being asked to share their information around the globe. The cultures we visit may have different concepts of preservation/conservation. This author's goal was to not impose western concepts of conservation but to initiate a dialogue with respect to their methods.

**PROGRAMAS DE INTERCAMBIO CULTURAL: COMPARTIR INFORMACIÓN DE CONSERVACIÓN EN AZERBAIJAN: RESUMEN** - Azerbaijan es una región separada de la ex Unión Soviética con una larga historia en tradiciones relacionadas con tejidos y alfombras. Hoy la población está intentando recuperar su legado cultural. Los gerentes de museos se esfuerzan por aplicar las mejores prácticas en todo el país abordando los problemas generales de los museos en equilibrio con las necesidades de las colecciones y la práctica de la conservación. Se han llevado a cabo intercambios profesionales a través del Fondo Nacional para las Artes y la Cultura y agencias de Gobierno de los Estados Unidos. El autor fue invitado por El Fondo para compartir información sobre la conservación de tejidos y para determinar futuras directivas. Se brindaron talleres de conservación para los profesionales de museos del área del Restoration Center, Carpet Museum, Museum of History y Academy of Science. El autor también consultó sobre el diseño de los nuevos laboratorios de conservación en el Carpet Museum. Hoy muchos profesionales de la conservación en todo el mundo son consultados para compartir su información. Las culturas que visitamos tienen diferentes conceptos de preservación/conservación. El objetivo del autor no fue imponer los conceptos occidentales de conservación sino entablar un diálogo con respecto a sus métodos.

## **1. INTRODUCTION**

Many conservators in this day and age are finding themselves invited far beyond their own borders and perhaps their comfort zones to share conservation expertise around the globe. Obviously there is an international need for these services (Brennan 2007, 2010; Lennard 2010, MACC 2010) (fig. 1).

Azerbaijan is an oil rich nation on the Caspian Sea, trying to recapture its cultural heritage. The Old City of Baku and several other historic places are classified as UNESCO World Heritage Sites (Chen 2008). Museum administrators are striving to increase their knowledge of cultural management to provide best practices throughout the country. Issues include serving tourists' needs, maximizing attendance versus collections needs, researching and developing exhibitions, caring for collections, and information dissemination. Several professional exchanges have been made through The Fund for Arts and Culture and US Government agencies (fig. 2).

The author was invited by the Fund for Arts & Culture in Central and Eastern Europe (The Fund) to visit Baku, Azerbaijan and conduct workshops on textile conservation in September 2009. The importance of this topic had been highlighted by Ward Mintz, Executive Director of the Coby Foundation Ltd, during the visit he had taken to Baku on behalf of the Fund in 2008 (Mintz 2008). The Coby Foundation is dedicated to funding textile projects making him particularly sensitive to issues related to textile conservation. While his trip to Baku focused

on the larger picture of museum management, his discussions with museum professionals revealed that textile conservation was an area of interest and need.



Figure 1 (left). Map of Azerbaijan (image taken by P. Ewer of Rand McNally ([www.randmcnally.com](http://www.randmcnally.com))).



Figure 2 (right). The Walled City of Baku: carpet dealer's shop (photo by author).

In addition, Jahangir Selimkhanov, Director of the Arts & Culture Program of the Open Society Institute (OSI, a Soros Foundation initiative), related in discussions with Mr. Mintz that the State Museum of Azerbaijan Carpet and Applied Art (Carpet Museum) was in the process of building a new museum and needed consultation on the design of its conservation laboratories.

The purpose of my visit, as determined by Mr. Mintz and Mr. Selimkhanov, was to find a conservator who could come to the US for a textile internship and to find an institution in the US that could accept a foreign intern. A secondary goal was to assist the Carpet Museum in the design of its conservation laboratories.

Trips for the Fund are usually set up with a team of people. This team was to consist of an American cultural institutional marketing expert, Mr. Charles Croce, Vice President of Marketing and Public Relations for the Kimmel Center for the Performing Arts in Philadelphia and myself as textile conservator (Croce 2010). Due to scheduling conflicts we were separated and Mr. Croce was placed in Baku during the second week of September and I followed in the third week.

## 2. PREPARATION

How does one prepare for going virtually into the unknown? There are few guidebooks, nor history books (some spy type novels), based on the specific currently named country of Azerbaijan. The greatest body of



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information to be found was on Wikipedia (Elliot 2004; Kohn 2000; Wiki 2009). From Mr. Mintz, who went the previous year, I was given an idea of what to expect. He introduced me to Rachel Shabica, the registrar at the Textile Museum in Washington, D.C., who had done a summer internship in the Carpet Museum in 2008. Ms. Shabica also owned the one book published by ICOM on the museums of Baku. Mr. Mintz and Ms. Shabica were most helpful with the day to day traveling details such as visas, electricity and social customs. Discussions on a professional level, and with information from Jahangir Selimkhanov, allowed the creation of two separate workshops: a very basic lecture on textile conservation and another on conservation laboratory design. There were no specifics on audience characteristics. Information stated that representatives from the major museums would be present. It was not disclosed if the individuals would be administrators, conservation professionals or docents.

To facilitate the workshop, 25 computer flash drives were created to present to people as references and small gifts. These drives included images of our home, family and sites throughout the US to give them a sense of life in America. This kind of informational exchange was encouraged by the Fund (Fund 2009) and is discussed by Brennan in her publications (Brennan 2010). Additional information on the flash drives included professional materials directly related to textile conservation, supplemental information related to conservation laboratory design, and a PowerPoint presentation outlining textile conservation work at Historic Royal Palaces in the UK. The flash drives also included a textile conservation bibliography, a list of conservation related web-sites, AIC Code of Ethics, the chapter list from the book *Textile Conservation: Advances in Practice*, and an information packet from Icon, a United Kingdom conservation organization outlining the roles and responsibilities for art conservation technicians. The drives that focused on laboratory design included laboratory equipment and supply lists, US and European suppliers, references for laboratory design, and a PowerPoint presentation on laboratory design (Ewer 2009). These drives were delivered to bench conservators and not just administrators of organizations. In addition to the flash drives, information packets from Testfabrics, Inc. and product catalogues from several USA conservation equipment and materials suppliers such as Gaylord, Talas and Museum Services Corporation were distributed.

### 3. ON SITE

As an introduction, the first day was spent touring the sites of the Old City with a guide, Gurban Bunyatov. That evening we attended the opening, held on the upper floor of the Carpet Museum, of the exhibition “The Nobels and Baku Oil” by The Baku Nobel Heritage Fund. There we met Zarifa Melikova, Director of the Center for Scientific Restoration of Museum Values and Relics (Restoration Center) and one of her textile conservators Ulviyya Sghirinova.

The first workshop on Wednesday, 16 September was attended by twenty-five conservators from a variety of disciplines, representing four Baku institutions: (1) The State Museum of Azerbaijan Carpet and Applied Art, (2) Museum of History, (3) Restoration Center, and (4) the Institute of Art-Azerbaijani Academy of Science). Introductions were made by Jahangir Selimkhanov, Director of the Arts & Culture Program OSI, Dr. Roya S. Taghiyeva, Director of the Carpet Museum and Zarifa Melikova, Director of the Restoration Center. The program progressed with the help of interpreter Gunay Rzayeva which enabled all to have open discussions of topics that conservators of all disciplines and nationalities experience. The presentation covered: (a) the various types of textile artifacts encountered in collections, (b) the different types of materials, (c) the nine agents of deterioration, and (d) preventive conservation methods. The program concluded with a number of conservation treatments including examples of cleaning and repair techniques with before and after images, generating the

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most interest from the audience. The presentation finished by briefly relating the latest engineering studies being done on the hanging of historic textiles, as there were many comments on science in conservation.

The participants were very eager to discuss issues of conservation vs. restoration and the client museums' perceptions of each. Also discussed was the use of different materials – natural (traditional) vs. synthetic (or modern). The participants were intrigued by the types of cleaning agents used in the US as well as adhesives. The dialogues amongst the conservators were very candid and thoughtful, with sophisticated analytical thought displayed towards their conservation treatments. This is not easily expressed by conservators new to the field or students. More time would have been appreciated for a longer discussion period with this entire group (fig. 3).



Figure 3. Textile Conservation Workshop (photo by author).

### 4. LABORATORY DESIGN DISCUSSION

The next presentation was for the Carpet Museum, attended by Roya S. Taghiyeva, Director of the Carpet Museum, their conservators, the head of the education department and one paintings conservator from the Restoration Center. The goal of this discussion was to address their specific conservation issues in relation to the creation of a new conservation laboratory to be housed in the new Carpet Museum building currently under construction. This presentation was based on the May 2009 Textile Specialty Group meeting of the American Institute of Conservation for Artistic and Historic Works meeting in Los Angeles, California.

Reviewed in this presentation were the basic principles of laboratory design and equipment needed for textile conservation. The group discussion ventured into areas of analytical work, integrated pest management, dyeing technology, display methods, departmental staffing plans and work processes. An interesting discussion of the definitions of the terms preservation-conservation-restoration was initiated by the museum's head of education. Specific requests for further information were delineated, and it was agreed that this author would supply them with further information once back in the States (fig. 4).

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Figure 4. Conservation Laboratory Design presentation attendees (photo by author).

### 5. MUSEUM VISITS

During the remainder of the week in Baku, tours and visits were planned for me to see the four major institutions in the city. On Thursday, September 17, 2009, I visited the Restoration Center which employs 45 conservators of all disciplines. This organization is similar to an American regional lab as they perform a great variety of work from paintings, metals, glass, pottery, and furniture to many types of textiles. The focus of discussions with these conservators again was about methods and materials. This facility was very dedicated to the use of traditional materials and techniques (fig. 5).



Figure 5. Textile Conservator doing costume conservation at the Restoration Center (photo by author).



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Friday, September 18, 2009, featured a visit to the Museum of History in an old, well-restored former 19<sup>th</sup>-century oil baron's mansion. The director, Naila Velikhanly, provided an enthusiastic tour through their own very impressive restoration laboratories. Introductions were made to the ten present conservators, including paintings, paper, textiles and ceramics. In addition, they have six collections care staff members. Tours were given in collections storage, which was climate controlled, as well as the galleries and laboratories. They have so much textile work that in addition to the four textile experts they employ, they send additional textiles in need of conservation to the Restoration Center. These conservators were also interested in the types of materials, especially adhesives for ceramics, that we use in the States (fig. 6).



Figure 6. Carpet Restoration at the Museum of History (photo by author).

Friday afternoon's visit was to the former home of opera composer Uzeir Hajibeyov. We toured the house with director Zarifa Melikova and several staff members from the Restoration Center to see the variety of collections conservation work they had done for this house museum.

On Saturday, September 19, 2009 I went to the Azerbaijan State Museum of Art to meet with Gulyana Mammadova, the Deputy Director. This museum was in the process of moving the collections to a newly renovated building which was to open the following week. We had very interesting discussions with Ms. Mammadova about conservation within her institution and her priorities for collections care and accessible exhibitions in the new space. Due to the construction health and safety concerns we were unable to see the new building.

Other visits included tours of the galleries in the Carpet Museum with an English-speaking guide. In addition I met again with Dr. Roya Taghiyeva, Director of the Carpet Museum. We went over the plans for the new



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museum and discussed in detail their conservation needs and the type of laboratory required for the new museum. We concluded with an agreement for consultation on the project for the new laboratory. Dr. Taghiyeva would be supplied with a list of analytical equipment and technical equipment, and a description of their potential use (fig. 7).



Figure 7. Gallery in Carpet Museum (photo by author).

## 6. CONCLUSION

To follow up on the general educational needs of the conservators, I proposed that it would be beneficial for the conservators to see conservation laboratories in Western Europe and the USA. This would allow them to see the variety of projects being worked on and the equipment and materials used to what purpose. As for the suggestion that a textile conservator come to the USA to do an internship I was hesitant to go forward with that recommendation. There were so many conservators, with a wide variety of education and experiences that it would be a hard choice to make. In my opinion it would be easier to pinpoint the different needs or experiences that would benefit a greater majority of the conservators and provide on-site workshops. Thus it was concluded that a one-time internship for one person would not be that beneficial for the greater good or very easy to fund. Rather a proposal for two – three week hands-on workshops in Baku that a number of conservators could attend would allow them to experience the techniques and materials used in the United States and Western Europe. There are several conservators who have experience doing such international workshops and who would be well-qualified to conduct this workshop. In regards to conservators working internationally, I found it to be an extremely rewarding experience.

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# **NOT MUCH LEFT: DIGITALLY RECREATING UPHOLSTERY IS A GROUP EFFORT**

**ANN FRISINA**

**ABSTRACT** – Documenting and recreating historic replacement upholstery show covers requires detailed analysis, research, and the understanding of current textile digital printing industry standards. The author examines the process of documenting upholstery for the James J. Hill House library chairs and sofa. Archival photographs and documents, physical evidence of the original upholstery, and historical research were used to recreate the upholstery fabric design with the aid of a textile designer. The design was digitally printed by a commercial digital printing firm to produce the final textile. The author discusses how the peculiarities and limitations of digital printing technology influenced decisions and designs application.

**NO QUEDA MUCHO; LA RECREACIÓN DIGITAL DE LA TAPICERÍA ES UN ESFUERZO MANCOMUNADO: RESUMEN** – Documentar y recrear el reemplazo de fundas de exhibición de tapicería histórica requiere de un minucioso análisis, investigación y entendimiento de los estándares actuales de la industria de la impresión digital textil. El autor analiza el proceso de documentar la tapicería de los sillones y el sofá de la biblioteca de la Casa de James J. Hill. Se utilizaron fotografías y documentos de archivo, evidencia física de la tapicería original e investigaciones históricas para recrear el diseño de la tela de la tapicería con la asistencia de un diseñador textil. El diseño lo imprimió digitalmente una imprenta digital comercial para producir el tejido final. El autor discute de qué manera las peculiaridades y limitaciones de la tecnología de impresión digital influyeron en las decisiones y en la aplicación de los diseños.

## **1. INTRODUCTION**

No project addressing the needs of replacement upholstery show covers within any historic house is easily accomplished. This paper reviews a project documenting and recreating upholstery fabric with digital printing for two 1890 wing back chairs and a sofa. The furniture belongs in the library of the James J. Hill House, in St. Paul, Minnesota, completed in 1891. While this historic house is part of the Minnesota Historical Society almost all interior textile furnishings within this historic home have been lost resulting in the need to find replacement textiles.

## **2. PHYSICAL DOCUMENTATION AND RESEARCH**

Whenever outfitting an historic room with replacement textiles it is important to gather documentation and information from as many sources as possible. Evidence from glass negatives, photographs, archives, and tacking edge analysis all assisted in documenting the original upholstery show covers. Decisions to identify and recreate the lost upholstery were implemented by the James J. Hill Library team which is comprised of three individuals: a collections curator, the Hill House site director, and a textile conservator. The Hill Library team was expected to find suitable replacement upholstery for two chairs and a sofa belonging to the library.

The first primary source of evidence reviewed was glass negatives taken in 1922, the earliest images of the home (figs. 1-3). The library images document a suite of furnishings upholstered in the same floral pattern, comprised of two wing back chairs, a side chair, and a large buttoned sofa. The upholstery show covers documented in these early images is a complex woven design of large and naturalistic floral elements. Unfortunately, none of the glass negative images documents a full repeat of the upholstery show cover design due to its buttoned application.



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Figure 1. Glass negative of Hill House library, 1921-1925, unknown photographer. Minnesota Historical Society (MHS).



Figure 2. Glass negative of Hill House library, 1921-1925, unknown photographer, MHS.

The Minnesota Historical Society has the two original wing back chairs in its collection and a replacement sofa. In an attempt to identify any remaining evidence of the original upholstery show covers, both chairs were brought to the society's Textile Conservation Lab for tacking edge analysis (figs. 4, 5). Physical files were created with samples of the current show cover campaigns removed and stored in the objects files. None of the current show covers were considered to be original due to the use of synthetic materials. However, careful examination of both chairs revealed fragments and fibers of earlier upholstery campaigns.

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Figure 3. Glass negative of Hill House library, 1921-1925, unknown photographer, MHS.



Figure 4. Hill Library Chair 1 before treatment.



Figure 5. Hill Library Chair 2 before treatment.

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Figure 6. Chair 1 tacking edge fragment.



Figure 7. Chair 2 yarns in situ.

Textile fragments found on the chairs provided much information. Fragments on the first chair's tacking edge have a single color cotton warp and polychromatic wool weft (fig. 6). The weft created all color changes while the warp acted solely as a structural element. Seven earthy colors were documented in the wool weft. There are approximately 16-18 p.p.i. and 20 e.p.i. in the fragments. This supplemental weave structure was commonly used in the late 19<sup>th</sup> century to create figured polychromatic designs on a jacquard loom with a cotton warp and wool weft. Excavation of the second wing back chair provided no tacking edge fragments, however long floats of single-ply woolen yarns matching the first chair's tacking edge fragments were found nestled in the horsehair of the inside back (fig. 7). These yarns proved to be a good source for color matching which is very difficult with samples less than half an inch long.

Another interesting source of information about the home's furnishings is found in Mr. Hill's personal records where each and every correspondence, note, and bill can be found today. One short letter from Irving & Casson, the interior designers, dated August 10, 1891 states:

...We send to-day by express, samples of woolen tapestries for coverings for the large Hall and Library Chairs. Mr. Hill wished us to select something for these chairs, and we have looked all through the market and cannot find anything entirely satisfactory. We send the best samples for the piece that we have found and have marked the ones that we think would be best for your approval (Irving & Casson 1891).

This document verifies the intent to use woolen upholstery with a figured floral design for both the library chairs.

The fragments found were likely remnants of the first upholstery campaign for three reasons. First, figured upholstery of the late 19<sup>th</sup> century was often fabricated with a cotton warp and wool weft matching the physical evidence found on Chair 1 and Chair 2. Secondly, the fragment colors were in the correct family and fit in as part of the room's overall decor. Finally, these are the only natural fiber fragments and yarns found on the chairs. All other physical evidence of the upholstery show covers is fabricated with manmade or regenerated fibers. Due to comparative analysis of the glass negatives, wool tacking edge fragments, and correspondence, it is highly probable that the polychromatic fragments and yarns are what remain of the first show cover application.



### 3. DESIGN PROCESS

The small fragments gave us an enormous amount of information to document the fiber, ply, weave structure, and colors. However, while the glass negatives show us a large portion of the pattern, nowhere is the full repeat shown. The overall design is fragmented by the lack of detail in the photo and the buttoned folds. The largest expanse of the upholstery pictured in the glass negatives is found on the outside arm of the sofa, which documents the width of the design (fig. 8). However, the overall length of the design is not decipherable. The Hill Library team sought out a textile designer, Anna Carlson, with interest in historic textiles to recreate the design using what original information we had.

The textile designer began by matching up elements pictured in the glass negatives, piecing as much of the design together as possible. Drawings were simply outlined at this beginning stage. The work was executed by integrating the digital images with hand drawings which were then scanned back into Photoshop and adjusted. This use of hand and computer generated images helped to create the overall design.



Figure 8 (left). Glass negative of Hill House library, 1921-1925, detail showing outside sofa arm, Unknown photographer, MHS. Figure 9 (right). Overall design in grey scale.

Also important in documenting the floral elements' scale correctly was a matching substitute sofa purchased by Hr. Hill's son Louis. Originally purchased from the A.H. Davenport Furniture company, owned and operated by the Irving & Casson design firm, this substitute sofa was donated by the Hill family. When the glass negative images were compared to the replacement sofa it was noted that the two sofas are an exact match to each other in every way except for an additional eight inches in length. The largest expanse of the upholstery documents the width of the repeat as 23 in. with the repetition of floral images (fig. 9). This image detail allowed the textile designer to emulate the correct proportion of the designs elements by comparing their scale and placement on the original sofa in the photograph to the substitute sofa's outside arm.



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In comparison, identifying the full length of the designs repeat was not possible due to the lack of detail in the glass negatives. The same floral elements had been used repeatedly, but they did not always face in the same direction. While reviewing images of historic textiles just prior to the 1890's the textile designer found the following reference in Linda Parry's *William Morris Textiles*:

Another characteristic Morris pattern style, first seen in designs printed at Leek, was that using a turn-over or 'mirror' repeat. Because of the nature of this type of design patterns tend to be wider than those with straight or half-drop repeats and Morris took full advantage of this by using the whole width of the fabric (36 inches for linens, and cottons and 24 inches for this velveteen) for the designs. "Do not be afraid of large patterns", he advised, "if properly designed they are more restful to the eye than small ones: on the whole, a pattern where the structure is large and the details much broken up is the most useful... very small rooms, as well as very large ones, look better ornamented with large patterns" (Parry 1983, 47).

William Morris would often mirror a design, creating a larger repeat with virtually half the work. With this process in mind Anna completed the overall design by reversing and stacking her current design to create a 59.5 in. long repeat.



Figure 10 (left). Overall design completed. Figure 11 (right). First three digitally printed samples.

Once the linear design had been created, seven colors identified from the tacking edge fragments needed to be applied. To do this the seven color palate was altered into a grey scale, where each color was given a specific grey value. Next the color palate was compared to the glass negative images, allowing the team to assign the appropriate grey color to the design (fig. 9). Finally the grey values were returned to their original colors. While it is not possible to prove that this process of using a grey scale was accurate it provided a methodology. Interest-

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ingly, the color placement surprised our 21<sup>st</sup> century idea as to what it would look like (fig. 10). The design now complete is quite muted and monochromatic.

### 4. FABRICATING THE UPHOLSTERY

Once the design was completed, a decision had to be made. Did the reinterpreted design warrant the expense of having it translated into woven goods, or could it be fabricated to look as if it was woven with digital printing? This design, while based on historic images and actual fragments, is just an approximation of the original design. Reproduction pattern drafting and weaving starts at \$460.00 per yard for a design as complex as ours. In comparison digital printing runs between \$25-\$50.00 per yard. Since this was not a truly historic design the expense of weaving such a large repeat was considered too great. The Hill Library team turned to digital printing as a medium for reproduction. The big question was whether it was possible to create the look of a woven tapestry and fool the eye without the expense of reweaving.

LTS, a textile digital printing establishment, was willing to establish the working relationship necessary to print replacement fabric. Recreating upholstery fabric for any historic application is demanding. The colors, texture, and overall design are expected to meet the exacting museum standards which are often at odds with industry standards. Many businesses simply don't have the time or patience to deal with our unusual field. Without a strong commitment to our standards this type of reproduction is doomed at best. Due to proprietary information LTS would not divulge the name or components in their ink. Because this fabric is separated from the object with barrier layers and sewing bases, the objects are not confined to cases, and the light level in the house is very low, the lack of specific knowledge of the archival qualities of the printed fabric was felt to be an acceptable compromise.

The first test prints of the design were executed on three different fabrics (fig. 11). While the colors are not right the quality of dye application and how the design would read was the first focus. At issue was how digital printing can appear to float on top of the textile's surface. The first three samples were executed on smooth to more textured cotton fabrics. Smoother fabric resulted in a more saturated design. However the textured fabric, while not as saturated, does have the strongest woven appearance.

After viewing these first samples the Hill Library team began to make some unusual requests of LTS. First, could LTS saturate the surface with ink, creating a deeper print? Secondly, could LTS apply a filter breaking the curved line into a stepped line fooling the eye to think it was woven? Our second sample was considered a success, where the design is saturated with ink on a textured ground fabric with the broken stepped design.

Our next hurdle was to establish the correct colors (fig. 12). There was great difficulty adjusting colors in the design due to the way it was created in Photoshop. Firstly, the design was developed in Photoshop as an RGB continuous tone image. RGB design, red, green, and blue, has millions of colors and allows you to create detailed images like photographs. A photograph often needs RGB because of its use of continuous tones, where the colors run into one another (fig. 13). The opposite of continuous tone is posterized, meaning the colors are reduced to a specific number and reside within specific shapes (fig. 14). Indexing an image changes the mode of a design from continuous to posterized which defines and separates each color from the other. Our design was created as a continuous tone but needed to be an indexed design.



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Figure 12. Second digitally printed sample with stepped line and saturated ink.

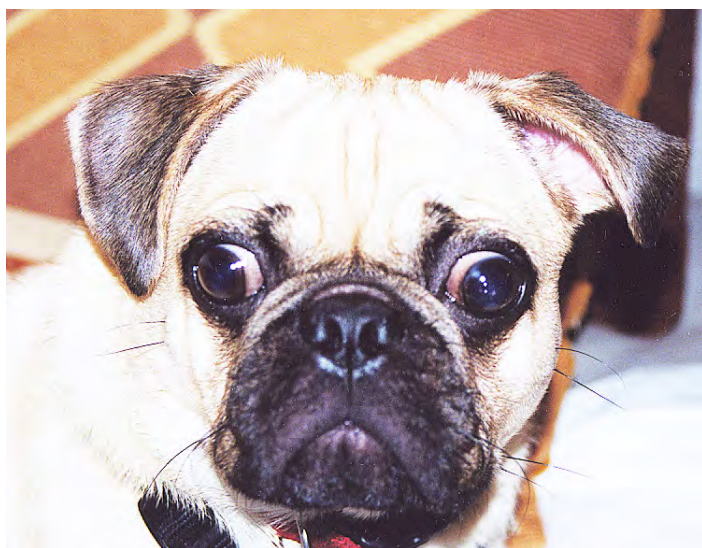


Figure 13. Sample image in continuous tone.

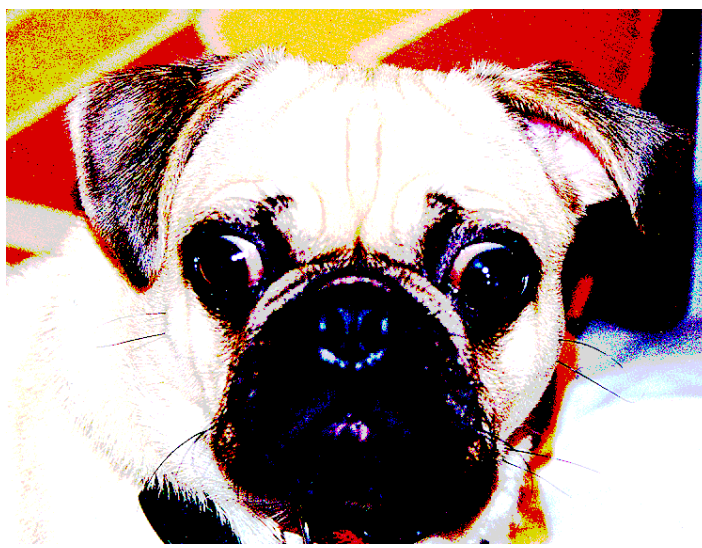


Figure 14. Sample image in posterized tone.

Also, how the colors were applied to the digital design also influenced how they were adjusted. This design had all the colors on a single channel. Having all the colors on the same channel means that if one wants to change one color, all of the colors will be changed in the same quality and degree. A color change that affects the entire design is referred to as a global adjustment. If the recreated design had its colors separated into different channels, a single color could then be adjusted without affecting the entire design. LTS did adjust individual colors for our needs but it took a lot more time to edit the design in this manner.

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Finally, when colors are very close in hue and value it is difficult for a digital printer to differentiate one from another; the printer reads them as one. This means that colors need a substantial difference to be successfully read by a textile digital printer. While the Hill Library team wanted two yellows close in value and hue it was not viable to have such subtle details printed. Finally, printing on a textile digital printer can require shorter yardage lengths (fig. 15). LTS could not guarantee that the value and hues of the colors would be the same if we were to print in 25 yd. lengths continuously. Consequently, we had our goods printed in 7 and 8 yd. lengths totaling 50 yds.



Figure 15. Final sample pinned in situ.

## 5. CONCLUSION

No project addressing the needs of replacement upholstery show covers within any historic house is easily accomplished. The task of documenting the original upholstery through research and analysis was easy in comparison to finding suitable replacement upholstery. Building relationships and understanding textile digital printing industry standards was an important part of this project. While the final upholstery fabric created for the Hill library chairs is not an exact replica, its overall design, which is singular in today's marketplace, is as close as possible with the information available.

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# FINDING SUPPORT: REASSESSING & DEVELOPING A NEW SUPPORT SYSTEM FOR ORIGINAL UPHOLSTERY

G. GUIDESS, W. DONNELLY, J. GARDINER AND J. WICKENS

**ABSTRACT** – A recent conservation treatment performed on a slip seat with surviving original under-upholstery provided an opportunity to assess a previous treatment. The slip seat belongs to one of a pair of Federal-era chairs purchased in January 2008 by the Winterthur Museum & Country Estate. The previous treatment did not adequately support the under-upholstery. This, combined with a curatorial desire for better visibility of the materials for study, precipitated the removal of elements of previous conservation. Other treatment methods that have been used to support upholstery were then considered for the retreatment but none were found to be completely appropriate. A new treatment was devised using a material that had not, to the authors' knowledge, been utilized in this particular area of conservation. The material, Vivak<sup>®</sup>, is a water-clear, thermoplastic co-polyester produced by Bayer Material Science Company.

Its chemical and material properties, which will be described, make it a readily adaptable material for conservation. Its properties avoided some of the shortcomings of previously used materials. For the new treatment a custom-shaped support was made and attached to the slip seat frame with a non-intrusive method. It combines virtual transparency with even, full support for the under-upholstery. When installed it also improves the overall profile of the slip seat.

**BUSCANDO APOYO: RECONSIDERACIÓN Y DESARROLLO DE UN NUEVO SISTEMA DE APOYO PARA LA TAPICERÍA ORIGINAL: RESUMEN** – Un tratamiento de conservación realizado recientemente en una silla con lo que sobrevivió de su tapicería inferior posibilitó evaluar un tratamiento previo. La silla pertenece a una de las dos sillas del Periodo Federal estadounidense adquiridas en enero de 2008 por Winterthur Museum & Country Estate. El tratamiento previo no benefició adecuadamente a la tapicería inferior. Esto, además un anhelo por procurar la conservación para lograr una mejor visibilidad de los materiales para su estudio, motivó la remoción de los elementos de la conservación anterior. Se consideraron entonces otros métodos de tratamiento que se utilizaron para el tratamiento de la tapicería de soporte pero ninguno resultó totalmente apropiado. Se creó un nuevo tratamiento utilizando un material que, según el conocimiento del autor, no se había utilizado en esta área de conservación en particular. El material, Vivak<sup>®</sup>, es un copoliéster termoplástico transparente producido por Bayer Material Science Company.

Sus propiedades químicas y materiales, las cuales se describirán, hacen que sea un material fácilmente adaptable para la conservación. Sus propiedades superaron algunas de las deficiencias de los materiales utilizados anteriormente. Para el nuevo tratamiento, se realizó un soporte personalizado y se adjuntó a la estructura del asiento con un método no intrusivo. Combina la transparencia virtual con el soporte total y equilibrado de la tapicería inferior. Una vez instalado también mejora el perfil general del asiento.

## 1. INTRODUCTION

In January 2008 Winterthur Museum & Country Estate purchased a pair of chairs at auction. The pair consisted of two chair frames, dated to 1780 – 1789, and their upholstered slip seats (fig. 1). Each detachable slip seat retained much of its original under-upholstery and was covered with the same flame stitch show cover. Curatorial research demonstrated a strong link between one New England family, the Gardiners of Gardiner's Island, to both the chairs and the flame-stitch needlework seat covers (Christie's 2004). The pair is numbered with Roman numerals on the back rail of the chair frame and along the underside center of the back rail of each slip seat. The examination and subsequent treatment of slip seat III, belonging to the chair frame marked III, provided an opportunity to revisit a previous intervention and consider another approach to meet the goals of treatment (fig. 2).

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Figure 1 (left). Before treatment image of the chair frame and slip seat on left; the frame and slip seat after treatment on right. Figure 2 (right). Before treatment image of the slip seat: some aspects of the previous intervention. The bottom image shows the underneath of the slip seat where the wood frame insert is visible. The arrow indicates the location of the insert within the slip seat. This view demonstrates the fragmentary nature of the needlework canvas. Losses are concentrated along the top and bottom rails.

During the course of its examination it became evident that components of the previous intervention no longer functioned as intended. With the object's transition from the market place into a museum collection, there were aspects of the intervention that did not mesh with the expectations and needs of a museum institution. Therefore the main component of revisiting the slip seat was to evaluate its treatment with respect to its preservation and its proposed use within a museum collection. The treatment proved challenging as there were several considerations that could potentially be in conflict. Fortunately, a material was found that met all the criteria. Vivak® has several working properties that lend it to many applications confronted by the textile conservator in both treating and displaying textiles with three-dimensional aspects.

### 2. DESCRIPTION: UPHOLSTERY UNDERSTRUCTURE & TOP COVER

Visual examination of the slip seat showed a layered under-upholstery structure. It consisted of a trapezoidal wooden frame that an x-ray revealed to be of mortise and tenon construction. Other aspects revealed suggested a sequence for the application of the upholstery: two pieces of linen webbing were stretched across the top of the slip seat, front to back, and a third piece was woven through them and stretched side to side. The method and means of fastening the webbing were located on the top of the slip seat and obscured by subsequent upholstery layers. Next, a plain weave, linen base cover was stretched taut over the webbing and secured to the top of the slip seat frame. The associated fasteners were not visible for examination but their relative positions were shown in the x-ray (fig. 3). A vegetable-based fill material with at least a skimmer of curled horsehair was used to create the seat's profile. Over top of the fill, a plain weave, linen fill cover was pulled around and secured to the underside of the slip seat and secured with rose-head ferrous tacks. The needlework canvas was spread over the upholstered slip seat and secured with flat-headed, blue-black ferrous tacks to the underside of the frame.

First the needlework was tacked to the front and back of the slip seat and then the sides were secured. Additional tacks were used to secure the corners. The tacks that held the needlework to the slip seat stood proud of the slip seat frame; the tack heads were not flat against the frame.

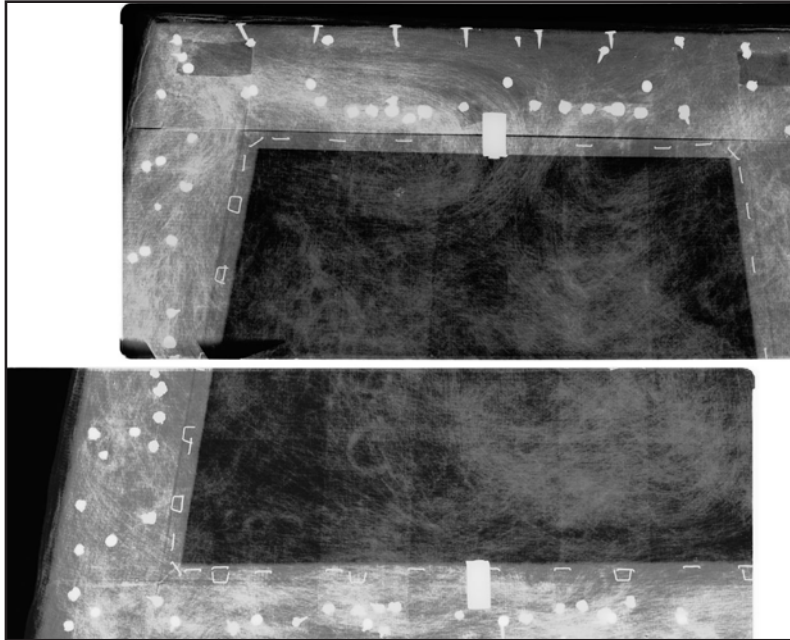


Figure 3. X-radiography used to analyze the slip seat's construction and the metal fasteners used in its upholstery and subsequent treatment intervention.

It was not known precisely when the needlework was affixed to the slip seat. A label was attached to the underside of the companion chair's slip seat that attributed the needlework to Mary Gardiner, and noted her birth as 1740. The needlework has a flame stitch design and was worked in a technique referred to as Irish-stitch (Swan 1995, Synge 2001). It was worked with wool yarns into a linen ground, with stitches aligned vertically and not crossing the interstices of the canvas weave. The stitches form a stepwise geometric pattern worked in several colors: three shades of blue, two shades of green (that in many locations now appear blue), yellow, orange, white, red, and pink. Examples of original upholstery with flame stitch show covers typically survive on Queen Anne and early Chippendale chair frames. They are found in the collections of Winterthur, Bayou Bend, and The Metropolitan Museum collections (Downs 1975, Warren 1975, and [www.met.org](http://www.met.org), accessed 2010). The date of the Gardiner chair is twenty years later than some of these examples (Fairbanks 1981).

### 3. CONDITION & PREVIOUS INTERVENTION

After close examination of the slip seat it was determined that there were several condition issues associated with the layers used to create the upholstery profile. Namely, the vegetable fill is brittle and extremely friable. There was debris filtering through the interstices of the base cloth. Some of the fill loss contributed to the slumping profile noted in the seat. On the underside of the slip seat, the lower layers of the under-upholstery, in the center of the seat, were found to have slumped such that they are nearly in plane with the bottom of the slip seat frame. The needlework canvas no longer held some of the yarns in the needlework show cover (fig. 4). This was noted along the front edge of the slip seat, where it meets the front rail of the chair frame. Where the ground was most damaged, the stability of the yarns of the needlework was jeopardized. These yarns were fraying in areas that have the most tenuous attachment. Underneath the slip seat the needlework canvas was found to be extremely fragmentary, particularly where the canvas had been pulled around and tacked. There were sections



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of the canvas along the back rail that were missing, revealing the wood frame. Each of the front corners of the canvas was also missing, exposing the fill cover.



Figure 4. Before treatment detail of the slip seat front rail illustrating some of the unstable yarns of the needlework show cover and the white net used in the previous intervention used to stabilize the needlework canvas.

A previous intervention had sought to address some of these condition issues. White net had been applied with a series of fine vertical stitches along the perimeter of the slip seat. The stitches passed through the net and secured it to the under-upholstery. This stabilized the edges of the canvas but did not extend upward to protect the vulnerable embroidery yarns. This net was also used to provide support to the under-upholstery. A wood frame insert was made to fit into the interior space of the slip seat frame. Prior to its installation, white net was stretched and secured to its top face with what were probably stainless steel staples. The frame and the net support were fit into the trapezoid shaped void of the slip seat. Additional pieces of white net were secured to the bottom of the wood insert and pulled up and secured to the upholstery in the manner described above. Where separate pieces of net met at each corner, the net was trimmed on a 45° angle and sewn together (fig. 5). The frame insert was secured into the interior of the wood drop seat using two L-clips, a low intervention attachment method (Lahikainen 1990). The L-clips were slid between the top face of the slip seat frame and the upholstery layers. The other end of the L-clip was secured to the wood insert with a screw. The snug fit of the frame insert maintained the orientation of the frame with respect to the slip seat and the L-clips hung the frame within the slip seat so it didn't fall out.



Figure 5. Before treatment detail, underside of the slip seat showing a corner join of white net. Note the two types of metal fasteners. Under-upholstery layers were attached to the slip seat with darkened rosehead tacks similar to the one found in the bottom left corner of the image. The four other tacks with blueish, flat heads, are examples of the type that fixed the show cover.

#### 4. EVALUATION

Although the previous treatment appeared to address previous condition issues of the slip seat's upholstery and show cover, when examined in 2009, some aspects were found to be insufficient. The white net did not adequately support the understructure of the upholstery. The portion of net stretched across the wood insert may have been taut initially but by the time of pre-treatment examination, the net had stretched and permitted the profile to sag. The application of the net did not protect the edges of the needlework. There are several areas where the canvas no longer holds the needlework yarns. These yarns are quite vulnerable to abrasion and further damage. The color and application of the net distorted the appearance of the under-upholstery. It made future study of the upholstery materials extremely difficult as it obscured visual information.

#### 5. TREATMENT

##### 5.1. GOALS & PLANNING

The new treatment sought to support the under-upholstery using a method that would permit both visual and physical access to it. Additionally, it sought to stabilize the needlework show cover so that it could withstand future study and improve its aesthetics for exhibition. Another aim of treatment was to keep the original construction undisturbed. Examination of the upholstery revealed that the needlework was fixed to the slip seat with a later generation of tacks and their removal to facilitate treatment was acceptable. The orientation, position, and fold patterns used in the application of the show cover were also to be maintained. Finally, it was hoped the developed approach could be used as a protocol for the treatment of the second chair in the pair.

##### 5.2 UNFORSEEN COMPLICATIONS

With the removal of the white net and interior frame support, additional damage to the under-upholstery was revealed. The proper left vertical webbing was severed along the front and back rail, the proper right webbing was severed along the back rail end, and the base cloth was torn along the back rail. The under-upholstery and fill retained a pronounced imprint of the inner frame support (fig. 6).



Figure 6. During treatment detail, underside of the slip seat taken after the interior frame support was removed. The imprint of the frame can be seen along the interior. The majority of the torn elements are located along the back rail, on the right side of the image.



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The location of the damage and the imprint of the frame into the fill material suggest that it was caused by compression of the upholstery against the interior frame support. In light of this development, a new under-upholstery support system was necessary.

Prior to the discovery of these conditions, a trapezoidal acrylic sheet was planned for the new support of the under-upholstery. However, with the expanded understanding of the condition of the seat, it was determined a sheet thick enough to offer support for the protruding middle of the under-upholstery would not support the newly revealed broken and torn base cover and webbing members. If an attempt was made to press the acrylic into the cavity of the slip seat frame to reorient the sagging base cover and better support the broken webbing, this would lead to additional compression of the brittle fill material and place the edges of the acrylic against the torn textile elements leading to abrasion and additional damage to the textiles. Either option would require introducing small holes into the slip seat frame to hold hardware to fasten the acrylic support into the slip seat frame. Therefore, a different material was sought that could provide gentle support to the irregular shaped under-upholstery. That material would also not abrade or exacerbate existing damage, and would be transparent allowing for future study of the upholstery. Ideally, there would be a way to fasten the new material to the slip seat without introducing new holes into the wood frame.

### 5.3 VIVAK®

A clear sheet stock, Vivak® had been used with success for a variety of display supports at Winterthur and this was suggested as a possible material for the support. It had been used to create both exhibition and storage mounts and is frequently used by book conservators to create cradles for the display of books. It may be bent in straight lines at room temperature and with heat and pressure it can form complex shapes. Using the heat moldable properties of Vivak®, interior display supports were shaped for an 18<sup>th</sup> century shoe in the Winterthur collection. The two-part support is unobtrusive when inserted into the interior of the shoe to support the heel and the vamp (fig. 7). A housing for a collection of ormolu mounts was created using tools readily available in the lab – scissors, paper cutter, and bending break (fig. 8). The front of the box drops to reveal individual padded trays that may be taken out and used for lectures. The Vivak® lids provide protection from dust but maintain visual access due to the material's transparency.



Figure 7. An interior support for an 18<sup>th</sup> century shoe: on the left, the heel support and on the right, the support for the vamp.

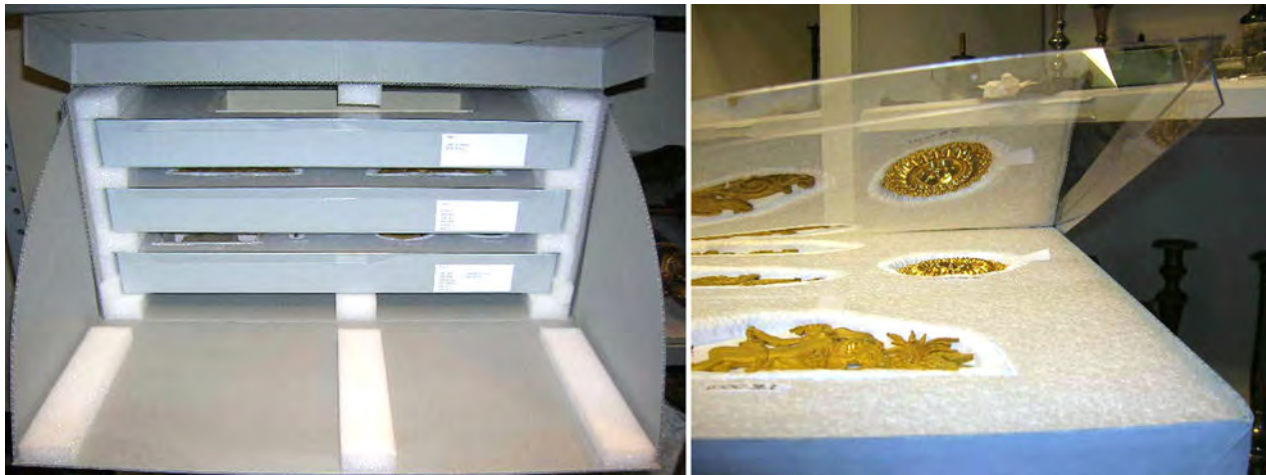


Figure 8. Left: box constructed for an ormolu mount collection at Winterthur Museum. The front of the box drops down to reveal three padded trays. Right: detail of one of the trays that features a Vivak® lid made by bending the material to form the top and sides.

Vivak® is a trade name for co-polyester sheet stock. It is part of the polyester family and is structurally very similar to polyester films like Mylar. Vivak® has a higher concentration of glycol in the polymer chain with occasional replacement of the glycol unit with 1,4 cyclohexylenedimethylene (Kroschwitz 2004). This creates an amorphous material with thermoplastic properties that the more crystalline Mylar lacks. The material is also marketed under the trade names Eastar by the Eastman Chemical Company and Ultros by Spartech Plastics (Kroschwitz 2004).

In theory, the material possesses long-term stability. However, it is affected by ultraviolet (UV) radiation. UV exposure will cause yellowing. Embrittlement occurs when the material is routinely subjected to the exterior environment. Under such conditions it is theorized that over time, Vivak®, like other polyesters, will lose its physical strength, but won't create volatile degradation products that would harm an object with which it was in contact (Williams 2010). A preliminary test supported this: an Oddy test was performed on Vivak® by the Winterthur/University of Delaware Program in Art Conservation Class of 2012 as a class exercise, and the Vivak® sample passed; no volatile components were produced (Wickens 2010).

#### 5.4 SUPPORTING THE UPHOLSTERY

To create a clear cradling support with this material for the slip seat, a form was made replicating the shape of the bottom face of the under-upholstery. A profile gauge was used to reproduce the profile at regular intervals onto archival corrugated board. The group of profiles were placed on edge and connected so as to create a pattern (fig. 9). A sheet of 0.06" (0.15 cm) Vivak® stock was slumped into the form using a heat gun and gentle finger pressure for shaping. White cotton gloves were worn while performing this work to minimize the transfer of texture from fingerprint ridges to the malleable material. Once the overall profile was replicated, the edges of the support were turned down, trimmed, and filed smooth. This resulted in a tray with a concave middle and raised edges that both supported and stabilized the damaged base cover and webbing (fig. 10).

To secure the support to the wood frame of the slip seat a non interventive method was created. Four slots were made at the edges of the tray for attachment. The location of each slot was dictated by available access around the slip seat frame. Due to the damage to both the webbing and the base cloth of the under-upholstery along the back rail, attachment in this area was avoided. Therefore the slots are not symmetrically placed. Brass sheet

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stock, 0.015" thick, was used to form c-clips (fig. 11). The 1" width of the c-clip creates a stable attachment and allows for a ½" flap to be cut in the bottom horizontal of the c-clip and bent backward to form a tab. Designed to slide along the top and bottom faces of the slip seat frame, the tabs of each c-clip mate with the slots cut into the Vivak® tray. When the tab is pressed away from each clip, it latches the tray underneath the seat. To protect the wood frame from abrasion, each C-clip was fit with a Tyvek® slipcase. The most visually prominent areas were covered with deep brown fabric to blend with the wood frame (fig. 12).

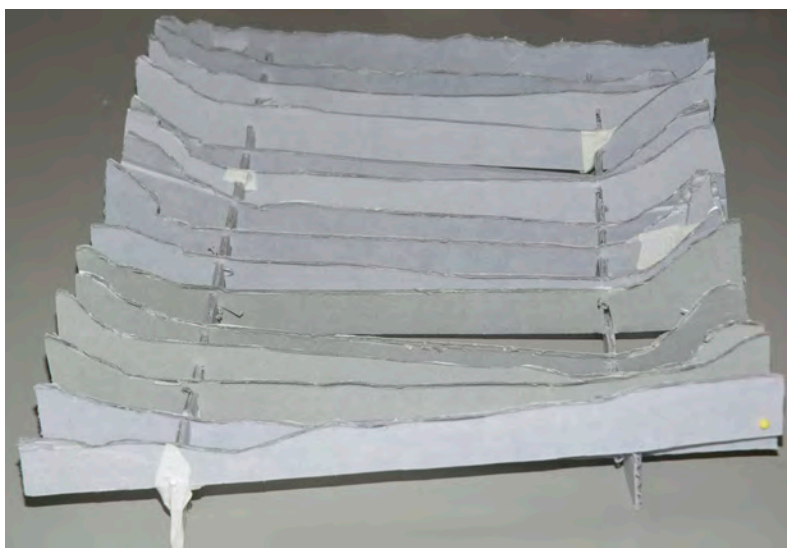


Figure 9. The finished form used to slump and shape the Vivak® support.



Figure 10. The upholstery support created through heat shaping.

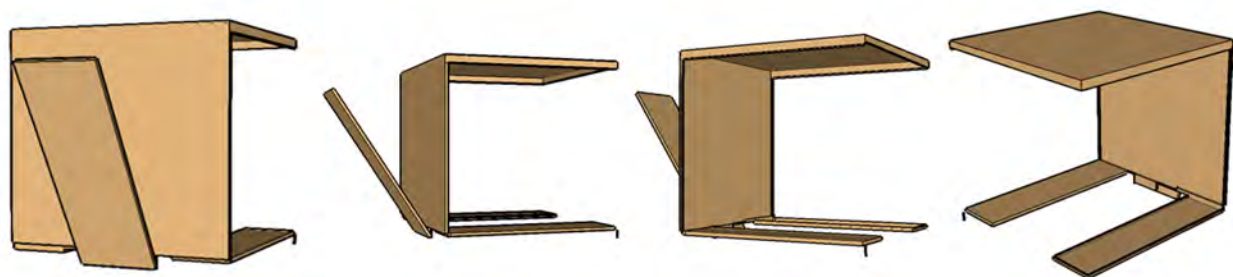


Figure 11. A rendering of the c-clip design used to mount the upholstery support to the slip seat frame. From left to right: the back, two side views, and a three-quarter front view.





Figure 12. Top: A detail of the L-shaped stitch edges prior to their encasement in brown fabric. The blue color is a protective film. Bottom: The slip seat after the stabilization of the needlework was complete; numbers 1 through 4 indicate the positions of the c-clips holding the four stitching edges along the bottom edge of each rail of the slip seat. The image shows all four edges of the needlework stabilized with the net sewn back to each L-shaped stitching edge; however, the net and hairsilk stitching are not readily visible in the image or at normal exhibition light levels.

## 5.5 NEEDLEWORK STABILIZATION

Work was conducted while the seat was inverted and the Vivak® support was temporarily removed. To stabilize and protect the needlework cover, the later generation of metal tacks were released, one side at a time, to allow for the edges of the needlework to be sandwiched between two layers of nylon bobbinet. The former location of the removed tacks were mapped and numbered on an image of the underside of the slip seat. Each tack was then mounted in numeric order into labeled polyethylene foam blocks for subsequent retention in the object's file. Net was selected as it is stronger in the long term than silk, can be dyed to become visually unobtrusive, and its edges do not require additional finishing. Its fineness and color were nearly invisible, yet strong.

The treatment progressed in reverse order of the needlework cover's installation. The previous campaign of vertical stitching was released and a layer of color-matched bobbinet was stitched with a dyed hair silk to either side of the needlework canvas. One layer of net was secured as far under the needlework as access allowed and the second was used as an overlay for both the edges of the needlework canvas and the loose yarns of the design. The two layers of net were stitched together through areas of loss. The net was then lightly tensioned and stitched to the adjacent stitching edge along the underside of the slip seat. The four stitching edges were created from Vivak®. Long, narrow strips were bent into an L shape and loosely covered with a dark brown fabric (fig. 12). The loose fabric cover permitted the edge to be placed snugly along the interior edge of the slip seat



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frame, providing a visually unobtrusive stitching edge for the net. Although the image shows the result of this treatment step completed, all four edges stabilized and stitched to the L-shaped stitching edges, the net and hair silk stitching are not readily visible in the image or at normal exhibition light levels. The stitching edges were held in place by the c-clips that in turn hold the under-upholstery support (fig. 13).



Figure 13. After treatment, top and bottom of slip seat III.

Although the c-clips perform both functions, to hold the stitching edges for the needlework stabilization and to secure the upholstery support, these two aspects work independently. The upholstery support tray may be removed by releasing its c-clip tabs without disturbing the stabilization of the needlework. Alternatively, the show cover may be substituted or replaced by removing the stitching edges and replacing the upholstery support. This allows these two aspects of this treatment to function independently. Either aspect of the treatment may be reversed without complete disassembly of the other.

## 6. CONCLUSIONS

During the previous intervention of the slip seat the materials and techniques used to address some of the condition issues of the slip seat were found to be inadequate or were no longer functioning in the way they were intended. The previous approach started with the extant upholstery and added a frame insert with layers of net. The revisited treatment removed those materials and replaced them with two layers of dyed bobbinet sewn to an L-shaped stitching edge that is held in place by a c-clip that also holds a support for the under-upholstery. Using Vivak® in conjunction with more traditional materials met the goals of the treatment. The under-upholstery is supported with a transparent, custom shaped support attached with a low interventive method. With proper support, the slip seat's profile has improved. Encasing the fragile edges of the needlework ground in net has provided it with much needed protection. Extending the coverage of the net to include the loose embroidery yarns has helped to protect the needlework cover and protect these elements from abrasion. With the completion of the treatment the curators assessed the treatment and found it met their expectations in terms of maintaining full visual access to the upholstered components of the chair. However, the dry and friable vegetable fill that composes the majority of the seat's profile remains both fragile and extremely vulnerable. The newly completed treatment does not provide any more protection than the last one, with respect to the risk of future compression damage caused by an accidental sitting. Likewise the fill may be subject to shattering if the slip seat is handled. Despite this limitation of the new treatment, it does provide for future flexibility. If in the future the elements of this treatment no longer meet curatorial requirements or if the object's interpretation changes, this treatment, like the last one may be reassessed, reversed, and retreated.

## ACKNOWLEDGEMENTS

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## FINDING SUPPORT: REASSESSING & DEVELOPING A NEW SUPPORT SYSTEM FOR ORIGINAL UPHOLSTERY

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### SOURCES OF MATERIALS

Archival corrugated board (single wall 1/8" thick)  
Archivart® Products for Conservation and Restoration  
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## **FINDING SUPPORT: REASSESSING & DEVELOPING A NEW SUPPORT SYSTEM FOR ORIGINAL UPHOLSTERY**

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# THE USES OF NONWOVEN FABRICS IN CONSERVATION

CATALINA HERNÁNDEZ

**ABSTRACT** – During an archaeological materials conservation project at the Gold Museum in Bogotá, Colombia, the limited budget available to the project compelled conservators to find alternatives to Tyvek® and Acid Free Tissue, which are commonly used in the United States and Europe, but are not affordable or available in many Latin American countries. Nonwoven Medical Fabrics, such as those used in scrub suits, proved to be safe, efficient and cost effective alternatives for these materials, and were readily available from fabric stores in Bogotá. Research into the possible uses of different types of Nonwoven fabrics in conservation and collections care was carried out at the Textiles Conservation Centre in the UK and at the Smithsonian Institution's National Museum of the American Indian in Washington DC. Several samples were tested as possible protective barriers for use during treatment of objects, in storage, and as breathable barriers for conservation treatments, such as alternatives for Gore-Tex® in contact humidification. The results have been very positive. The specific characteristics that make a Nonwoven fabric adequate for use in conservation have been identified, and recommendations on how to find a commercially available fabric with these characteristics are provided.

**RESUMEN** – Durante un proyecto de conservación de materiales arqueológicos en el Museo del Oro de Bogotá, Colombia, el bajo presupuesto con el que se contaba llevó a los conservadores a buscar alternativas para Tyvek® y papel desacidificado, que son comúnmente utilizados en los Estados Unidos y Europa, pero que son costosos y difíciles de encontrar en varios países latinoamericanos. Algunos tipos de telas no tejidas del tipo quirúrgico, aquellas con las que se fabrican trajes para cirugía, fueron utilizados y resultaron ser materiales seguros, eficientes y fácilmente asequibles en Bogotá. Las propiedades de los mismos fueron investigadas en el Textile Conservation Centre en Inglaterra y en el Smithsonian Institution's National Museum of the American Indian en Washington D.C., para determinar si diferentes tipos de telas no-tejidas pueden ser utilizadas como barreras protectoras para objetos durante procesos de intervención o en depósito, y como materiales permeables a sustancias gaseosas en procesos con humidificación por contacto, como alternativas para el Gore-Tex®. Los resultados hasta ahora han sido supremamente positivos, donde las características que hacen que una tela no-tejida sea adecuada para la conservación han sido claramente identificados y recomendaciones sobre como adquirirlas han sido provistas.

## 1. INTRODUCTION

The search for new materials and resources in conservation often arises from a difficulty to obtain materials commonly used for basic conservation processes, especially in third world countries. Without appropriate materials the quality of a conservator's work can be compromised, which in turn can lengthen or delay processes considerably or make it impossible to successfully complete them. It takes a great deal of resourcefulness to maintain a high level of quality in conservation work under less than ideal circumstances. The objective of this research is to find effective, safe and cost effective alternatives for materials that can be difficult to find in countries like Colombia, specifically Tyvek®, acid free tissue and GoreTex®.

Nonwoven fabrics used in medicine proved to be very good candidates for this purpose when used as protective covers against dust and as filter materials during a conservation project of the collection of Mummies at the Museo del Oro de Bogotá, Colombia. Their excellent performance started the current project, which is divided into three phases: Phase I, the author's Graduate Dissertation project for the MA Textile Conservation at the Textile Conservation Centre (TCC), University of Southampton, in the UK, researched into testing the performance of nonwoven medical fabrics to perform specific uses in conservation. Phase II, the author's Research Project for the Andrew W. Mellon Fellowship in Conservation at the Smithsonian Institution's National Museum of the American Indian (NMAI), Suitland, Maryland, focused on identifying the specific characteristics that

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would make a nonwoven fabric adequate for use in a conservation laboratory under normal working conditions, regardless of what purpose it is initially designed for (medical, industrial, agricultural, etc.). Phase III, is hoped to focus on the performance of these materials under emergency situations (fire, flood, pest infestation, objects having to be left outdoors, etc.), to determine the levels of protection they can provide or if they can become risk factors and why. Because it has not yet been carried out, Phase III will not be discussed in this paper.

### 2. PHASE 1

During the project for the Conservation and Documentation of Four Archaeological Mummies and a Cranium, belonging to the Gold Museum of Bogotá Colombia (Fundación de Investigaciones Arqueológicas Nacionales FIAN 2004; October 2003 – June 2004), the author and her colleagues were in need of a material to be used as protective covers during treatment and storage of the objects. Tyvek® and acid free tissue would normally be the first choice, but in Colombia these materials are imported from the United States or Europe, and orders for them in the field of conservation are not usually large enough to make them cost effective. Therefore, the search for alternatives began.

Attention was drawn to nonwoven medical fabrics, the type which compose surgical drapes and gowns, because they are primarily breathable barrier materials (vapor is transferred easily throughout their surface area), with characteristics of cleanliness and stability. Certain types were ideal for functioning as protective covers, and also as effective air filters for atmospheric pollutants when secured over a window, which was the only source of ventilation. In Bogotá these medical fabrics are found in fabric stores and at approximately \$1.50 USD a yard (approximately \$2800 Colombian pesos), they are also very cost effective.

Tyvek® is a nonwoven fabric which is similar to nonwoven medical fabrics, but these differ in structure. Nonwoven fabrics are similar to paper in their manufacture techniques and resulting sheet-like form of mostly randomly orientated fibers bonded by friction, cohesion or adhesion. Most nonwovens are made of synthetic fibers like Polyethylene (PE), Polypropylene (PP) or Polyester (PET), and can possess a wide range of textile properties (Table 1), such as breathability, water repellency and good physical integrity, which are determined by their intended consumer end use (medical, industrial, etc.), composition and method of manufacture.

Type of structure and fiber polymer	Achieved through additives
Abrasion resistance	Antistatic
Breathable	Water and volatile liquid repellent
Resilient	Resistant to UV radiation (using UV stabilizers)
Microbial resistance	Flame retardant
Flame retardant	Range of colors
Non-absorbent of chemical substances	
Non-conductive of an electric current	
Lint free	
Ironable	
Chemically stable	
Sewable	
Smooth	
Soft	
Rigid	
Light	
Washable	
Possible to sterilize	

Table 1. List of properties a single nonwoven fabric can be manufactured to have.

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During Phase I, the performance of several samples of nonwoven medical fabrics from the European branches of Kimberly Clark™, DuPont™ and Don&Low™, was compared to that of Tyvek®, acid free tissue, polyethylene sheeting, cotton calico (cotton muslin), GoreTex® and SympaTex®, where applicable, through testing of their physical and chemical characteristics, to identify which properties makes a nonwoven medical fabric a safe, efficient, effective, and cost effective alternative to the materials mentioned. Results showed that certain types can be good alternatives to be used as padding and packing materials and protective covers for storage of objects, as preventive conservation aides during interventive conservation treatments, as vapor barriers for contact humidification and adhesive reactivation in simailar ways as GoreTex® or SympaTex® and as the mentioned materials are often used in the conservation laboratory.

Unfortunately, in the UK and in Europe, nonwoven medical fabrics are not available from fabric stores, but are ordered from the manufacturer directly. Minimum orders involve several tons of material which can add up to thousands of sterling pounds, making them cost effective only in situations where a great deal of material is required.

### 3. PHASE II

This project was continued at the National Museum of the American Indian (NMAI) to corroborate the results from Phase I. Obtaining fabric samples from North American manufacturers was more difficult than in Europe, therefore nonwoven samples were sought outside the medical field. Fortunately, testing determined that most types of nonwoven fabrics, regardless of their intended consumer, posses many or all of the properties of a good breathable barrier. Most of these fabrics are also found in mass produced products such as reusable shopping bags, pillow and mattress covers and garment or car covers, making them some of the most widely distributed products in the world.

The samples tested included fabrics for car covers manufactured by Kimberly-Clark® and two “all purpose fabrics” manufactured by Polymer Group International® (Table 2) (figs. 1-4). These were chosen because, of their availability in countries around the world. However, there are types of nonwovens that are inappropriate for the previously discussed purposes because of their open and sometimes uneven fiber distribution, such as Hollytex®, Reemay®, Cerex® and poly-felt poly-wadding. All of these fabrics are currently used in conservation for very different purposes than those proposed here.

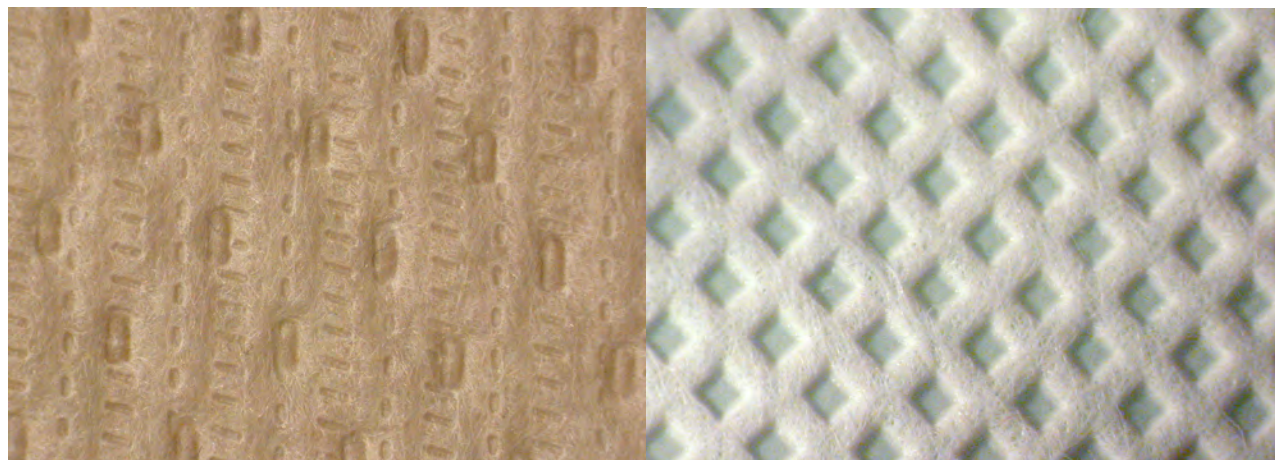


Figure 1 (left). Sample #1 Kimberly-Clark™ Block-It 380 Series Car Cover fabric.

Figure 2 (right). Sample #2 Polymer Group International™ Bonlam 90B4 all purpose fabric.



## THE USES OF NONWOVEN FABRICS IN CONSERVATION

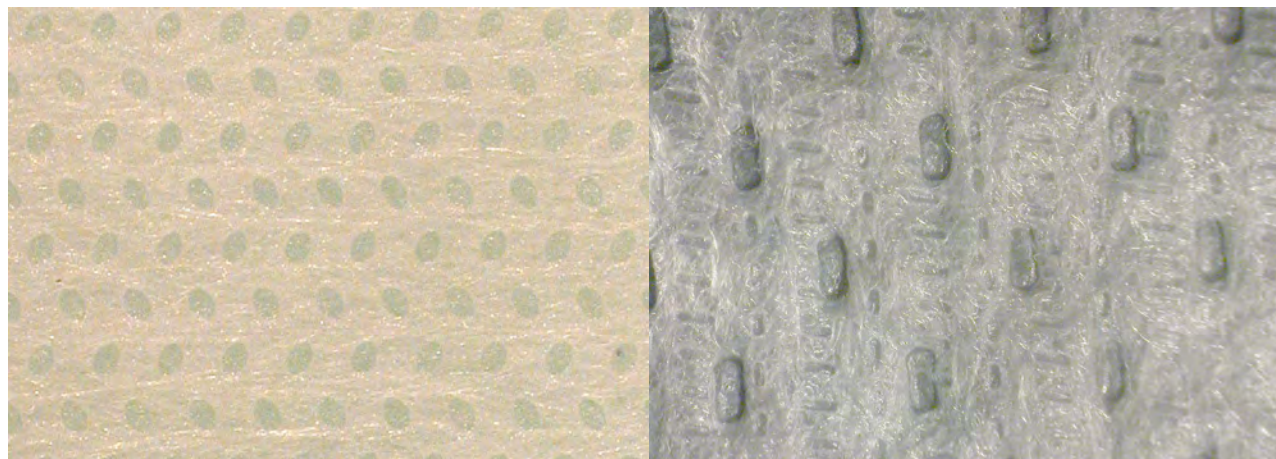


Figure 3. Sample #3 Polymer Group International™ Bonlam all purpose fabric.

Figure 4. Sample #4 Kimberly-Clark™ Dustop Soft as Flannel Car Cover fabric.

Samples 1 and 4 Kimberly-Clark™ Block-It 380 Series and Kimberly-Clark™ Dustop Soft as Flannel Car Cover fabrics

Samples 1 and 4 are more similar to felt, being very thick and cushion, with loosely packed fibers, where the weld points are considerably far apart, allowing for the different layers that make them up to be somewhat separated from each other.

Samples 2 and 3 Polymer Group International™ Bonlam 90B4 and Polymer Group International™ Bonlam all purpose fabrics

Samples 2 and 3 are more like paper, flat, smooth, show some rigidity, and are completely white. This is because their fibers are tightly packed by weld points that are close together, effectively fusing all the layers into one sheet that is impossible to take separate.

Table 2. Description of Nonwoven fabric samples for Phase II.

Phase II also focused on the performance of these fabrics under normal conservation laboratory working conditions, referring to those of a well equipped laboratory with a controlled climate (temperature, humidity and light levels), to create an adequate environment for the daily treatment of objects. This excludes emergency or disaster situations.

The samples' performance was once again tested in comparison to that of Tyvek®, acid free tissue and GoreTex® where applicable, obtaining results that corroborated those from Phase I and producing new information, which is described in heading 4 Results. Several tests were performed in collaboration with professionals from the Smithsonian Institution's Museum Conservation Institute (MCI) in Maryland.

The tests performed were a handling test, where conservators at NMAI used the fabrics in their daily work and provided comments. Ms. Lean Lewis, manufacturer of the protective covers for storage of the large-scale objects belonging to the Smithsonian Institution's National Museum of Natural History using Nomex® fire retardant fabric, also collaborated with this test.

The second test was chemical resistance via prolonged immersion (12 hours) in acids (Acetic acid, for dye fixation, calcareous deposit remover at 3%), sodium hydroxide (3%) used for identification of dyes, acetone and ethanol (100%) used for solvent cleaning, adhesive reactivation, and others, hydrogen peroxide (3%) used as a bleaching agent for stain removal sodium dithionite (0.15M = 26.1g/L) used as a chelating agent and for

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identification of dyes, tap water, petroleum Benzene (pure) used for adhesive solutions, xylene (pure) used for adhesive solutions, zip strip (solvent for spot cleaning), pH testing of samples before and after chemical testing (surface spot testing using pH measurement strips and maceration and immersion of samples in deionized water and testing the pH of the liquid using an electronic pH meter.

Tensile strength was the third test, and it was carried out before and after chemical testing, in collaboration with Dr. Marion F. Mecklenburg, Senior Research Scientist at MCI. The fourth test was Oddy testing, carried out in collaboration with Conservator Emily Kaplan, and Mellon Fellows Yoonjo Lee and Anne Gunnison from NMAI, and was carried out using metal coupons that were not in contact with the samples and metal coupons in direct contact.

Lint production testing was the fifth test and consisted of running pieces of fabric through several cycles of washing and drying. Breathability testing was then carried out using only Sample #2 PGI® Bonlam 940B being compared to GoreTex®, by performing spot humidification for crease removal via moisture evaporation, carried out by Susan Heald, Senior textiles conservator at NMAI (figs. 5,6). Ms. Heald tested the fabric during treatment of a Shipibo cotton shirt chosen for display at the Infinity of Nations Exhibit (which went up at the George Gustav Heye Center in New York City at the end of 2010) and adhesive reactivation via solvent evaporation: Using three pieces of the same size of a Lascaux mix of adhesive film cast over red silk crepeline and later adhered to a piece of silk habotai fabric, one using GoreTex® as a breathable film, another using sample #2 and another using sample #2 over a piece of Hollytex® meant to act as a barrier between the fabric and the solvent, to prevent the solvent from wetting sample #2. This is the same purpose of the fluffy DuPont™ Sontara® fabric placed on one of the sides of GoreTex®



Figure 5. Contact humidification for crease removal during breathability testing using GoreTex® (left) and sample over a Shipibo cotton shirt. © NMAI.

Opacity and light barrier testing was carried out by placing the samples between a light meter and a working light using both incandescent and fluorescent light bulbs that when turned on at the same time produce approximately 32.2 foot candles. Moisture absorbency was also carried out, to determine if the fabrics absorb moisture from the air in comparison to samples of linen fabric, also carried out in collaboration with Dr. Mecklenburg from MCI. And finally, fiber identification testing via Raman Spectroscopy analysis of the samples, carried out in collaboration with Conservator Odile Madden from MCI.

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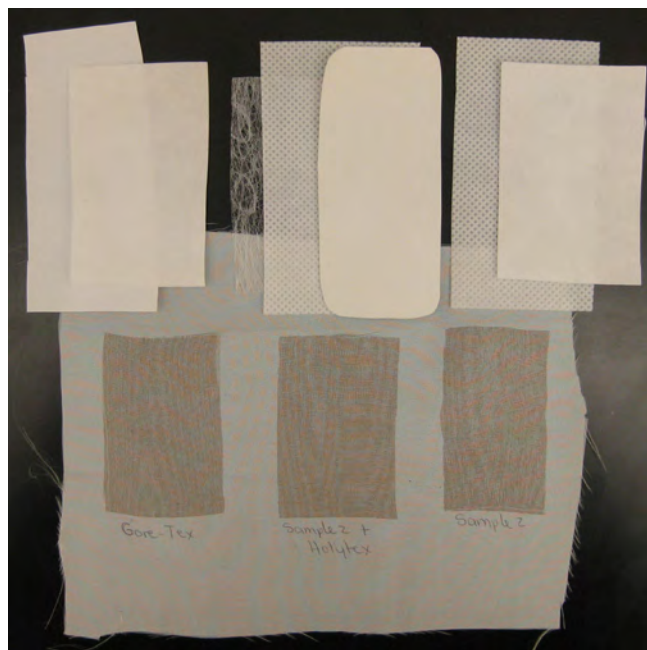


Figure 6. Adhesive reactivation setup for breathability testing using GoreTex® (left), Sample #2 and a Hollytex® barrier (center) and only Sample #2 (right) as breathable films.

### 4. RESULTS

After testing, all four samples showed excellent performance in that (Hernández 2009) they are resistant to exposure to the mentioned chemicals, showing no physical changes after testing., their pH will remain neutral even after exposure to acids, alkalis and soiling, where any changes in pH will probably be due to substance residue on the surface of the fabrics, they are extremely strong, and their tensile strength does not appear to be affected by exposure to chemicals. Tensile strength testing also showed that fiber distribution in these fabrics does have a definite direction, giving them more strength along one axis, and is not completely random as it was advertised by the manufacturer. This is because certain manufacturing techniques will inevitably provide some level of directionality to the fibers. Furthermore, during Oddy testing none of the metal coupons developed any corrosion or color changes to indicate that the fabrics were releasing any harmful substances. However, a light yellow discoloration of unknown nature appeared over the areas of the samples that were in direct contact with the coupons. This must be evaluated by future testing.

Moisture absorbency resulted in that none of the fabrics showed any significant weight increase, staying below 0.65%, to indicate that any moisture was being absorbed from the air, compared to the weight increase of the linen samples tested simultaneously, which reached 15%. Fiber identification corroborated the information provided by the manufacturer on fiber composition samples 1 and 4 were good matches for Polypropylene and Polyethylene, sample 2 was a good match for Polypropylene and sample 3 was a good match for Polyethylene.

All of the samples also failed in that, during the handling test, Lewis observed that they are too light to be used as covers for outdoor materials, unless a way can be found to secure them and keep them from moving in the wind enough to stop abrasion occurring to the underlying object and the fabric. They all also readily absorb volatile substances such as alcohol and acetone. Samples 2 and 3 will also absorb liquid water when submerged due to the large spaces between their layers and fibers.



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The fabric sample that showed the best levels of performance was Sample #2 PGI® Bonlam 940B, thanks primarily to its ease of use, structural integrity and versatility. This is because it is completely smooth on one side but also slightly rougher on the other without being grabby, which can help keep objects from sliding off slippery surfaces, as does happen when using Tyvek® or acid free tissue. It is the lightest, whitest making it very comfortable to work with and has enough rigidity to work well as a support sheet for moving objects. The excellent quality of the bond between the layers and fibers keeps it from producing any lint even after repeated rubbing, also meaning that it will not suffer dimensional changes after repeated laundering. It showed an equal performance to that of GoreTex® during the breathability test: according to Ms. Heald's observations, contact humidification on different parts of a creased area in the Shipibo shirt using sample #2 resulted in effective and even softening of the crease, at the same level as GoreTex®. The result of adhesive reactivation through solvent evaporation showed that sample #2 performed at the same level as GoreTex® in adhering the adhesive film to the silk habotai, and actually performed better than GoreTex® when not using the Hollytex® barrier. Care must still be taken that the blotter paper used to deliver the solvent is merely moist enough to hold some of the solvent to avoid wetting sample #2. However, it is not considered an adequate light barrier, as it blocked only 30% of the light directed at it during the light barrier test (light readings using sample #2 were of 22.9 foot candles compared to 32.2 foot candles produced by the light).

Sample #3 performed well, but was not preferred because it can be too soft in situations where some rigidity is necessary, such as when using as a support sheet for transporting light weight objects and its rougher side is also slightly grabby and degraded fibers or surface decoration elements in objects can catch on it and become detached. This grabby side can also develop some lint after repeated use. It showed uneven breathability throughout its surface area and performed equally as sample #2 when tested as a light barrier.

Samples #1 and #4 performed poorly in most tests, primarily because of their structure, which makes them too thick, too soft and too pliable, which is uncomfortable to work with. The larger spaces between their layers create the risk of snagging or catching onto sharp or pointy objects, their colors can conceal residue on their surface and they showed considerable deformation after being laundered three times.



Figure 7 (left). Deformation of sample 1 after placing through a third washing and drying cycle.

Figure 8 (right). Lint forming on sample 1 when placed as a table top cover during the handling test.

Furthermore, their open structure easily allows liquid penetration which appears to displace or disorganize the fibers resulting in changes in texture and appearance, as was the case during chemical testing, where the fabrics appeared thicker or ruffled after exposure (figs 7,8).



## THE USES OF NONWOVEN FABRICS IN CONSERVATION

This open structure also means a low resistance to abrasion, a high tendency to develop lint, and very uneven breathability throughout their surface, which in the presence of liquid substances can lead to condensation.

They may however, be very good for packing of objects where thicker and softer padding materials are required, and they also blocked approximately 63% of direct light, making them relatively good light barriers (light readings were of 11.9 foot candles compared to 32.2 foot candles produced by the light).

Other results of this project include the completion of a series of recommendations for conservators that the author began compiling during Phase I (Hernández 2009), on what properties conservators should look for in nonwoven fabrics, considering what they are going to be used for and what types of fabrics are available (based on the three basic uses that were proposed in Phase I). The basic properties a nonwoven fabric must have include fibers from a good quality polymer, preferably polyolefins: for high tensile strength, chemical resistance, light weight, non-absorbent of chemical substances and non-reactive as well as weld points that are close together, that will provide a more robust and stable structure, will have no interstices where soiling can accumulate or that can absorb liquid water, impedes fibers from lifting or creating lint and makes the fabric easy to clean. They must possess a soft texture, yet have stiffer hand for better support, being soft enough not to be abrasive and stiff enough to not easily collapse under light weights. White color is preferred because it will not conceal particulate matter on its surface. A melt blown layer is also recommended (a polymer film containing a very small pore aperture size and very even pore distribution, providing good breathability throughout the whole surface area of the fabric, making it a good alternative to GoreTex®). Preferably it should have both a smooth and a rougher (not grabby) side, if possible for more versatility, and should not possess additives or stabilizers, minimizing the danger of cross contamination or of chemical reactions occurring between additives of unknown nature and objects the fabric comes in direct contact with.

Other recommendations discuss the subject of how to find nonwoven fabrics in your area, understanding that they are often available in countries where materials such as Tyvek® might not be. This will depend on where on the globe you are located. For example, European law demands that all technical information on nonwoven surgical fabrics be accessible in their entirety to anyone who requests it, under penalty of prosecution because there are believed to be health risks involved. Therefore, if in Europe, it may be more practical to obtain samples of nonwoven medical fabrics instead of industrial fabrics.

In the United States, on the other hand, technical information on most products is considered proprietary, and manufacturers will be very reluctant to provide this information or large amounts of samples. And just like in Europe, suppliers only sell large amounts of fabrics, making them cost effective only for large scale conservation projects. However, conservation materials suppliers such as Gaylord® or Talas® can make smaller amounts available if there is enough demand, as they do with Tyvek® and other materials initially designed for other purposes. This involves further testing and marketing of the fabrics, which can take some time. In many South American countries however, these can simply be bought off the rack in fabric stores.

Fabrics from large scale manufacturers, such as Kimberly-Clark®, Polymer Group International® and DuPont® will likely be found in most countries around the world. However, these corporations cater differently to different areas and specific references of nonwoven fabrics belonging to the same manufacturer may not be available in every country serviced by them.

Conservators must keep in mind that determining what a particular fabric can be good for depends on

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its properties and limitations. It is more practical to have one “all round” fabric that can fulfill most of a conservator’s needs, considering that not many types of fabrics might be available. Carrying out the types of tests described in this paper where possible will answer most questions about the fabrics’ properties, especially if the manufacturer is reluctant to provide technical information.

In the author’s experience a global company dedicated specifically to the manufacture of nonwovens may be a better option for finding the fabric one needs, because they may be capable of producing more versatile products and cater to specific clients individually. On the other hand, global companies that produce a wide range of products besides nonwovens may not be as versatile because it is more profitable to maintain specific product lines that can cater to a larger number of clients. Yet, small or local nonwoven fabric manufacturers may also be very versatile on how they cater to their clients, but their product line may be more limited and they tend to specialize on one specific type of nonwoven (only medical, construction, agricultural, geothermal, etc.). However, this does not mean that they do not possess a product that will fit the conservator’s needs.

Three of the largest manufacturers of nonwoven fabrics are Polymer Group International<sup>TM</sup> (PGI<sup>TM</sup>), Kimberly-Clark<sup>TM</sup> (KC<sup>TM</sup>), and DuPont de Nemours<sup>TM</sup> International S.A. (DuPont<sup>TM</sup>).

## 5. CONCLUSIONS

The results of this project not only proved once again that certain types of nonwoven fabrics are indeed very good alternatives for other materials that may be more expensive or in some cases unavailable, but it also showed that those that possess the right characteristics exhibit properties that make them superior to materials currently used in certain situations, suggesting that for certain processes these materials may be the optimum choice. In the future the author hopes to move on to Phase III, to continue testing these fabrics in extraordinary situations as mentioned before and if the results continue to be positive, to further inform conservators about these materials and work to make them more accessible with the objective of contributing to the constant advances in our discipline.

## ACKNOWLEDGEMENTS

The author would like to thank the members of the staff of the Gold Museum of Bogotá (2003-2004), the staff of the Textile Conservation Centre, University of Southampton (2004–2006) conservation department of the NMAI who participated in this project at the time, and the staff at MCI, for participating in this project.

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Hernández, C. 2009. The uses of nonwoven fabrics in conservation. Unpublished Research project report for the Andrew W. Mellon Fellowship in Conservation at the National Museum of the American Indian. Suitland, MD. 2009. 20 – 99.

## THE USES OF NONWOVEN FABRICS IN CONSERVATION

### SOURCES OF MATERIALS

Cotton muslin and silk habotai.

Testfabrics, Inc

415 Delaware Avenue

PO Box # 26

West Pittston, PA 18643

(1) 570-603- 0432

Fax.: (1) 570-603-0433

testfabric@aol.com

<http://www.testfabrics.com/>

EDM Chemicals Inc. pH- indicator strips non bleeding pH 4.0-7.0 and 6.5-10.0 colorphast.

Corning pH meter 430.

EDM Chemicals Inc

North American affiliate of Merck KGaA, Darmstadt, Germany, 2010

<http://www.emdchemicals.com/>

Micro-tension tester frame A and B.

Designed by Dr. Marion Mecklenburg.

Smithsonian Institution's Museum Conservation Institute.

Museum Support Center

4210 Silver Hill Road

Suitland, Maryland 20746

Telephone: (301) 238-1240

FAX: (301) 238-3709

E-Mail: MCIweb@si.edu

<http://www.si.edu/mci/>

General Eastern Hygro-M2 Dew Point Monitor

Telephone: +1 203 373 2211 or 1.800.448.0329

<http://www.gesensing.com>

General Eastern Optica Dew point Monitor

Telephone: +1 203 373 2211 or 1.800.448.0329

<http://www.gesensing.com>

Precision Scientific Inc. THELCO, Laboratory Oven. Model 130.

“Precision Plaza” 397, Anna Salai,

Teynampet,

Chennai - 600 018.

India.

Telephone: 24335025, 24338144, 24338841.

Email: [precisionscientific@gmail.com](mailto:precisionscientific@gmail.com)

<http://www.precision-scientific.com/>

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Maytag® Neptune™ Front Loading Washer, Model MAH4000AWW, Serial No. 40268345WM  
Maytag Customer Service  
553 Benson Road  
Benton Harbor, MI 49022  
Telephone: 1 (800) 344-1274 U.S. or 1 (800) 688-2002 Canada  
<http://www.maytag.com>

Maytag® Neptune™ Front Loading Dryer, Model MD4000AWW, Serial No. 10808761WM  
Maytag Customer Service  
553 Benson Road  
Benton Harbor, MI 49022  
Telephone: 1 (800) 344-1274 U.S. or 1 (800) 688-2002 Canada  
<http://www.maytag.com>

Humidity chamber  
Designed by Dr. Marion Mecklenburg  
Smithsonian Institution's Museum Conservation Institute.  
Museum Support Center  
4210 Silver Hill Road  
Suitland, Maryland 20746  
Telephone: (301) 238-1240  
FAX: (301) 238-3709  
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<http://www.si.edu/mci/>

General Eastern Hygro-M2 Dew Point Monitor  
Telephone: +1 203 373 2211 or 1.800.448.0329  
<http://www.gesensing.com>

Broncolor FCM 2 Light meter  
Bron Elektronik Ltd.  
Hagmattstrasse 7  
CH - 4123 Allschwil / Switzerland  
Phone + 41/ 61 485 85 85  
Fax + 41/ 61 485 85 00  
e-Mail: [info\(at\)bron.ch](mailto:info(at)bron.ch)  
<http://www.bron.ch>

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9335 Harris Corners Parkway  
Suite 300  
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Tel: +1 704 697 5100  
Fax: +1 704 697 5116



## THE USES OF NONWOVEN FABRICS IN CONSERVATION

<http://www.polymergroupinc.com/>

### In the United States:

Charlotte, North Carolina (Worldwide headquarters)  
Benson, North Carolina  
Kingman, Kansas  
 Mooresville, North Carolina  
North Little Rock, Arkansas  
Waynesboro, Virginia

### In Canada:

Magog, Quebec  
North Bay, Ontario

### In Latin America:

Buenos Aires, Argentina  
Cali, Colombia  
San Luis de Potosí, Mexico

### In Europe:

Bailleul, France  
Cuijk, The Netherlands

### In Asia:

Nanghai, China  
Suzhou, China

### KIMBERLY-CLARK PROFESSIONAL

1400 Holcomb Bridge Road  
Roswell, GA 30076  
Attn: Customer Solution Center  
Telephone: 1-888-346-4652  
Fax: 1-800-654-8270  
Email: [kcpinfo@kcc.com](mailto:kcpinfo@kcc.com)  
[www.kcprofessional.com](http://www.kcprofessional.com)

### DuPont de Nemours™ International S.A. (DuPont™)

Corporate Information Center  
Telephone(U.S. callers only): 1-800-441-7515 or 1-302-774-1000  
[www.dupont.com](http://www.dupont.com)

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# REVISITING THE TREATMENT OF 12TH CENTURY MONGOLIAN DEELS

ALLISON MCCLOSKEY, MYAGMARSUREN BUTEMJ AND CYNTHIA LUK

**ABSTRACT-** This paper assesses the conservation treatment of three 12<sup>th</sup> century deels (traditional Mongolian cloaks) that were placed in the care of the Center for Cultural Heritage (CCH) of Mongolia. When Allison Mc Closkey and Cynthia Luk, conservators from the Williamstown Art Conservation Center, Williamstown MA, traveled to the Mongolian capitol of Ulaanbaatar as part of a bilateral exchange, an opportunity for further collaboration arose. Conservators at the CCH presented the work that had been performed on the deels to date, and initiated discussion on the merits of the treatments and what next steps would best preserve these archaeological textiles.

Conservators from the CCH first immersed the silk deels in an alcohol bath where they separated the deels, which had been a single entity when excavated. They followed this immersion with an aqueous cleaning in a solution of commercially available detergent. The garments were then stitched to fabric covered supports.

Conservators at Williamstown analyzed fragments of the deels to determine the present condition of the silk, and what steps may be undertaken to best preserve them now. This analysis will provide the conservators at the Center for Cultural Heritage of Mongolia with valuable information to plan a further course of action.

**REVISIÓN DEL TRATAMIENTO DE TRAJES MONGOLES DEL SIGLO XII: RESUMEN** - Este ensayo evalúa el tratamiento para la conservación de tres trajes del siglo XII (atuendos mongoles tradicionales) bajo el cuidado del Center for Cultural Heritage (CCH) de Mongolia. Cuando Allison Mc Closkey y Cynthia Luk, conservadoras de Williamstown Art Conservation Center, de Williamstown MA, viajaron a la capital Mongolia de Ulaanbaatar como parte de un intercambio bilateral, surgió la oportunidad de seguir colaborando. Los conservadores de CCH presentaron el trabajo que se había realizado en los trajes hasta la fecha y discutieron sobre los méritos de los tratamientos y cuáles serían los próximos pasos que contribuirían a preservar mejor estos tejidos arqueológicos.

Los conservadores de CCH primeramente sumergieron los trajes de seda en un baño de alcohol donde separaron los trajes, que constituían una única entidad desde la excavación. Luego de la inmersión procedieron a realizar una limpieza en agua con una solución de detergente de venta comercial. Las vestimentas luego fueron sujetadas con puntadas a los soportes cubiertos con tela.

Las conservadoras de Williamstown analizaron los fragmentos de los trajes para determinar la condición actual de la seda y qué pasos se tomarían para preservarlos de la mejor manera en lo sucesivo. Este análisis brindará a los conservadores del Center for Cultural Heritage de Mongolia valiosa información para diseñar un futuro plan de acción.

## 1. INTRODUCTION

In June 2009, Cynthia Luk, International Project Specialist and Paintings Conservator at Williamstown Art Conservation Center (WACC), and Allison McCloskey, Assistant Textile and Objects Conservator at WACC, held a week-long workshop at the Center for Cultural Heritage of Mongolia (CCH). This workshop was part of an ongoing exchange funded by the Trust for Mutual Understanding and the Asian Arts Council. Its goal was to address the unique and challenging treatment issues involved with *thangka* paintings, which usually have a vulnerable matte paint surface, a flexible and essentially unrestrained fabric substrate, and one or more decorative silk borders. These paintings are often rolled and unrolled on their support dowels for storage, and this manipulation compromises their condition. The workshop focused on techniques of matte paint and silk

## REVISITING THE TREATMENT OF 12TH CENTURY MONGOLIAN DEELS

fabric stabilization, and treatment considerations for the Buddhist religious practices involving these paintings.

The conservators of the CCH are also dealing with the aftermath of a fire in the adjacent Modern Art Museum which was a result of political riots a few months prior to the visit, and a second fire due to an electrical malfunction. The nearly 1000 fire and smoke-damaged paintings have become a priority for the conservators at the CCH, and they set aside time during the week to show some of the damaged works to the visiting conservators and to begin a dialogue on how to approach such a large-scale recovery.

Another goal for the visit was to discuss the treatment of a group of three silk deels, traditional Mongolian cloaks, dating from the 12<sup>th</sup> century that had been discovered in a plundered tomb outside of the capital city of Ulaanbaatar. The deels were brought to the CCH for treatment in 2003, and the staff wanted to discuss the treatment steps that they had taken and investigate whether any additional treatment would contribute to the deels' preservation.

### 2. THE DEELS

The deels were discovered in the region of Delgerkhaan, just to the southeast of the capital city Ulaanbaatar. They were received in a large mass, and the conservators did not initially identify three separate garments. The tomb where the deels were discovered had been plundered, so a good amount of archaeological information had been compromised.



Figure 1 (left). Deel 1, on exhibit in the Zanabaazar Museum in Ulaanbaatar in 2009.

Figure 2 (right). A during-treatment shot of deel 1 from the CCH files.

Figure 1 shows the first deel, which was on exhibit in the Zanabaazar Museum in Ulaanbaatar in 2009. It is mounted on a padded support, and light levels in the display case are kept much lower than adjacent cases. This deel is made of a fine plain weave silk fabric with silk applique around the collar, sleeves, and along the borders of the skirt. Figure 2 shows the deel during treatment at the CCH. The thread count is approximately 128 warps per inch and 88 wefts, and the yarns are thrown multifilament cultivated silk yarns.

Deel 2 was in storage at the time of the WACC visit (fig. 3). Its fabric has a weft-faced plain weave with multicolored discontinuous wefts. There are small open slits between changes in color field. The warps are



Figure 3. Deel 2, in storage at the Zanabaazar Museum.

a 2-ply silk yarn, plied in the z direction, and there are approximately 42 warps per inch. Wefts are thrown multifilament silk yarns, with up to 112 weft yarns per inch in the fragment reserved for examination.

The third deel was in the textile conservation laboratory at the time of the visit (fig. 4). It is made of a multicolored complex weave with a supplementary weft, 128 warps per inch, 48 primary wefts per inch, and 48 pairs of secondary weft yarns per inch.



Figure 4. Deel 3, in the Textile Conservation Laboratory of the Center for Cultural Heritage, Ulaanbaatar.



## REVISITING THE TREATMENT OF 12TH CENTURY MONGOLIAN DEELS

### 3. THE TREATMENT OF THE DEELS

Treatment was performed by Chinzorig Samdan, Chief of Conservation at CCH, and Myagmarsuren Butemj, textile conservator. The first step was an immersion in ethanol and distilled water (fig. 5). The deels were separated at this time.



Figure 5. Deels as received, in initial bath of 70% ethanol and 30% distilled water; Chinzorig Samdan, Chief of Conservation at CCH, and Myagmarsuren Butemj, textile conservator.

The ethanol rinse was followed by aqueous cleaning with distilled water and Johnson's Baby Shampoo. The deel components were dried between blotter papers and glass weights. As communicated through a translator, the conservators chose this as their surfactant formula based on pH, limited additives, and material availability. Table 1 shows the ingredients list as posted on Johnson and Johnson's website. The primary surfactant is amphoteric, so its ionic charge is dependent upon the pH of the surfactant and water solution. The use of distilled water was probably beneficial in this regard, as it becomes acidic down to about a pH of 5 as it dissolves ambient carbon dioxide in the air. Since this is close to the isoelectric point of silk which is approximately 5.5, it is likely that this surfactant did not significantly swell the silk substrate and likely rinsed easily from the deels. The second surfactant, PEG-80 Sorbitan Laurate, is a nonionic surfactant, which should also rinse readily from the silk fabric. The anionic surfactant Sodium Trideceth Sulfate might not rinse quite as readily from a proteinaceous fiber, and by itself would have a high pH, but is present in a relatively low concentration. The pH of the shampoo is adjusted to neutral, which is safer for this application than many alkaline commercial cleaning products. Since the ethylenediaminetetraacetic acid (EDTA) tested safe for the dye systems present, it could effectively serve to chelate soils during the wet cleaning. The fragrances, dyes, and preservatives do not contribute at all to the cleaning in this application; on initial investigation they are primarily water-soluble. The humectant additives may pose the biggest danger, since they are designed to remain behind and draw ambient moisture to the hair follicle. Another danger here is the variability of proprietary products, whose formulations can change at any time. A personal care safety discussion list from 2003 (the year that the deels were treated) listed additional ingredients from an earlier formulation of Johnson's Baby Shampoo (also listed in table 1).

<b><u>Johnson's Baby Shampoo</u></b>	
<i>Ingredient</i>	<i>Function / description</i>
Water	vehicle
Cocamidopropyl Betaine	amphoteric surfactant
PEG-80 Sorbitan Laurate	nonionic surfactant
Sodium Trideceth Sulfate	anionic surfactant
PEG-150 Distearate	nonionic surfactant / emulsifier / thickener
fragrance	(no camphor)
Polyquaternium-10	conditioner / humectant
Tetrasodium EDTA	buffer / chelator
Quaternium-15	preservative, water-soluble antimicrobial
Citric Acid	pH adjuster, from molasses and/or corn syrup
D&C Yellow 10 and Orange 4	Water-soluble colorants
sodium hydroxide	pH adjuster (may contain)
<i>(<a href="http://www.johnsonsbaby.com">http://www.johnsonsbaby.com</a>)</i>	
<i>Past formulations may have included</i>	
Glycerine	humectant
Lauroamphoglycinate	amphoteric surfactant
Sodium Laureth-13 Carboxylate	anionic surfactant
<i>(<a href="http://answers.google.com/answers/threadview?id=137974">http://answers.google.com/answers/threadview?id=137974</a>)</i>	

Table 1. Ingredients of Johnson's Baby Shampoo for the 2003 treatment and previous ingredients.

The conservators and curators are very interested in preserving the deels as aesthetic and historic works. A rigid padded support panel with a fabric cover was prepared for each deel. Layers were interleaved with acid-free paper, and folds were cushioned with piping of cotton fabric and polyester fiberfill. The deels were stitched to the support panel. To limit the stitching needed through the tightly woven plain weave fabric of the first deel, the conservators overlaid a dark nylon net for additional support. This was a step which they reconsidered and did not include for the treatment of the other two deels.

#### 4. ANALYSIS OF THE WETCLEANING SURFACTANT ON THE SILK

Fragments from each of the deels were brought from Ulaanbaatar to Williamstown for analysis. These fragments had separated from their respective garments, and were not secured to the support panels since their original locations were not definitive. The fragment from deel 3 was wet cleaned as described above, but the fragments from deels 1 and 2 were not. Fourier Transform Infrared Spectroscopy-Attenuated Total Reflectance was performed with Dr. Christopher Goh at Williams College. The technique in theory is nondestructive, though the pressure of the diamond cell will damage a fragile textile. Practicing the technique on known fabrics analyzed for comparison, spectra were obtained from very small samples that had broken off of the deel fragments. Control samples of new silk fabric, hair silk thread, and aged shattering silk were also analyzed under the same parameters for comparison.

The spectrum for the washed fragment from deel 3 (fig. 6) exhibits all of the expected peaks for silk: amide I at  $1622\text{ cm}^{-1}$ , amide II at  $1510\text{ cm}^{-1}$ , and amide III at  $1225\text{ cm}^{-1}$ . The broad peak at  $3275\text{ cm}^{-1}$  is a N-H stretching bond. These peaks were all consistent among the known silk samples analyzed. The peak at  $2919\text{ cm}^{-1}$

## REVISITING THE TREATMENT OF 12TH CENTURY MONGOLIAN DEELS

corresponds with  $\text{CH}_2$  and  $\text{CH}_3$  bonds in alkyl groups. One peak at  $2852\text{ cm}^{-1}$ , which corresponds with  $\text{CH}_2$  bonds in alkyl groups, was clearly seen in the third deel fragment and in the new hair silk thread. Peaks in this location were significantly less prominent in the other silk control samples.

The spectra from the unwashed deel fragments were dominated by a large peak at around  $1000\text{ cm}^{-1}$ , which is likely the wagging  $\text{CH}_2$  bond within silicates in the deposited soil. This large peak did not allow for clear definition of the amide III peaks.

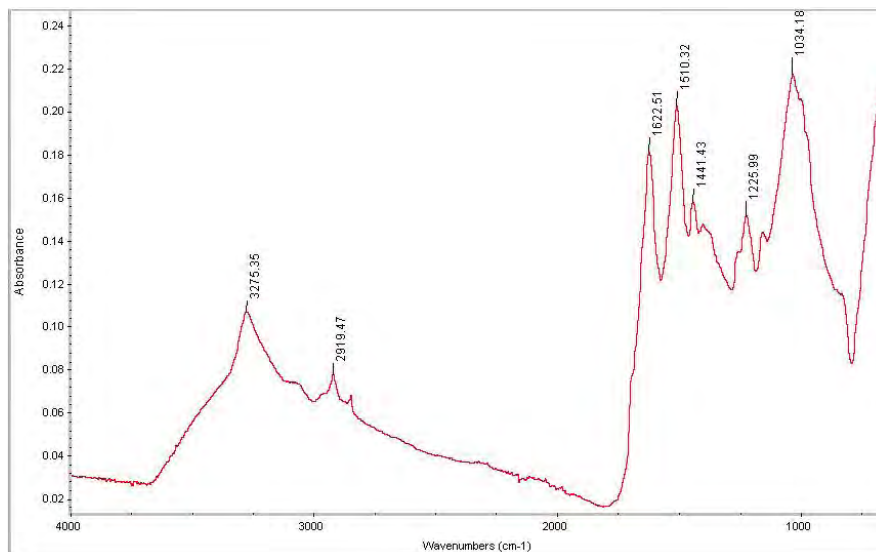


Figure 6. FTIR-ATR spectrum from fragment of deel 3.

To determine how much of the fibroin structure was in the stable  $\beta$ -pleated sheet formation, and how much had lost its crystalline structure, amide III peak intensities were compared (Shao et al. 2003). The values for the deel fragments were all comparable with the aged and unaged samples: 46.99% relative crystallinity for deel 3, and 45.86% for deel 2, compare favorably with 45.79% for a new silk fabric and 47.1% for new hair silk yarn. (table 2) This is commensurate with studies on silk degradation; if silk has lost its crystallinity to a measurable degree, it will likely have lost its integrity as a fabric, yarn, and fiber. All of the deel fragments retain a good amount of their original form as a woven fabric. Relative levels of tyrosine were also compared between the samples, to determine if the surface of the deel fragments were more depleted in this amino acid than the control samples. The washed sample from deel 3 had a high relative tyrosine level, comparable with the hair silk thread, and significantly more than even the new silk fabric samples (table 3).

• Talas hair silk (new)	47.05%
• Deel 3 fragment (washed)	46.99%
• Deel 1 fragment (unwashed)	45.91%
• Deel 2 fragment (unwashed)	45.86%
• Weighted 19c western silk	45.79%
• Forensic silk fabric sample	45.79%

Table 2. Approximate percentages of crystalline  $\beta$ -pleated sheet structure in silk samples.

• Talas hair silk	0.789
• Deel 3 fragment	0.784
• Weighted 19c Western silk	0.562
• Forensic silk fabric sample	0.452
• Deel 1 & 2 fragments had heavy peaks for silicates at $1000\text{ cm}^{-1}$ , which prevented this comparison	

Table 3. Comparative levels of tyrosine in silk samples.

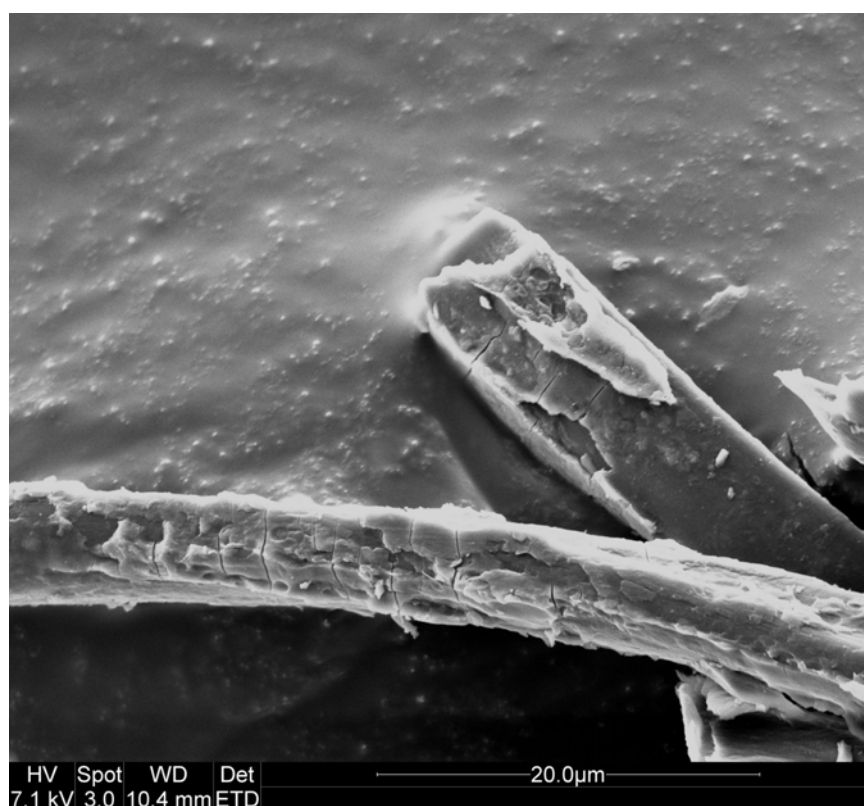


Figure 7. SEM image of fragment from deel 3.

Scanning Electron Microscopy imaging of the washed fragment from deel 3 clearly showed damage to the embrittled and broken fibers (fig. 7). One of the most friable areas of the fragment from deel 3 was selected for destructive SEM analysis, since they had already broken off of the larger fragment. In addition to ragged breaks, a surface accretion was evident that itself has embrittled and cracked, obscuring most of the otherwise smooth surface of the fibers. Similar accretions are visible on the hair silk, and noticeably absent on other silk samples imaged. One possible explanation for this coating is that the sericin was not completely removed by scouring in hot water and alkali during the degumming stage of silk processing. The peak at 2850 wavenumbers seen in the spectra of both the deel fragment and the hair silk may be related to this coating. If this coating is residual sericin, it remained intact through the gentle wet cleaning and may not necessarily pose a preservation risk to the deels at this point. Sericin would darken as it ages and may actually act as a light filter for the fibroin to reduce cumulative light damage (Becker et al. 1995).



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### 5. CONCLUSIONS

Recommendations for further treatment of the deels based on this analysis are minimally interventive. Vertical display is placing a significant amount of stress on the deels at the points of attachment. While conservators and curators would like to maximize the access and visual impact for the public, they are also aware that this is compromising the deels' preservation. They have taken down the one deel that was on exhibit last year and placed it in storage along with the other two. This will also reduce the cumulative light exposure for the deels, which had been protected from light in their burial environment for centuries.

Another important preservation issue to address is the choice of storage and mount materials, which is challenging because of the differences in product availability. Using an appropriate barrier layer on top of the plywood substrate of the support panel is one important step, along with avoiding any buffered paper products.

The CCH conservators specifically asked if analysis suggests any need to revisit the surfactant cleaning of the deels, and if there is residue that might be removed with another rinsing or wet cleaning. There does not appear to be enough evidence of any residue to warrant this, especially considering the risks involved due to the fragile condition and evident deterioration of the deels. Possible techniques for detecting trace surfactant residues are being explored, including Desorption Electrospray Ionization (DESI) Analysis. Issues that should be considered for similar treatments in the future include avoiding proprietary surfactant solutions with unwanted additives, and looking at characteristics of the water such as pH and ion content, as much as the available resources will allow. This project has facilitated a productive cultural exchange along with the practical application of some instrumental analysis to an important group of objects with complex preservation issues.

### ACKNOWLEDGEMENTS

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# THE NEW YORK STATE BATTLE FLAG PRESERVATION PROJECT: TEN YEARS LATER

SARAH C. STEVENS

**ABSTRACT** – The New York State Battle Flag Preservation Project’s conservator and curator have been caring for and interpreting flags for ten years. To date, five-hundred flags have been conserved, giving ample opportunity to assess previous restoration campaigns and revisit treatments carried out in the last ten years.

The project’s conservator and curator have generally taken a minimally interventive approach to the flags, working towards stabilizing the entire collection of over 2,000 flags. This approach has led to a somewhat standardized treatment protocol. Over the course of the project, some of the treatment steps have been refined, as the conservator has become more familiar with the collection and learned of different conservation materials and techniques. Additional analysis done on some of the flags has also led to treatment refinements. On occasion, the conservator and curator decide that a flag needs additional treatment, usually because of its condition. The additional treatments have also been modified over the years.

This paper will discuss the benefits and drawbacks of previous treatments. It will describe the decision-making process for the current treatments and evaluate their success or failure.

**PROYECTO DE CONSERVACIÓN DE BANDERAS DEL ESTADO DE NEW YORK – DIEZ AÑOS MÁS TARDE: RESUMEN** – El conservador y curador del Proyecto de Conservación de Banderas del Estado de New York se interesa por las banderas y las interpreta hace diez años. A la fecha, se han conservado cinco mil banderas, con la amplia posibilidad de evaluar campañas de restauración previas y revisar los tratamientos realizados en los últimos diez años.

El conservador y curador del proyecto adoptó un enfoque de mínima intervención respecto de las banderas y trabajó para estabilizar toda la colección de más de 2000 banderas. Este enfoque indujo a un protocolo de tratamiento relativamente estandarizado. Durante el transcurso del proyecto, algunos de los pasos del tratamiento fueron redefinidos, a medida que el conservador se familiarizó más con la colección y aprendió acerca de los diferentes materiales y técnicas de conservación. Otros análisis de algunas de las banderas también llevó a corregir el tratamiento. En ocasiones, el conservador y curador determina que una bandera requiere más tratamiento, generalmente debido al estado de la bandera. Los tratamientos adicionales también fueron modificados con los años.

Este ensayo discutirá los beneficios y desventajas de los tratamientos anteriores. Describirá la toma de decisiones para los tratamientos actuales y evaluará su éxito o fracaso.

## 1. INTRODUCTION

### 1.1 THE COLLECTION

The New York State Battle Flag Collection began in 1863 when the state requested all flags be returned for safe-keeping by the *Presentation of Regimental Colors to the Legislature*. This precedent continues to this day and the collection now has over 2,000 flags with examples ranging from the War of 1812 to the present. The flags vary in size from 2 feet square to large, garrison-size flags of 14 by 24 feet. They are constructed from silk, wool, cotton, and synthetic materials and can be painted, embroidered or appliquéd.

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### 1.2 THE NEW YORK STATE BATTLE FLAG PRESERVATION PROJECT

In 1997, the New York State Office of Parks, Recreation and Historic Preservation Peebles Island Resource Center Staff (PIRC) and the Division of Military and Naval Affairs (DMNA) conducted a survey of the flags in the New York state capitol (Stevens 2000). The survey report noted that most of the nineteenth-century flags are in fair to poor condition. Specifically, the flags were being damaged by their current storage in glass-fronted cases on the first floor of the capitol, where they were rolled too tightly around their staffs, crowded into cases with uncontrolled temperature and relative humidity, and exposed to excessive light, stress from gravity, and soils from the surrounding urban environment (fig. 1).



Figure 1. Flags rolled around their staffs and stored upright in storage cases in the Capitol, Albany, NY. Most were covered with tissue during the 2000 survey. Photo courtesy of the author.

In 2000, Governor George E. Pataki and the New York State Legislature provided funds to implement the preservation recommendations of the 1997 survey. To insure the flags' long-term preservation, DMNA curators and PIRC conservators developed a program of care for the flags that includes the creation of a flag archive in which the collection could be conserved, stored, and studied.

The main goals of the New York State Battle Flag Preservation Project are to document the flags, using written reports and photography; create accessible storage for scholars, curators and the public; stabilize the flags to reduce deterioration following the AIC Code of Ethics; store and exhibit the flags in a controlled environment; and reduce the handling of the flags after conservation by storing and displaying them flat, using the same mount for storage and exhibition where possible. The aim is not to restore the flags to their original appearance, but stabilize what remains after their original use and previous storage condition.



# THE NEW YORK STATE BATTLE FLAG PRESERVATION PROJECT: TEN YEARS LATER

## 2. CONSERVATION TREATMENT PROTOCOL

Many of the flags required similar treatment, so a protocol was developed that includes documentation, surface cleaning, realignment and storage on a support panel. As each flag is examined, the treatment is determined by the conservator and approved by the collection curator.

### 2.1 HUMIDIFICATION

For the smaller flags in the collection, using a damp cloth over Gore-Tex® to introduce moisture worked very well. The small scale allowed enough time to realign the fabric once the Gore-Tex® and damp cloth were removed. For larger flags, a tented table-top and a humidifier was used (fig. 2). Unfortunately the table-top had two disadvantages: the center of the flag was difficult to reach from the edge of the table and when a conservator was standing at the edge, the humidification leaked out, limiting the time available to work. The solution was found after speaking with the Peebles Island Maintenance Department. They recommended a converted outdoor car garage; large enough to accommodate a table with a bridge to reach the center of the flag (fig. 3). Since the garage material is not opaque, it let in some light and made a fairly pleasant work environment.



Figure 2. Table-top humidification set-up. Photo courtesy of the author.



Figure 3. Humidification chamber with bridge and table. Photo courtesy of the author.

## 2.2 WETCLEANING

While in storage at the Capitol in Albany or at armories around the state, acidic soils have accumulated on the flags. Though it is not in the general protocol, some of the flags in the collection have been wet-cleaned; this decision was made due to the condition of the flag and the time available for its treatment. Both a bath and a suction table have been used and have been effective. The suction table has been somewhat less effective as many of the flags have a loose weave, letting too much air through and lessening the suction aspect. For the larger flags, wet-cleaning in a bath has been the only feasible option and has worked quite well.

## 2.3 PAINTED FLAGS

Painted flags in poor condition also require treatment beyond the general protocol. Some painted areas exhibit a white haze or bloom caused by stearate salts migrating from the ground layer to the top layer. Recent research indicates the haze or bloom appears to be an inherent defect in the ingredients of the ground layer as driers were added to accelerate the process (Zucker 2007).

After consultation with Peebles Island Paintings conservators, B72 was used as a consolidant in the affected areas. This gave the paint a shiny appearance that was not previously present and required solvent extraction while working. Shortly after the first flag was treated, the Peebles Island Paper conservator had a similar problem with a watercolor. She rubbed the area gently with a vinyl eraser and had some success; similar success was achieved with the painted areas of the flags (fig. 4).



Figure 4. Left - before reduction of haze. Right - after reduction of haze. Photos courtesy of the New York State Military Museum and Veterans Research Center.

Over the last 140 years, the oil paint used to decorate the flags has dried to such an extent that it is now inflexible, except under high humidity. This has created breaks in the painted areas, causing loss. After consultation with Nancy Pollak, a paintings conservator working with flags, small, 1/8" x 1/2", pieces of Stabiltex<sup>®</sup> coated with Beva<sup>®</sup> 371 – were used to hold loose pieces together (fig. 5). These band-aids are heat-set mainly on the reverse side of the flag and their placement is marked on an image of the flag for reference in case they require removal at a later date. Different colors of Stabiltex<sup>®</sup> are used to match the color of the areas being held together to visually mask where the band-aids are placed.

## THE NEW YORK STATE BATTLE FLAG PRESERVATION PROJECT: TEN YEARS LATER

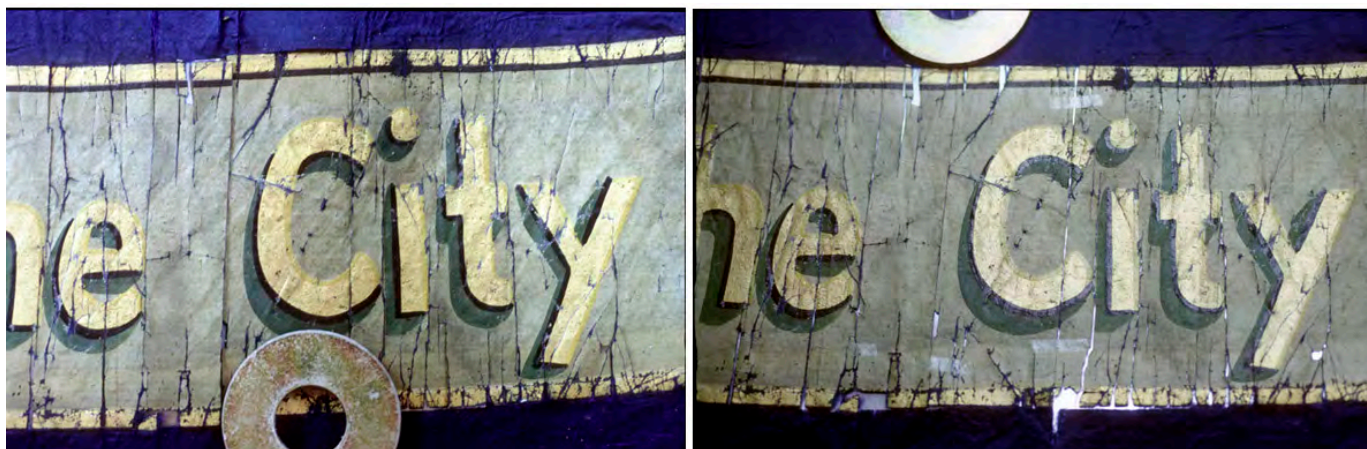


Figure 5. Detail image of 'bandaids': Left - before application, Right - after application.  
Photos courtesy of the New York State Military Museum and Veterans Research Center.

### 3. PREVIOUS RESTORATIONS

During the course of this project, several previous conservation treatments from the 1960s have been evaluated. These previous treatments, which include lamination and encapsulation in net, may have come from both a desire to preserve the flags as well as a desire to use them for centennial parades. Both have negatively impacted the current condition of the flags.

#### 3.1 LAMINATION

In the 1960's, four flags in the collection had damages that were difficult to repair by stitching, and were sent to Switzerland for lamination. The flags were sandwiched between two layers of PVC, plasticized with di(2-ethylhexyl) phthalate (Ormsby 2004) and heat-set. While lamination did keep all the loose pieces together, the weight of the laminate creates additional problems when the flag is re-rolled on its staff. As time passed, the plastic hardened and became yellow and distorted and the lamination process compacted the flag and fringe and obscured original construction details of the flag. As the flag is rolled and re-rolled, the paint continues to crack and brake inside the plastic.

##### 3.1.1 TREATMENT

After testing various solvents and heat to remove the laminate, it was found that an acetone solvent vapor chamber worked best. The solvent chamber is created using a two-inch square piece of Gore-Tex<sup>®</sup> with an acetone soaked piece of blotter paper on top, and covered with Mylar<sup>®</sup> polyester film. After about five minutes, the plastic has softened and the chamber is removed. If the fabric is strong enough beneath it, the laminate can be quickly peeled away (fig. 6). In more fragile areas, acetone can be applied directly to loosen and mechanically remove the laminate.

After the laminate was removed, treatment continued as if the laminate had not been present, using band-aids where necessary. Two of the laminated flags have had the laminate removed so far, one of which is pictured here (fig. 7).



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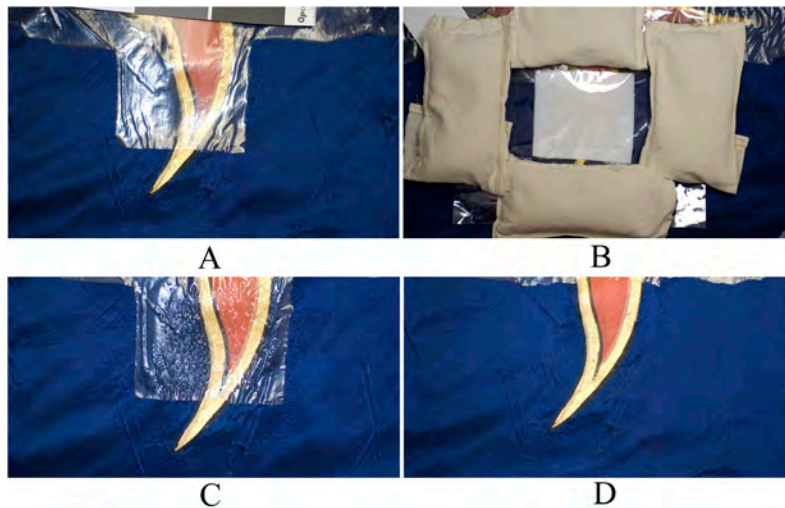


Figure 6. Laminate Removal: A – before removal; B – Solvent Chamber; C – Just before peeling laminate away; D – After laminate removal. Photos courtesy of the New York State Military Museum and Veterans Research Center.



Figure 7. 46<sup>th</sup> Infantry, Regimental Color, before treatment (above) and after treatment (below). Photos courtesy of the New York State Military Museum and Veterans Research Center.



## THE NEW YORK STATE BATTLE FLAG PRESERVATION PROJECT: TEN YEARS LATER

### 3.2 ENCAPSULATION IN NET

Between 1961 and 1976, Mrs. Josephine Roser treated 650 silk and wool flags of various sizes (Stevens 2000). She sandwiched each flag between thick, abrasive, color-matched nylon net and secured the net to the flag with closely spaced rows of machine zigzag stitching. In some instances Roser removed the fringe, staff sleeve seam or additional seams, applied the net, and then reassembled the flag. Although the netting treatment does keep the flags together, we discovered that the many rows of stitching created additional breaks and losses in the flags. The netting is a bright color that obscures the original color of the flags and the numerous rows of stitching along the edges obscure original construction details.

#### 3.2.1 TREATMENT

Removal of the net is desirable because of the abrasion it causes and the details it obscures, but its removal could potentially cause more damage to the already fragile silk and wool fabric. To understand if the net could be detached safely and if its removal would benefit the flags, net was removed from two small flags, one of wool and one of silk, as an experiment. For the silk flag, the regular pattern of the stitches created diagonal lines of small holes and losses where the silk could more easily tear. Because of these numerous holes, the silk flag was more vulnerable to additional losses after the removal of the net. In addition, even after humidification, the stitch holes and the impression of the net remain in the fabric (fig. 8). The test for the wool flag had better results. The stitch holes in the wool fabric did not shatter the fabric because the fabric had a looser weave than the silk; the holes pushed the yarns aside instead of making actual holes. The wool retained its body and was not more vulnerable to damage after removal of the net. After humidification, the stitch holes receded and the impression of the netting disappeared, improving the flag's appearance (fig. 9). On the basis of this trial, the conservators decided to remove the Roser netting only from the wool flags.

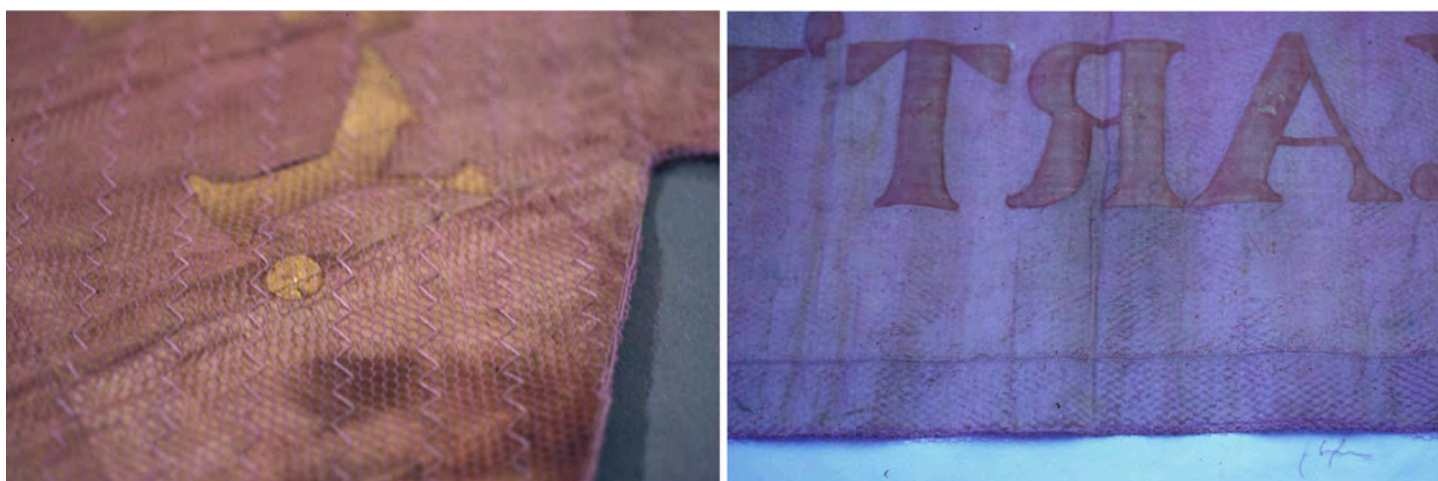


Figure 8. Detail images of silk flag: Left-before net removed; Right-after net removed.  
Photo courtesy of the New York State Military Museum and Veterans Research Center.

To stabilize the silk flags with Roser netting that have broken areas of painted silk, a modified protocol was developed that would address the splitting of the painted silk, but not overly disturb the Roser net treatment (fig. 10a). The necessary stitches were clipped and the net cut and folded out of the way. Then, after stabilizing the painted areas using band-aids, the net was folded back over the flag and the net layers were stitched together along losses in the paint (fig. 10b).



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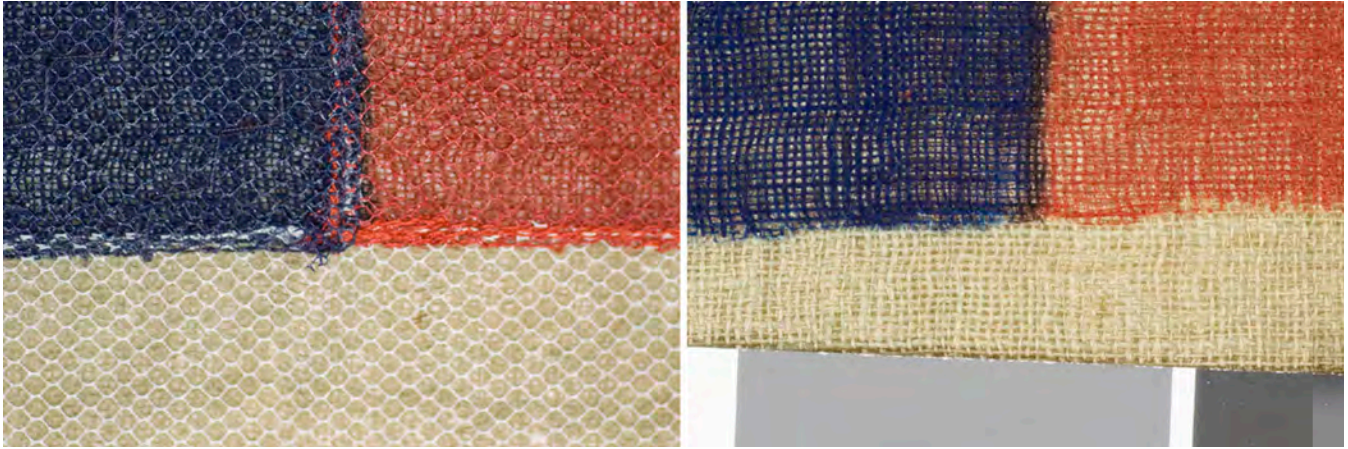


Figure 9. Detail images of wool flag: Left-before net removed; Right-after net removed. Photo courtesy of the New York State Military Museum and Veterans Research Center.



Figure 10. Detail image of painted area: Left-before; Right-after. Photo courtesy of the New York State Military Museum and Veterans Research Center.



Figure 11. Detail image of tape: Left-after netting removed but before tape removed; Right-after tape removed and remoistenable tissue applied. Photo courtesy of the New York State Military Museum and Veterans Research Center.



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Recently an additional complication with this type of intervention has been discovered. Some larger painted flags with damaged paint were consolidated with scotch tape before the netting was applied (fig. 11). Although the goal of saving the original was achieved, the tape will likely discolor over time and the adhesive may damage the paint. The tape is currently being removed. When the tape is on the front of the flag, remoistenable tissue with a water soluble adhesive (Hackett and Szuhay 2003) is used to secure the loose pieces in anticipation of turning the flag to the back side. Once the flag is turned to the back (Stevens 2005), a more sturdy adhesive treatment is performed to stabilize the painted areas. The flag is then turned back to the front to remove the tissue.

### 3.2.2 REPLACING FAILING NET TREATMENTS

Some previous netting treatments from the early 19<sup>th</sup>-century have not retained their strength. Either the net, the thread used to sew it or both have weakened over time. In one case for the New York Battle Flag Project, the netting was removed and the flag was strong enough to not require replacement of the net. In another case, the flag was so fragile, that it was determined that the failing net and silk stitching would be replaced with a fine, nylon bobbinet. Airbrushed dyes were used to color-match the net and all stitching was done between losses, to prevent the creation of new stitch holes (Britton 2007).

During a separate project for the Illinois State Military Museum, the Peebles Island Textile Lab treated a federally issued Regimental color used by the 114<sup>th</sup> Illinois Regiment. The flag had been encapsulated in rayon and silk net and hand-sewn with silk thread in the 1920s. This netting treatment was failing and the flag was fragile underneath, so the netting was replaced with bobbinet, dyed to match the blue silk. The owner also wanted visual compensation so that museum visitors could get a better sense of what the flag would have looked like despite the losses in the original. An image from a similar flag from the New York State collection that was more complete was digitally printed onto polyester to act as an underlay (Britton et al 2006).



Figure 12. 114<sup>th</sup> Illinois Regimental Color: Left-back after; Right-back after underlay cut to match register and basted on. Photos courtesy of the Illinois State Military Museum.

Despite careful measurements, the register of the New York image did not quite match the Illinois flag. The New York image was of a flag that had the Roser treatment, so its dimensions likely shifted after the netting was applied. Instead of a complete, full length of fabric for the underlay, the underlay was cut up, matched to the Illinois flag design on the front and basted to the back net layer (fig. 12). Visually, the underlay works well (fig. 13). For the next time, the underlay image and the original flag image will be merged together in Photoshop to solve the register problem, hopefully resulting in one large underlay instead of many smaller pieces.



Figure 13. 114<sup>th</sup> Illinois Regimental Color after treatment.  
Photo courtesy of the Illinois State Military Museum.

#### 4. CONCLUSIONS

Over the last ten years, the conservation of the flags has continued to evolve as new techniques come to light and new complications arise. The five hundred flags treated thus far are greatly improved and have taught us how to better care for the remaining flags in the collection. In addition to the enormous conservation undertaking, non conservation staff members working on the flag project have increased public awareness and access of this important historical collection through exhibitions, education programs and a website (<http://dmna.state.ny.us/historic/btlflags/btlflagsindex.htm>). Approximately 75% of the collection, including nearly half of the Civil War flags, still needs conservation. Due to the severe fiscal crisis, New York State removed the allocation to the flag project in the 2010 budget. However, conservation work will continue on flags as they are sponsored or as grant money is awarded.

#### ACKNOWLEDGEMENTS

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## THE NEW YORK STATE BATTLE FLAG PRESERVATION PROJECT: TEN YEARS LATER

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### SOURCE OF MATERIALS

Outdoor car garage (humidity chamber)

Fred's Tents and Canopies

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# COMPARATIVE APPROACHES IN TEXTILE CONSERVATION: THE WHALLEY ABBEY VESTMENTS & ALTAR FRONTAL

LEANNE C. TONKIN

**ABSTRACT** – The Whalley Abbey vestments are known to be one of only two surviving sets of pre-Reformation High Mass vestments which were conserved in the UK in the 1980s and early 1990s. The Whalley Abbey altar frontal is associated with the vestments but was not considered for treatment until 2009 following its re-discovery during a collections survey. The author explains how and why there were differences in the conservation treatment of the textiles within the group. Analyzing the treatment of the Whalley Abbey vestments and comparing these approaches to the conservation of the Whalley Abbey altar frontal, some twenty years later, raised an important awareness of the developing demands of the viewer and the developing ethics of the textile conservator. The final treatment of the altar frontal sought to value all elements as significant parts of the altar frontal, thus preserving the evidence of its previous use as well as its future role as a displayed textile. At the same time the treatment also took into account the previous conservation work that was completed on the other vestments to maintain aesthetic continuity within the display.

**ENFOQUES COMPARATIVOS EN LA CONSERVACIÓN DE TEJIDOS: LAS VESTIDURAS DE WHALLEY ABBEY Y EL ALTAR FRONTAL DE WHALLEY ABBEY: RESUMEN** – Las vestiduras de Whalley Abbey son conocidas como algunos de los dos únicos juegos sobrevivientes de vestiduras de Misa Mayor de la pre-Reforma que se conservaron en el Reino Unido durante los años 1980 y comienzos de 1990. El altar frontal de Whalley Abbey está relacionado con las vestiduras pero su tratamiento recién fue considerado en 2009 luego de su redescubrimiento durante una inspección de las colecciones. El autor explica cómo y por qué había diferencias en el tratamiento de conservación de los tejidos dentro del grupo. Analizar el tratamiento de las vestiduras de Whalley Abbey y comparar estos enfoques con la conservación del altar frontal de Whalley Abbey, unos veinte años más tarde, creó conciencia de las demandas progresivas del espectador y la ética del conservador de tejidos. El tratamiento final del altar frontal procuró evaluar todos los elementos como partes significantes del altar frontal, y preservar así la evidencia de su uso anterior como también su futura función como tejido en exhibición. Al mismo tiempo, el tratamiento también consideró el trabajo de conservación previo que se realizó en otras vestiduras para mantener la continuidad estética en la exhibición.

## 1. INTRODUCTION

The Whalley Abbey altar frontal was conserved at the Textile Conservation Centre (TCC), formerly of the University of Southampton, UK as partial fulfillment of the author's MA studies. During the decision-making process of conserving the altar frontal, the dilemma of examining the past and envisioning the future, the theme of the 38<sup>th</sup> annual meeting of the American Institute for Conservation in Milwaukee, became an important platform for discussion. This paper will discuss the comparative conservation treatments of the Whalley Abbey vestments conserved between 1987 and 1992 and the Whalley Abbey altar frontal treated in 2009, concentrating on how and why there were differences in conservation treatments and the impact this had when the altar frontal was finally placed back on display.

## 2. WHALLEY ABBEY, THE VESTMENTS AND THE ALTAR FRONTAL

Whalley Abbey was a Cistercian monastery situated in Lancashire, England from 1296. Following the dissolution of this monastery (1537), a set of vestments dating from the first half of the 15<sup>th</sup> century was taken by Sir John Towneley (1473-1541) (Monnas 1994), a member of a Catholic recusant family, and brought to nearby Towneley Hall, Burnley, Lancashire. In 1903 Towneley Hall became a museum and art gallery and is presently owned by Burnley Borough Council.

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The vestments consist of two dalmatics, one chasuble, and one maniple and remained in the Towneley family until 1922, when they were sold at auction. One of the dalmatics, the chasuble, and the maniple were bought by Burnley Borough Council so they could remain at Towneley Hall. The other dalmatic was purchased by the Burrell Collection in Glasgow, UK. Embroidered panels known as orphreys and referred to as *Opus Anglicanum*<sup>1</sup> adorn the fronts and backs of the chasuble and dalmatics, depicting chronological scenes from the Life of the Virgin and the Infancy of Christ (Monnas 1994). These four pieces are referred to as the Whalley Abbey Vestments and are thought to be one of only two complete sets of Pre-Reformation English High Mass<sup>2</sup> vestments in existence (Monnas 1994). The Whalley Abbey altar frontal was also sold at the same auction and it too remained at Towneley Hall.

The Whalley Abbey altar frontal (also referred to as the Whalley Abbey Orphreys) was potentially used to cover the front of an altar during mass (fig. 1). The point of assemblage of the altar frontal is unclear, but it may have been put together during the 19<sup>th</sup> century due to the reassertion of Catholicism. The altar frontal consists of two side pillar orphreys of similar style depicting pairs of saints which could date from the late 14<sup>th</sup> to the early 15<sup>th</sup> century (Dean 1958; King 1963; King and Levey 1993; Monnas 1994). In the center of the altar frontal is an early Tudor cross orphrey showing the crucifixion, c. 1500 (King 1963; Johnstone 2002). The three orphreys have been mounted onto a late 18<sup>th</sup> to early 19<sup>th</sup> century crimson silk (Rothstein 1990) and have been edged with silver bobbin lace typical of the early 17<sup>th</sup> century (Earnshaw 1985; Dillmont n.d.). The orphreys are lined with blue linen which is very typical of *Opus Anglicanum*, suggesting their original use to decorate liturgical vestments. The textile was backed with a coarse, undyed linen fabric and tacked to a wooden board and placed in a glass frame.



Figure 1. The Whalley Abbey altar frontal before treatment. 2009.  
Courtesy of the Textile Conservation Centre (TCC), UK.

Subsequent comparison of the Whalley Abbey textiles confirms there is no direct relationship between the vestments and the altar frontal. The orphreys on the vestments and the altar frontal are very different in style and quality. Despite these differences in style, the orphreys on the altar frontal still belong to the period before the dissolution of Whalley Abbey. The material evidence of the blue linen lining suggests the orphreys on the altar frontal could have belonged to the vestment collection at the Abbey or, perhaps, other neighboring Catholic dioceses being cleansed at the time of the Reformation.



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The Whalley Abbey vestments at Towneley Hall are currently on long-term display (figs. 2, 3) and were conserved by Jean Glover MBE and Eleanor Palmer at the North West Museums Service Conservation Department (NWMS) between 1987 and 1992. The NWMS was previously based at Griffin Lodge in Blackburn, Lancashire and provided conservation services to museums and art galleries throughout the North West of England. The second dalmatic in the Burrell Collection was last treated to go on long-term display in 1983 by Shelia Phipps, who worked in the conservation studios at the Burrell Collection. The altar frontal was not conserved with the rest of the vestments at Towneley Hall because it was considered less important. Advancements in digital photography allowed closer access to the embroideries on the altar frontal which revealed their detail and rarity, hence the significance of the altar frontal increased. The curator acknowledged the altar frontal was not stable enough to go back on display and was in need of conservation work. The Whalley Abbey altar frontal was conserved at the Textile Conservation Centre, University of Southampton, in 2009 by the author.



Figure 2 (left). The Whalley Abbey chasuble and maniple on long-term display, Towneley Hall. 2009. Figure 3 (right). The Whalley Abbey dalmatic on long-term display at Towneley Hall. 2009. Courtesy of the Towneley Hall Art Gallery and Museum, Burnley Borough Council, UK.

### 3. COMPARATIVE APPROACHES: THE CONSERVATION OF THE WHALLEY ABBEY VESTMENTS AND THE WHALLEY ABBEY ALTAR FRONTAL

Around twenty years had elapsed since the Whalley Abbey vestments were conserved and much has been learned in those years. Preserving textiles in the UK in the 1980s seemed to involve an aim for beauty and originality. For instance, cleaning textile objects helped to restore their original appearance and aesthetic appeal. Textiles requiring further stabilization such as the Whalley Abbey vestments were routinely subject to cleaning in order to achieve this aim. The vestments were separated into their component parts to allow cleaning and support. Comprehensive documentation and photography were used during the dismantling process to help with later reassembly (Glover 1992a; Glover 1992b). In the period of conserving the vestments the profession of

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textile conservation was still establishing itself and the growing profession was still reliant on the experience of pioneers, including Jean Glover. Glover established the Textile Conservation Department at the NWMS in 1968 after leaving her previous profession as a home economics teacher (Lochhead and Eastop 1993). During her professional life, Glover acknowledged the value that stains may have for historians, however, “in general it is preferable that textiles should be cleaned” (Glover 1986, 49). Perhaps it was Glover’s previous domestic science background that provided the platform for her contribution to establishing textile conservation as a profession in its own right.

In contrast to the vestments, all the components were regarded as a single entity when considering the treatment of the altar frontal. It was accepted that the point of historical significance was when the altar frontal was put together. The wooden board was removed because of the potential by-products being produced by the wood which, if left in-situ, would encourage future deterioration of the textile fibers. This procedure allowed more information to be released about the altar frontal by revealing extended lengths of the orphreys and exposing the blue linen lining beneath them. The undyed linen backing attached to the reverse side of the altar frontal showed signs of previous use that was not reminiscent of an object on static display. Examining the photograph taken of the altar frontal in 1922 when it was sold at auction revealed the linen backing was not attached to the object, hence, it was only used to facilitate the framing process during the object’s transition into a museum piece. Therefore, the backing was removed as it was a relatively recent addition. Full documentation took place when the wooden board and linen backing were removed to help preserve this aspect of the object’s working life.

### 3.1 CLEANING

The altar frontal was not immersed for wet-cleaning or solvent cleaning in any way due to a greater understanding of the effects of the differential swelling and shrinkage rates of the various fibers, the brittle condition of the floss silks on the orphreys, and minimal staining which did not warrant such treatment. Surface cleaning and spot cleaning on a customized suction table, in small areas of the crimson silk using only de-ionized water, were the only procedures used to clean the altar frontal (Tonkin 2009) (fig. 4).

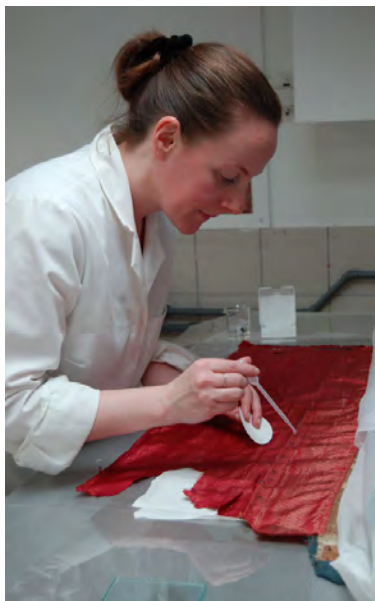


Figure 4. Spot cleaning the Whalley Abbey altar frontal on a customized suction table using only de-ionized water. 2009. Courtesy of the TCC, UK.

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On the other hand, cleaning was a major part of the treatment procedure of the vestments, apart from the dalmatic in the Burrell Collection which received very little treatment due perhaps to its better condition. With reference to the vestments at Towneley Hall, Glover and Palmer solved the problem of differential reactions to treatments by dismantling and thinking about each element separately (fig. 5).



Figure 5. The dismantling of the Whalley Abbey dalmatic during treatment at the North West Museums Service, Blackburn, Lancashire. 1987-1992. Courtesy of Lancashire Conservation Studios, Lancashire County Council, UK.

The various textile components that made up the vestments were separated according to their fiber type and type of staining, and they were cleaned and supported accordingly, before being reassembled. Developments in ethical considerations, such as the varying context and future role of the object, and more advanced techniques for supporting textiles and expanding interpretation have encouraged a more hands-off approach so the object retains much of its physical integrity (Clavir 1998). The emphasis on cleaning the textile to look newer or fresher has become less important, although this remains an added bonus if achieved after treatment. Eleanor Palmer reflected on what she would do differently if she were to treat the dalmatic at Towneley Hall again.

...I think, possibly, I would, really, just do more surface cleaning and vacuuming...The washing I'm not sure about; solvent-dry cleaning I'm not sure about now. I'm tending towards the hands off....that's my personal view. That's the way I would be going...such a lot of information can be gleaned from the original that...once you take away the dirt, then...you're taking away evidence, really... (Palmer 2008).

Apart from the ethical considerations, much more is known about the physical effects of cleaning textiles with metal threads. The inherent fragility of their manufacture, combined with the presence of the organic core and surrounding fabric make wet-cleaning a difficult process if not impossible (Garside 2002; Berkouwer 2002). Removing corrosion from the metal threads is rarely undertaken due to the risks of damaging the metal layer (Rogerson and Garside 2006) and the reoccurrence of corrosion causing further loss of metal. Ecclesiastical textiles are rarely wet-cleaned, although there are case studies which have overcome this dilemma (Matteini *et al* 1999).

### 3.2 DECISIONS TO CLEAN AND NOT TO CLEAN: ANALYSING THE METAL THREADS

No fiber analysis was completed on the vestments. However, analytical testing using scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) was conducted on several samples from the altar frontal to make further observations that were not achievable using light microscopy techniques. SEM allowed a more detailed examination of regions of interest, including areas of corrosion, and EDS provided information on the composition of the metal components and corrosion products. The combined analytical techniques allowed the threads to be further characterized while reinforcing the reasons why wet-cleaning and solvent cleaning were not carried out.

The SEM-EDS analysis revealed that there was silver, gold, and copper content in the make-up of the metal filaments. The analysis also highlighted the unusual triple wound joins which occur along the length of the metal threads used to embroider the cross orphrey (fig. 6). Significant tarnishing is noticeable in these areas, which suggests the construction of the triple wound join is causing increased oxidization of the alloy composition of the metal filaments, creating a layer of corrosion of similar thickness to the metal filament. The triple wound joins seem to be trapping extra moisture from the atmosphere between each layer of the filaments and when combined with oxygen is significantly increasing corrosion in these areas (Garside 2002) (fig. 7).

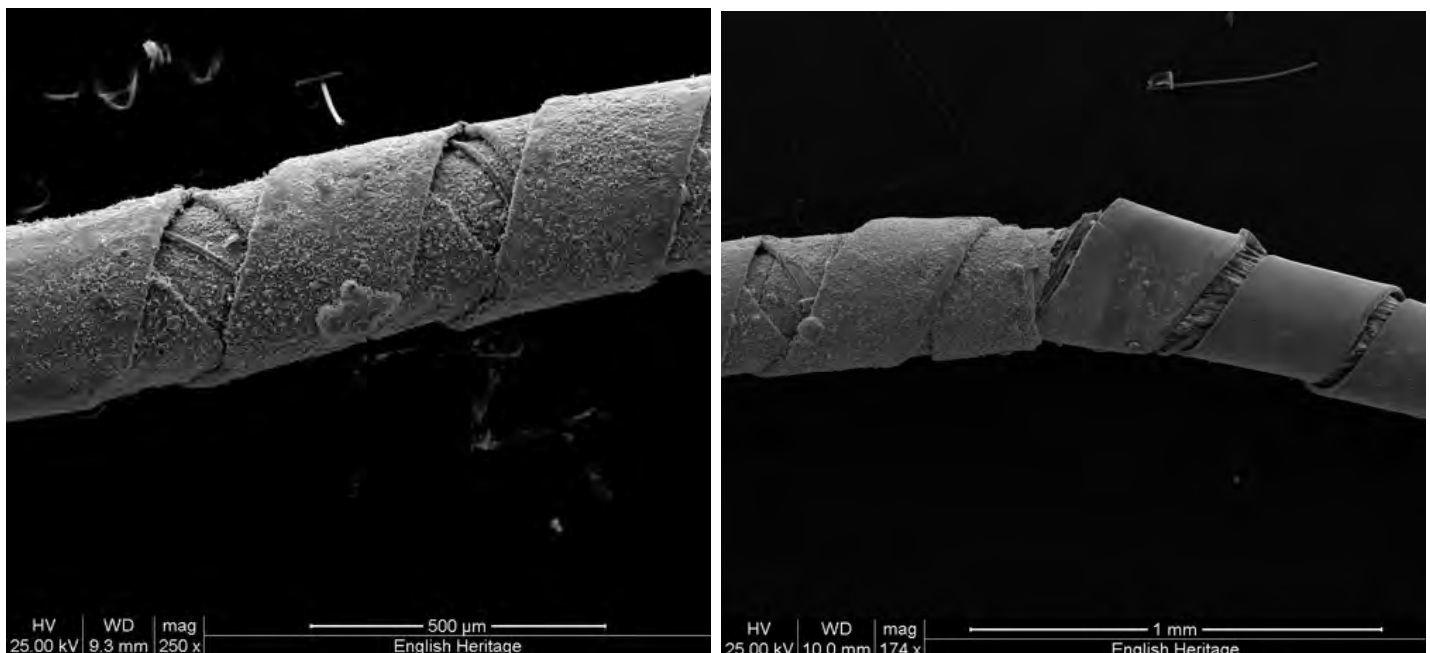


Figure 6 (left). Sample of the triple wound metal thread and enhanced corrosion taken from the background of the center cross orphrey on the altar frontal. Figure 7 (right). Sample of the triple wound metal thread where it joins the rest of the thread. The enhanced corrosion can be seen where the metal filament is triple wound in comparison to the better condition of the rest of the thread. The samples were examined on a scanning electron microscope, model: *FEI INSPECT F*. 2009.

An exposed area of the metal filament appeared to be in reasonable condition, implying that the corrosion layer was protecting the original metal filament to a certain extent (fig. 8). The analysis of the triple wound joins on the metal threads revealed an unusual ‘Z’ spun characteristic of the central metal filament when usually metal threads are ‘S’ spun. These areas showed a much lower content of gold and silver and high contents of corrosion products, for instance, silver sulfide. The less corroded areas showed an increased presence of gold and silver and a much lower presence of corrosion products. Hence, even if cleaning was possible, it is the inherent



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manufacture of the threads that have caused this severe corrosion, thus, there are no guarantees that the corrosion will not reoccur in the future. The analysis also revealed the vulnerability of the surface of the metal threads (fig. 9).

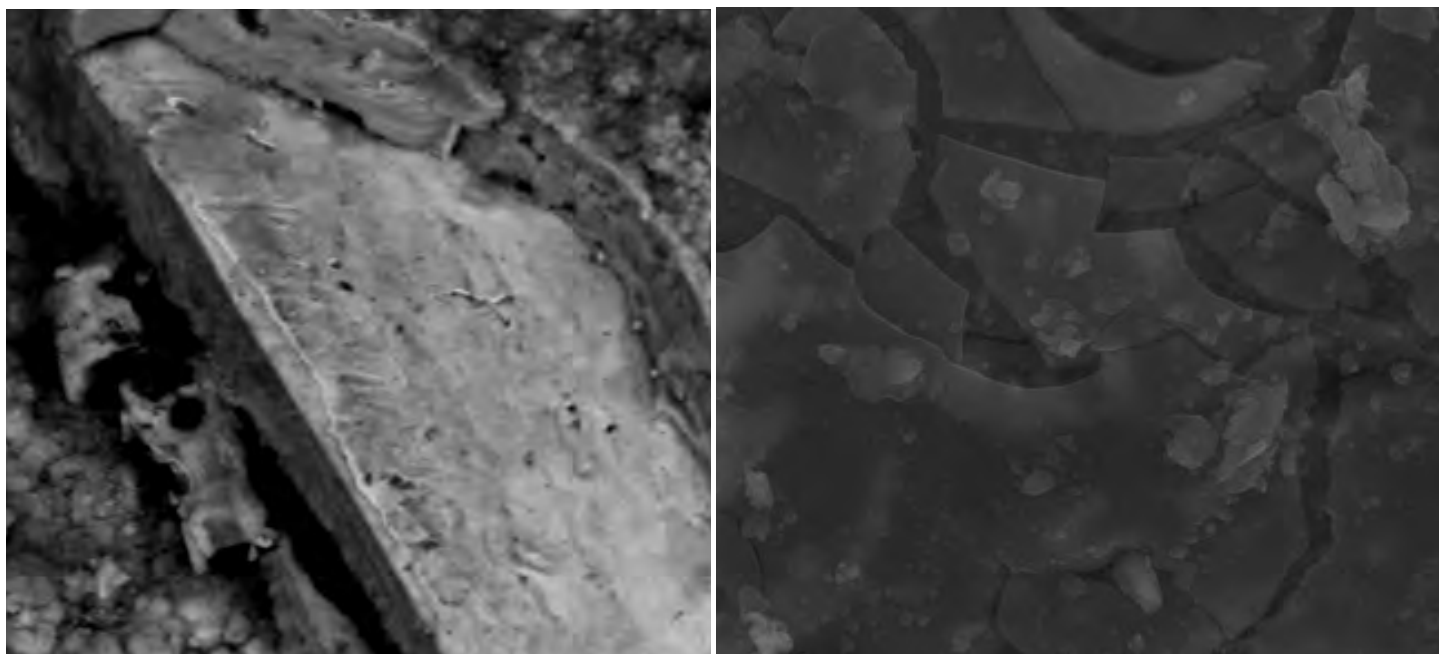


Figure 8 (left). Detail of triple wound metal thread in figures 5 and 6, showing an exposed area of the metal thread and the thickness of the corrosion layer. Figure 9 (right). Detail of the surface of the metal thread taken from the center cross orphrey from the Whalley Abbey altar frontal. The samples were examined on a scanning electron microscope, model: *FEI INSPECT F*, 2009.

Wet-cleaning or solvent cleaning would have, potentially, removed some of the surface of the metal filament which would have resulted in losing evidence and encouraged further corrosion to the exposed areas, hence hindering the long-term preservation of the orphreys. The images produced from the SEM-EDS analysis, when compared with each other, explain how the metal threads may deteriorate at different rates despite belonging to the same object and so the level of deterioration cannot be characterized at any one time.

In contrast to the decisions for not cleaning the altar frontal, many of the separate components of the vestments, including the cloth of gold, were wet-cleaned by immersion. The silver braids from the chasuble and maniple were further cleaned by using a non-aqueous organic solvent. “Silver Dip”, a tarnish remover, was used on some braiding which had been removed from the chasuble to help reduce the corrosion which had formed on the surface of the silver metal thread. According to the maniple report, silver braids were later painted with an acrylic lacquer to prevent further tarnishing. From a visitor’s perspective this procedure seems to have been successful as there is no visual evidence that the corrosion has re-occurred. The wet-cleaning and solvent cleaning stages of treatment and de-tarnishing of the metal threads and braids on the vestments at Towneley Hall were considered a revelation. Their improved appearance confirmed they were made from a more precious metal than previously anticipated, increasing their interpretation. This improvement in appearance was considered important and successful at the time of treatment. The development and more accessible use of analytical research in both practice and publications since the treatment of the vestments has allowed the textile conservator to become more informed concerning the short and long-term effects of treating textiles with metal threads.

### 3.3 LOCALIZED CONTACT HUMIDIFICATION

Localized contact humidification using blotting paper dampened with de-ionized water and “Sympatex”, a breathable membrane, as the barrier was conducted on the altar frontal to help reduce the bulk and tension caused by the crumpled blue linen lining beneath the orphreys. A polyethylene sheet and glass weights were used to help raise humidity levels to the areas being treated. The period of humidification was restricted to no longer than one hour to prevent water marks occurring on the crimson silk. Custom-made “Melinex” barriers were used to help protect the embroidered orphreys from moisture uptake when humidifying the blue linen lining as moisture absorption can adversely affect the flossy silks and metal threads (fig. 10). Most of the sharp creases were relaxed in the crimson silk, and the edges of the blue linen lining became less crumpled which enabled good support stitching. The humidification process was an intricate operation as a result of treating the altar frontal as a single entity.



Figure 10. Localized contact humidification of the blue linen lining behind the orphreys. 2009. Courtesy of the TCC, UK.

### 3.4 TO KEEP AND NOT TO KEEP: ORIGINAL STITCHING AND OLD REPAIRS

The original stitching and old repairs on the altar frontal were left in-situ and were not disturbed to facilitate treatment as they were not harming or causing unnecessary tension to the surrounding textile (fig. 11). The old repairs were also considered to be an integral part of the object’s history. On the other hand, repair threads were removed from the vestments, including the dalmatic in the Burrell Collection, and original stitching cut to help treat the vestments at Towneley Hall. The most obvious treatment on the dalmatic in the Burrell Collection are the cuts in the blue linen lining at the underarm and lower back hem areas where the lining was tight and causing distortion to the cloth of gold. Unpicking original threads from a textile to facilitate treatment may still be necessary under today’s ethics. For instance, the dalmatic in the Burrell Collection, if conserved today, may

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warrant some of the original stitching being released to reduce the tightness of the lining which caused the dalmatic to be distorted. Slashing the blue linen lining has permanently damaged the textile artifact and has left the underside of the cloth of gold unprotected in these areas. However, it was interesting to note when examining the dalmatic that more historical evidence has been preserved because of the limited treatment it received. The stitching and physical elements of the cloth of gold and other composite trims have been untouched allowing a more complete view of the construction of the dalmatic when it was last used.



Figure 11. Old repairs on the embroidered orphreys from the altar frontal. 2009. Courtesy of the TCC, UK.

### 3.5 SUPPORT

The Towneley Hall vestments were supported using similar stitching techniques to those used to support the altar frontal. The only differences were the types of threads and support fabrics used and these can change with technological development, different suppliers, and differences in preference. Hence, there were some common practices in treatments between the vestments and the altar frontal.

A thermoplastic adhesive was used to treat many elements on the vestments. Adhesive support was not a consideration within the decision-making process of treating the altar frontal, perhaps due to its better condition. Adhesive support seemed to be a common formula in treating many textiles in the 1980s and the choice of adhesive was very limited. Extensive testing would be encouraged nowadays using various types of adhesives that are currently available. The final selection of an adhesive would bear in mind the effects of the adhesion, drape, texture, and appearance. More choice in conservation materials and, again, more published articles relating to the treatment of case studies have widened the possibilities and knowledge of the conservator, making the decision to use adhesives a less formulaic one. Perhaps other ways may have been sought to support the weak areas on the vestments if they were conserved today.

### 3.6 MOUNTING

The altar frontal was mounted on 8mm thick “Cellite” fiber panel, a composite rigid aluminum honeycomb board; this was similar to the board used to mount the vestments (fig. 12). The color of the fabric used to cover the mount board reflected the cream colored fabric used on the mounts for the other vestments at Towneley Hall to maintain their association with one another and to provide aesthetic continuity.





Figure 12. The Whalley Abbey Altar Frontal after treatment. 2009. Courtesy of the TCC, UK.

#### 4. THE EFFECTS OF THE DIFFERENT TREATMENTS ON THE VIEWING EXPERIENCE OF THE WHALLEY ABBEY TEXTILES AT TOWNELEY HALL

The areas of loss and weakness are more obvious on the altar frontal than they are on the vestments (fig. 13). The blue linen lining beneath the orphreys on the altar frontal is noticeable and no attempt has been made to neaten them or conceal them as this represents the original manufacture of the orphreys and provides signs of their previous history and use (fig. 14). These areas are perhaps the most striking difference when viewing the vestments and the altar frontal as final display objects. Areas of deterioration are less obvious on the vestments



Figure 13 (left). Detail showing areas of loss and weakness on the embroidered orphreys on the Whalley Abbey altar frontal after treatment. Figure 14 (right). Detail showing the blue linen lining beneath the embroidered orphreys on the Whalley Abbey altar frontal after treatment. 2009. Courtesy of the TCC, UK.

due to the conservation they have undergone, whereas the conservation on the altar frontal reveals previously hidden elements such as the extensions of the orphreys once the altar frontal was released from the wooden board. The effect of exposing these elements means that more stories are revealed about the object. For instance, the areas of loss in the orphreys and crimson silk illustrate the period when the altar frontal first became



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an exhibition piece and the crudeness with which textile artifacts were treated to accommodate these needs in the early 20<sup>th</sup> century. The blue linen lining explains to the viewer how these orphreys were constructed and the irregular seams and patterns of deterioration on the crimson silk provide an insight into the re-usable nature of ecclesiastical textiles. The acceptance of old repairs helps document the value of ecclesiastical textiles as they have been handed down over the centuries. The repairs also reiterate initial preservation techniques to recapture the essence of the biblical scenes. These multiple histories can be deciphered and submerged into the viewing experience when looking at the altar frontal, opening up interpretation, today and for the future, whereas these elements are somewhat concealed in the vestments.

### 5. CONCLUSIONS

The aims of improving the appearance and stabilizing the object were shared when thinking about the altar frontal and the treatment of the vestments, however the objectives were different. Aesthetic considerations were far more important for the vestments at Towneley Hall than they were for the altar frontal, illustrating previous conservation requirements which aimed to make a textile as attractive as possible while on display (Finch 1985).

Despite the understandable differences in the conservation approaches of the Whalley Abbey textiles, all the stages of conservation work were and are considered successful. However, the outcomes from the treatment on the altar frontal when compared to the vestments at Towneley Hall clearly indicate developments which have occurred within the ethics of textile conservation. The conservation of the vestments seemed to follow a more formulaic methodology which was consistent in treating many textiles at that time, whereas the conservation of the altar frontal addressed the present and future context of the textile artifact as well as the object itself. The considerations surrounding the conservation of the altar frontal revealed more information about the textile, including its ecclesiastical importance as an altar frontal, which was most likely used in the chapel at Towneley Hall. The varying levels of interventionary treatment carried out on the Whalley Abbey vestments and Whalley Abbey altar frontal indicate that priorities have changed in the way textile artifacts are viewed and appreciated by both the textile conservator and the viewer.

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END NOTES

<sup>1</sup> 'English work', embroidery typical of the late medieval period which was almost always professional work. The height of manufacture in England was 1250-1350.

<sup>2</sup> The term *High Mass vestments* are referred to within the framework of the Roman Catholic Church in Western Europe where matching vestments are worn by the priest and deacons to celebrate High Mass.

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### SOURCES OF MATERIAL

Sympatex  
Preservation Equipment Ltd  
Vinces Road  
Diss  
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# THE EFFECTS OF LONG TERM DISPLAY ON PREVIOUS TREATMENTS

ABBY ZOLDOWSKI

**ABSTRACT** – In 2009 two early nineteenth-century trapunto bedcovers from Schuyler Mansion State Historic Site in Albany, NY were removed from display for a long overdue treatment and “rest”. This gave the textile conservators at Peebles Island a chance to revisit the past treatments performed on the bedcovers and to determine how well they withstood long term display. Between 1976 and 2009, the two bedcovers had a total of three treatments each. This paper will give a brief description of the treatments and evaluate the success or failure of each when faced with long term display.

## LOS EFECTOS DE LA EXHIBICIÓN PROLONGADA EN TRATAMIENTOS ANTERIORES: RESUMEN

– En 2009 dos edredones de trapunto de inicios del siglo diecinueve de Schuyler Mansion State Historic Site en Albany, NY fueron quitados de exhibición para recibir un largo y atrasado tratamiento y “descanso”. Esto brindó a los conservadores de tejidos de Peebles Island la posibilidad de revisar tratamientos anteriores que recibieron los edredones y determinar cómo resistirán la exhibición prolongada. Entre 1976 y 2009, los dos edredones recibieron un total de tres tratamientos cada uno. Este ensayo brindará una breve descripción de los tratamientos y evaluará el éxito o fracaso de cada uno de ellos al enfrentar una exhibición prolongada.

## 1. INTRODUCTION

Schuyler Mansion State Historic Site in Albany, NY was the residence of Revolutionary War General and US Senator Philip J. Schuyler. The house is a late 18<sup>th</sup> century Georgian style home, which was occupied by the Schuyler family between 1763-1804. The house changed ownership several times before the state acquired it in 1911 (fig. 1).



Figure 1. Interior view of bedroom with bedcover on historic bed.  
Courtesy NYS OPRHP Schuyler Mansion State Historic Site.

In 2009 two early nineteenth-century trapunto bedcovers were removed from display in the Schuler Mansion where they had been on view for more than thirty years. The removal of the bedcovers gave the textile conservators at Peebles Island a chance to examine past treatments performed on the bedcovers and to determine how well the bedcovers and the previous conservation treatments withstood long term display.

The bedcovers are comprised of two layers, a fine woven plain weave cotton face fabric and a more coarsely

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woven back fabric. The trapunto work is created by inserting cotton stuffing and stitching to form a design. The face and back fabrics are held together with finely woven decorative edging tape, 5/8" wide, which is folded to form a 5/16" band around the perimeter and hand stitched. The face fabric of both bedcovers has two vertical seams that join three pieces of fabric. The back fabric of bedcover #1 has three vertical seams that join four pieces of fabric. Bedcover #2 has an additional flap that has two vertical seams that join three pieces of fabric on the face and the back of the flap one vertical seams that joins two pieces of fabric. All the seams are hand-sewn with cotton thread in a whip stitch.

### 2. BEDCOVER #1 SM.1973.237

#### 2.1 TREATMENT #1 1976

##### 2.1.1 CONDITION

The bedcover was described in 1976 by Textile Conservator Karen Clark in a Survey Report as being in a "very weakened state." Oxidation discoloration and overall staining was visible throughout the piece. The bedcover was reported as being "in rotting condition with excessive losses and breaks." The backing material was improperly identified as linen (fig. 2).

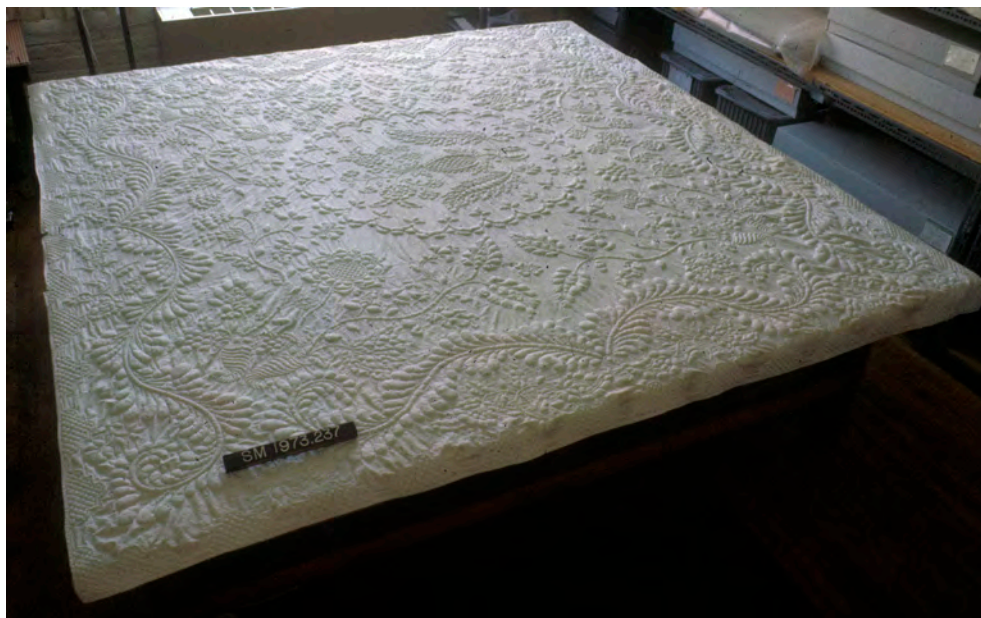


Figure 2. After treatment of SM 1973.237 taken in 1976. Courtesy NYS OPRHP Schuyler Mansion State Historic Site.

##### 2.1.2 TREATMENT PERFORMED

The Laboratory Treatment Report prepared by Clark in 1976 indicated that the treatment included an overnight soak in sodium perborate followed by wet cleaning, extensive rinses, and extraction. It was covered with cheesecloth and air dried. A recent email conversation with the conservator at the time gave no further explanation for the term "extraction", when looking back at some of the treatment reports from the 70's this term is used often but never explained. The current Textile conservator, Deborah Trupin, believes "extraction" is not used to describe the process of taking the piece out of the bath but could possibly refer to the use of a dry cleaning machine. It was rolled on a Permalife™ tube covered with glassine on covered tables.

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### 2.1.3 OUTCOME

The conservation staff did request that the bedcover be taken off display and placed in storage. There is no documentation on the outcome of this treatment and no notes on how the already weak fibers responded to the cleaning. It is assumed that the bleaching treatment reduced the overall yellowing and contributed to further weakness of the fibers. Unfortunately after wet cleaning, the bedcover was returned to the site and placed on display on a historic bed until 1982.

### 2.2 TREATMENT #2 1982-1984

In 1982 this bedcover returned to Peebles Island for examination and treatment. The 1982 Survey Report prepared by Textile Conservator Vicky Kruckeberg noted that the bedcover was “too large for the bed and must be turned under at the edges to fit.” It was noted in this report that the backing was indeed cotton and not linen as previously reported.

#### 2.2.1 CONDITION

Six years after the first treatment the bedcover was described in the condition report as weak and brittle. The piece was yellowed and contained stains. Losses were considered moderate in the cotton filling (fig. 3).



Figure 3. Before treatment of SM 1973.237 in 1982. Courtesy NYS OPRHP Schuyler Mansion State Historic Site.

#### 2.2.2 TREATMENT PERFORMED

According to the Conservation Treatment Log prepared by Kruckeberg in 1982-1984 the proposed treatment was to wet clean and cover the face of the bedcover with a crêpe line. It was hoped by the conservation staff that



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this overlay treatment would “prevent any new tears from occurring.” The conservator mentions that the piece needs to be wet cleaned before the overlay is in place “since the crêpeline will act as a barrier in releasing detergent and soils.”

The 1982 treatment began with a wet cleaning in two baths of deionized water and a 0.5% solution of Orvus followed by several rinses (fig. 4). The bedcover was air dried with no drying cloth. Once dry, the face of the bedcover was covered with crêpeline. Large basting stitches of cotton thread were used to hold the overlay in place. These were removed and replaced with smaller stitches of thread pulled from crêpeline. Small basting stitches of cotton thread were used around the stuffed elements. The entire stitching treatment was supervised by the textile conservator but executed by two volunteers, working one day a week. The whole stitching process took about two years.



Figure 4. During treatment photo of wet cleaning SM 1973.237 in 1982.  
Courtesy NYS OPRHP Schuyler Mansion State Historic Site.

Once the stitching was completed the conservator wanted to wet cleaned the bedcover one more time to “remove body oils that had accumulated” during the treatment. It was soaked in deionized water and a .5% solution of Orvus and rinsed several times. Again no drying cloth was used when air dried.

The conservation treatment logs indicated that after the second wet cleaning several small new areas of damage appeared. These were repaired using small stitches of threads pulled from crêpeline through the overlay and the bedcover, in rows about three inches apart. The piece was then returned to the site for display on a historic bed.

### 2.3 TREATMENT #3 2009

In 2009 this bedcover was again taken off display and brought to Peebles Island for evaluation and treatment.

#### 2.3.1 CONDITION

The crêpeline overlay was weak, degraded and prone to tearing when handled. The breakdown of the crêpeline overlay may have been enhanced due to exposure to light. It is in the recent past that the shutters were used to keep the sunlight out of the room. The overlay appeared to be too small for the surface of the bedcover, and was causing further distortion to the face fabric. Many of the threads used to secure the crêpeline were releasing and



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pulling through the overlay fabric (fig. 5).

The face fabric was weakened overall and somewhat brittle. The weave structure appeared thin overall, especially in the areas that were stuffed. The surface was severely, but unevenly, discolored and stained. The face fabric was very tight in stuffed areas, while the fabric between the stuffed areas was loose and puckering. The three previous wet cleanings may have caused tension changes within the cotton fabric.

The face fabric had scattered small tears and holes (fig. 6), ranging from 1/8" to 1/2" in diameter. These could be seen through the crêpeline overlay; either they were not addressed at the time of the overlay or were new.



Figure 5 (left). Before treatment photo of SM 1973.237 taken in 2009. Figure 6 (right). Detail photo of holes created from the crêpeline overlay treatment of SM 1973.237 in 1982. Courtesy NYS OPRHP Schuyler Mansion State Historic Site.

### 2.3.2 TREATMENT PERFORMED

The first step in the 2009 treatment began with the removal of the crêpeline overlay by clipping the stitches from the reverse and gently pulling the threads. The cotton stitches around the stuffed areas were easily seen and quickly removed, the crêpeline stitches, on the other hand, were much more difficult to see and remove. As the stitches were removed and the crêpeline overlay peeled back, numerous small holes and tears were discovered. It became apparent at this point that the piece was completely and unnecessarily overstitched and could not withstand any further stitching. The conservators had originally proposed a treatment step of isolated protective overlays in the areas of loss and weakness, but once the extent of the damage from the previous treatment was evaluated, it was decided that this portion of the treatment would only further damage the fabric and so it was not performed.

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Wet cleaning was preformed to bring the pH levels close to neutral, to help reduce the brittleness of the fibers, and possibly to lessen the discoloration. Testing indicated that water might reduce discoloration somewhat, but that use of detergent would not increase this reduction, so it was not used. A 135" square tank of 2x4 boards and 2 layers of 10-mil polyethylene plastic sheeting was assembled. The softened, filtered water was tested and the water conditions were as desired for wet cleaning. The pH of the bottom corner of the bedcover was re-measured at 5.1 in the stuffed area and 4.8 in the unstuffed. A Basic pH Meter by Denver Instrument Company was used to measure the pH levels.

Munsell color chips were used to give a range of the discoloration of the bedcover before cleaning. Since the bedcover had many different shades of discoloration, three locations were used that best represented the color ranges. The locations were marked on pieces of Mylar so the same location could be measured after treatment.

The bedcover was unrolled, face side up, onto a mesh screen that was supported by PVC pipes in the tank. A top mesh screen, also with a PVC pipe frame, was placed on the over the bedcover and locked into place. The two screens were then stitched around the perimeter of the bedcover to minimize any movement of the bed cover during wet cleaning.

The tank was filled with water. The bedcover was observed closely as it got wet; it absorbed the water quickly. The initial bath showed visible yellowing after 15 minutes. The first bath was drained about 30 minutes after filling began. After the second rinse and bath no yellowing appeared in the tank. The samples taken also indicated that the pH level between the two baths did not change. At this point it was determined that the introduction of detergent would not help remove any of the discoloration.

A tube was rolled under the plastic forming the tank to help push the water to one location of the tank as sump pumps removed the water. The stitches holding the screens were clipped and removed and the top screen was carefully lifted. The bedcover was blotted twice with terry cloth towels, aligned and covered with cotton drying cloths. The drying cloths were left on throughout the drying process to prevent any discoloration products from staining the bedcover. The bedcover and bottom screen were then placed on buckets so the air could circulate on both sides as it dried (fig. 7).



Figure 7. Screen and bedcover placed on buckets after wet cleaning in 2009, SM 1973.237. Courtesy NYS OPRHP Schuyler Mansion State Historic Site.

## THE EFFECTS OF LONG TERM DISPLAY ON PREVIOUS TREATMENTS

### 2.3.3 OUTCOME

The drying cloths appeared to have wicked up a good amount of discoloration, but more was expected (fig. 8). Color comparisons using Munsell chips before and after wet cleaning in the same locations on the face of the bedcover documented the changes as a result of cleaning (fig. 9). The results indicate that the bedcover overall is lighter and less discolored.



Figure 8 (left). Detail photo of stains that remained after 2009 wet cleaning of SM 1973.237. Figure 9 (right). Gretechen Guidess and Abby Zoldowski using the Muncell color chips to evaluate the change of discoloration that occurred after wet cleaning in 2009, SM 1973.237. Courtesy NYS OPRHP Schuyler Mansion State Historic Site.

After wet cleaning, the bedcover had a softer hand and was not as brittle to the touch. The pH was measured again. The overall appearance was only slightly brighter in the light areas and darker areas of previous discoloration lightened only a modest amount. There was faint puckering between the stuffed and un-stuffed areas, much of that was present before the wet cleaning. The bedcover was temporally rolled on a tube and placed in storage.

Due to the fragile state of the bedcover and the damage that has occurred while on display for many years it was previously recommended that the bedcover be removed from display and allowed to “rest”. Once the crêpine overlay was removed and the extent of the damage was assessed it was determined that the damage to the bedcover was far more severe than previously thought.

The extensive amount of discoloration and severe brittleness from light damage that had occurred from 1982 to 2009 will only continue if the bedcover were to return to display. Because this bedcover was on display for almost 30 years, it was recommended that it be rolled on a padded tube and placed into long term storage. Only short periods of display are recommended in the future and this should only be considered after a period of rest. Because of its fragility, if the bedcover is displayed in the future, it should be displayed flat or on a slight angle, on a fabric-covered support, protected by a case. Display on a bed or hanging display is not

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recommended.

### 3. BEDCOVER #2 SM. 1973.303

#### 3.1 TREATMENT #1 1976

##### 3.1.1 CONDITION

A condition survey conducted in 1976 by Clark lists the face fabric as in fair to poor condition. It is described as “extremely weakened” and “tender.” Losses were reported in several areas but they were noted as being small. The report mentions that some of this loss “is due to stains eating away at the fibers.”

Discoloration from age and sunlight was evident and the oxidation on the right side of the bedcover was noted. The back or as the report calls it the “linen side” was described as in “worse condition” with excessive stains and sun damage.

##### 3.1.2 TREATMENT PERFORMED

The Laboratory treatment report prepared by Clark in 1976 indicated that the treatment included two clear rinses, the application of sodium perborate bleach from 12:00 pm to 8:30 am, followed by five clear rinses, an acetic acid rinse, extraction, air drying with cheese cloth, and finally, rolling on a Permalife™ tube for return to the Schuyler Mansion.

##### 3.1.2 OUTCOME

There is no indication in the treatment records on the outcome of the bleaching treatment. It can only be assumed that the bleach helped to reduce the discoloration, but probably did not reduce the severely dark areas. It can also be assumed that the bleaching treatment was not favorable to the already weakened fibers.

#### 3.2 TREATMENT #2 1990

The piece was on continuous display from 1976 to 1990 when it was brought back to Peebles Island for treatment. The treatment approach was slightly different than that of bedcover #1 (the 1982 treatment). The piece was examined and treated by then intern Gwen Spicer, and supervised by Deborah Trupin.

##### 3.2.1 CONDITION

Spicer described the overall condition as fair to poor. The fabric was worn, fragile and weak from use and light exposure. Stuffed areas were of particular concern, as they appeared ready to break or split. Numerous scattered small losses were detected throughout the surface and several larger losses and splits were noted.

The fabric was “unevenly discolored to a yellowish brownish color” with the worst area at the proper right side and the bottom flap. Whiter areas located between the stuffed areas are noted within the dark discolorations, which may have been caused by improper drying after the last wet cleaning.



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The fabric was puckered and rippled from tension changes from the previous wet cleaning. Fabric in the stuffed areas is very taut while there is excess fabric in unstuffed sections. At this time it was noted again that the bedcover was extremely fragile and recommended it should only be displayed for a year and retired to storage.

### 3.2.2 TREATMENT PERFORMED

Before treatment the bedcover measured a very acidic pH level of 4.3-4.5. Wet cleaning was performed to bring the pH levels close to neutral, to help reduce the brittleness of the fibers, and possibly to lessen the discoloration. The bedcover was cleaned with water; detergent was not added to any of the baths because it was felt that any extra baths that would be needed to rinse out all the detergent would be more damaging to the already weakened fibers. The first bath resulted in a considerable amount of discoloration being removed. The bedcover was rinsed and drained three times and wet cleaning was ceased when the water's pH reading reached a 7.1. The bedcover was covered with a cotton sheet, blotted dry with towels and left to dry. Once dry the broken stitch lines were repaired, the loose stuffing was eased back into position and stitched with a single strand of DMC cotton floss. In two locations the stuffing had migrated from the design area, and it was not possible to reinsert the stuffing.

Patches to support the torn stuffed areas were made of white Stabiltex. The Stabiltex was stretched on a sheet of glass with the warps and wefts aligned. The Stabiltex was cut with a hot knife following the Mylar pattern that mimicked the areas of damage. The patches were attached to the bedcover with a single thread of DMC cotton floss, following the original stitch holes. Patches for the unstuffed areas were secured by inserting a cotton fabric patch between the two layers of the bedcover (figs. 10, 11).

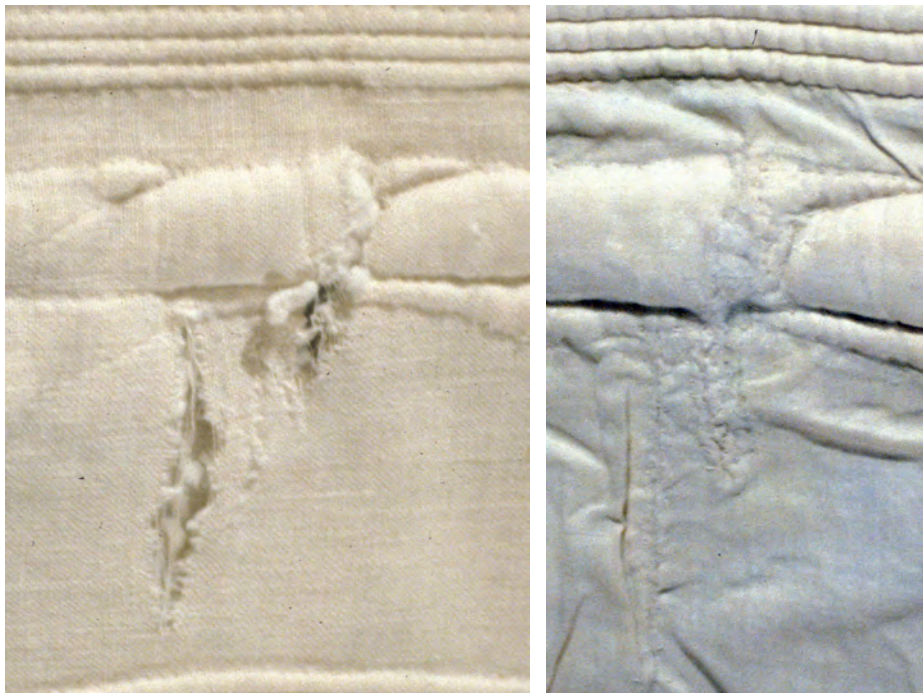


Figure 10 (left). Detail photo of tear before 1990 treatment of SM 1973.303. Figure 11 (right). Detail photo of tear after 1990 treatment of SM 1973.303. Courtesy NYS OPRHP Schuylar Mansion State Historic Site.

These patches were secured with rows of couching stitches, using silk threads. In the areas where the slit was on

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both the top of the bedcover and on the reverse, a second fabric patch was inserted on the reverse and couched down.

### 3.2.3 OUTCOME

The treatment did lighten the bedcover overall, but the yellow discoloration was still present. At this time it was noted again that the bedcover was extremely fragile and recommended it should only be displayed for a year and retired to storage. It was returned to the site and placed on display for nineteen years.

## 3.3 TREATMENT #3 2009

### 3.3.1 CONDITION

The face was severely discolored and brittle, all due to light damage while on display. The fabric was unevenly discolored with spots that appear whiter; this may be due to an uneven drying process from the two previous wet cleaning treatments. The fabric was weak and thin overall but especially in the areas that are stuffed. In the stuffed areas the fabric was very tight, while the fabric between the stuffed areas was loose and puckering. The previous wet cleanings may have caused tension changes within the cotton fabric. These tight areas appear to be vulnerable and could be easily damaged over time. This bedcover did have a few tears and holes, about 27-30 total, most of which happened after the 1990 treatment. There was only one place where the previous treatment seemed to fail; a tear has extended slightly above the overlay.

### 3.3.2 TREATMENT

The bedcover was wet cleaned in the same manner as the first bedcover (refer to Section 2.3.2).

### 3.3.3 OUTCOME

The initial introduction of water indicated that a good amount of the discoloration was being removed. After the second rinse and bath, no yellowing appeared in the tank. The samples taken also indicated that the pH level between the two baths did not change a great deal. At this point it was determined that the introduction of detergent would not help remove any of the discoloration. The pH of the bedcover before cleaning was measured at 7.72 in the stuffed areas and 8.02 in the unstuffed (part of this pH reading may have been effected by the screen below) at the end of the wet cleaning. The final pH of the bedcover once dried was 7.51 in the stuffed areas and 6.99 in the unstuffed.

The drying cloths appeared to have wicked up a good amount of discoloration, but more was expected. Color comparisons using Munsell chips before and after wet cleaning in the same locations on the face of the bedcover documented the changes as a result of cleaning. The results indicate that the bedcover overall is lighter and less discolored. After wet cleaning, the bedcover had a softer hand and was not as brittle to the touch. The overall appearance was only slightly brighter and there was faint puckering between the stuffed and un-stuffed areas, which was present before the wet cleaning (fig. 12). Since the Curatorial staff and the site staff had already agreed to take both bedcovers off display, the stabilization phase of the treatment did not occur and instead the bedcover was immediately rolled and placed in storage.

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Figure 12. Detail photo of tear before 1990 treatment of SM 1973.303.  
Courtesy NYS OPRHP Schuyler Mansion State Historic Site.

### 4. CONCLUSIONS

When comparing the two treatments the amount of damage that had occurred with the complete overlay was severe. The overlay treatment was proposed to help “prevent any new tears from occurring,” this did not happen; it instead it did just the opposite. New holes and tears were created throughout the bedcover when the threads began to pull. Would this have been avoided if the piece was displayed completely flat instead of on a bed? Could the damage have been lessened if the overlay was only stitched around the stuffed areas as was proposed? These questions need to be considered when proposing a large overlay treatment.

Much less damage occurred on the bedcover with localized overlays. The new damages were most likely caused from long term display and could have been avoided if the piece was taken off display or periodically rotated with other textiles as previously suggested. The 1990 treatment performed did not seem to cause any further damage. The touchy topic with both bedcovers is the fact that all examinations and treatment records stressed that the bedcovers be taken off display for a period of time. As museum and conservation staffs become bogged down with more work, less help and dwindling funds, many projects get pushed to the back of the list; unfortunately, in this case, the textiles suffered.

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### ACKNOWLEDGMENTS

The author would like to thank Deborah Lee Trupin for all her guidance before, during and after the treatment of these two projects. Many thanks also go to the rest of the staff at Peebles Island for all their constructive criticisms in preparing for this presentation and publication.

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## THE CONSERVATION OF THREE HAWAIIAN FEATHER CLOAKS

ELIZABETH NUNAN AND AIMÉE DUCEY

**EXPANDED ABSTRACT** - Sacred garments worn by the male members of the Hawaiian ali'i, or chiefs, these feather cloaks and capes serve today as one of the most iconic symbols of Hawaiian culture. During the summer of 2007 the Bishop Museum in Honolulu, Hawai'i, under the supervision of its conservator, Valerie Free, commenced a project to stabilize the cloaks so that they could be safely exhibited in the museum. This project was funded by a grant from the Institute of Museum and Library Services.

Over the course of the summer three of the twelve cloaks in the museum's collection were treated: the "Chapman" cloak, the "Joy" cloak and the smaller second "Joy" cape. The Bishop Museum completed a conservation survey documenting the condition of the cloaks before treatment. Because exhibition requires frequent handling and manipulation of these large and fragile textiles, the main purpose of the treatment was to stabilize the existing damages in the cloaks, primarily in the form of tears and losses. In addition to stabilizing preexisting damage to the cloaks, the museum designed a new mounting system that would fully support them as well as provide a culturally appropriate display.

The best way to display these cloaks has been a challenge for many years. In the past they were hung vertically on the wall, which was very stressful where the textile was attached to the wall. Also, the flat format, while easy to take in visually, does not accurately represent the effect of the design of the cloaks. The patterns are meant to be seen in three dimensions as they would be when worn by a member of the ali'i.

In the spring of 2007, Bob Barclay, a visiting conservator from the Canadian Conservation Institute, developed a new design for displaying the cloaks in the round. This mount displays the cloak in the round, with gently undulating folds in the fabric, and at the same time distributes the weight of the cloak over many points of contact with the structure, relieving stress on the object itself.

The conservation of these cloaks has provided the Bishop museum with a proven methodology for treatment of the remaining cloaks in the museum. The new mounts ensure that these cloaks can be safely exhibited, allowing the public to enjoy these treasures of Hawaii's royal history.

The full paper complete with illustrations can be found on the Institute of Museum and Library Services website within the archived project profiles (<http://www.imls.gov/profiles/Apr09.shtm>). Additionally, a PDF copy of the paper can be found on the website of co-author Elizabeth Nunan (<http://www.aandnartconservation.com/bethnunan/bishopmuseum.html>).

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# FAILURE TO BIND: A RE-EXAMINATION OF THE AGEING OF HOOK AND LOOP FASTENERS

JOY GARDINER AND JOSEPH WEBER

**ABSTRACT** – Hook and loop fasteners, the most well-known brand being Velcro®, have been in production for over 50 years and are widely used by conservators in the mounting of textiles. In the past few years, there have been two incidents at the Winterthur Museum in which window hangings on long term display in the museum's rooms in the house have fallen spontaneously. It was found in both cases that the method of attachment was hook and loop fasteners and the detachment was the result of the failing of the join of the two sides of these fasteners. This brief investigation would indicate that the cause of the malfunction was the degradation failure of the fibers which resulted in the mechanical failure of the support system. Objects with this type of fastener on long term display should be monitored or have the fasteners replaced periodically.

**FALTA DE ADHERENCIA: UNA REVALUACIÓN DE LA ANTIGÜEDAD DE LOS CIERRES DE GANCHO Y BUCLE: RESUMEN** – Los cierres de gancho y bucle, cuya marca más conocida a nivel mundial es Velcro®, se producen hace más de 50 años y son ampliamente utilizados por conservadores para el montaje de tejidos. En los últimos años, han tenido lugar dos incidentes en el Winterthur Museum en los cuales se cayeron simultáneamente colgantes de las ventanas en exhibición prolongada en las salas del museo. En ambos casos se determinó que el método de sujeción era el de cierres de gancho y bucle y el desprendimiento se debió a una deficiencia en la unión de los dos extremos de estos cierres. Esta breve investigación demostraría que la causa del desperfecto fue la degradación de las fibras que causaron la deficiencia mecánica del sistema de soporte. Los objetos con estos tipos de sujeción en exhibiciones prolongadas deben ser supervisados o bien los cierres deben reemplazarse periódicamente.

## 1. INTRODUCTION

In the past few years, there have been two incidents at the Winterthur Museum in which window hangings on long term display in the museum's rooms in the house have fallen spontaneously. It was found in both cases that the method of attachment was hook and loop fasteners and the detachment was the result of the failing of



Figure 1. Detail of failed loop portion of fastener on valance (Winterthur #1968.0339.003). Note amount of “loop debris” on lining.

the join of the two sides of these fasteners. After the second of two window valances hung using this method had fallen (fig. 1), it was decided to try to determine the cause. Also, there is concern that textiles in this collection and others may be suspended with similarly aged fasteners (fig. 2). Hook and loop fasteners,

## FAILURE TO BIND: A RE-EXAMINATION OF THE AGEING OF HOOK AND LOOP FASTENERS

the most well-known brand being Velcro®, have been in production for over 50 years and are widely used by conservators in the mounting of textiles. Upon examination, the hook side of the fastener appeared to be noticeably softer in feel and less able to grab and hold than new material and the loop side was quite grayed. Written records for the fallen piece were not specific, but it would appear that the hook and loop were attached in 1968.



Figure 2. An overall view of the window (a, left) and a detail view (b, right) of a valance (#1955.0561.001c) in the Portsmouth Room at Winterthur showing another example of hook and loop fasteners starting to fail. These were applied in 1972. Photos courtesy of Winterthur, J. Schneck.

A few past discussions in the conservation literature (Gates 1993; Gilberg 1994; Leath and Brooks 1998) have mentioned concerns for the long term chemical stability of these fasteners and the need to use brands found to be most inert and stable. Nylon, the main fiber type used in these fasteners, does degrade over time. But as the initial join of the two sides is so strong, hook and loop fasteners are sometimes used to hang textiles for years that are on long term display. Although known to be far from ideal, long term display of certain textiles is required in some institutions. This study further investigates the chemical causes of degradation as well as exploring possible physical interactions attributing to the failure.

## 2. PHYSICAL DETERIORATION

With each closure and release of hook and loop fasteners, there is potential for a small amount of mechanical deterioration. That familiar “ripping sound” during the peeling is in fact, caused in part by the hooks breaking the loops that were holding it in position and the loops being stretched (fig. 3). The fasteners can be used numerous times as they are designed to have enough extra loops to engage with the hooks for each closure. Velcro USA, Inc produces four grades of hook and loop fasteners: disposable, low, medium, and high. The high grade is expected to hold for up to 10,000 closures (Lambert 2010).

The window valances that fell were rarely moved and therefore would not have numerous cycles of closure and releases to create extensive ripping of the loops. However, the scanning electron microscopy images show extensive physical damage to the loops from some cause.

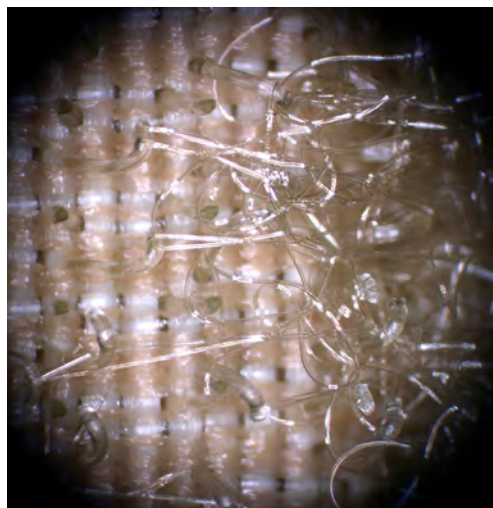


Figure 3. Physical deterioration is shown in a photomicrograph of the hooks pulling the loops at 45X magnification.

With the grayed appearance of loops, initially it was thought that the failure may have been partially due to particulate soiling interrupting the hold of the hooks onto the loops. When the two sides are closed, air can still move vertically through the joined area and may have been acting as a dust filter. Examination under magnification and the scanning electron microscopy images revealed that there were very few particulates on the fiber, indicating that this was not part of the problem.

### 3. SCANNING ELECTRON MICROSCOPY

As seen in figure 4, some old hooks are broken, but most of the damage is on the top surface indicating mechanical stress on an oxidatively degraded polymer. This could be from photo-oxidation as failed examples were at windows, but they were not directly exposed to the light. It is more likely that it was a thermo-oxidative process, which can be a slow room temperature oxidation activated by mechanical stress.

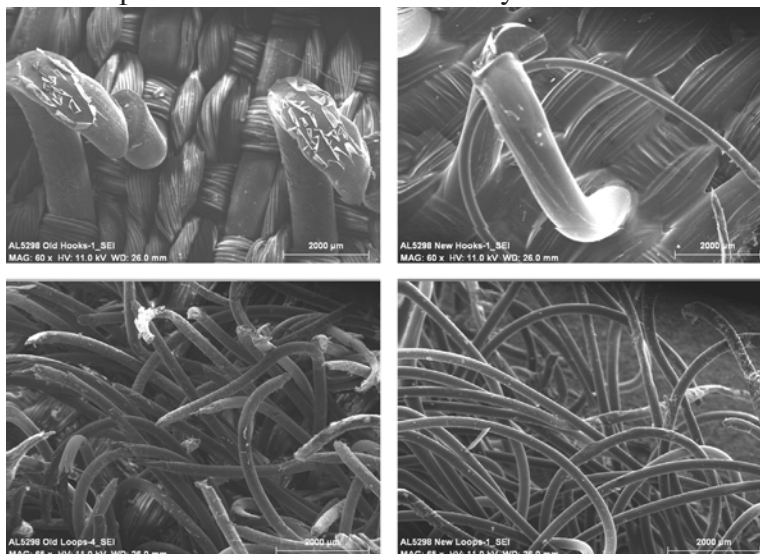


Figure 4. SEM images of old versus new fasteners (Topcon ABT-60 scanning electron microscope operating in secondary electron mode at 11 keV with a tilt angle of 20°; samples were flash coated with carbon).



## FAILURE TO BIND: A RE-EXAMINATION OF THE AGEING OF HOOK AND LOOP FASTENERS

The old loops show clear evidence of being extensively broken off at the surface. Despite the grayed appearance of the old loops, very little particulates are found. This indicates that it was not airborne soils deposited on the fasteners that contributed to the failure. The new loops, being of Nylon 6 (determined by hydrolysis and gas chromatography-mass spectroscopy), show the monomer caprolactam, which has migrated to the surface.

### 4. X-RAY FLUORESCENCE SPECTROSCOPY ANALYSIS

In the old hook and loop fasteners, a significant amount of titanium (Ti) was detected in the XRF analysis (fig. 5). This indicates the use of titanium dioxide ( $\text{TiO}_2$ ) as a delusterant, which would not have been needed for this application. This suggests that the yarns used were designed for a different application. The  $\text{TiO}_2$ , if unprotected, has the potential to act as a photo-oxidative catalyst. Also, there were no detectable amounts of manganese which is added to the fiber as a photo-stabilizer, leaving the yarns susceptible to degradation.

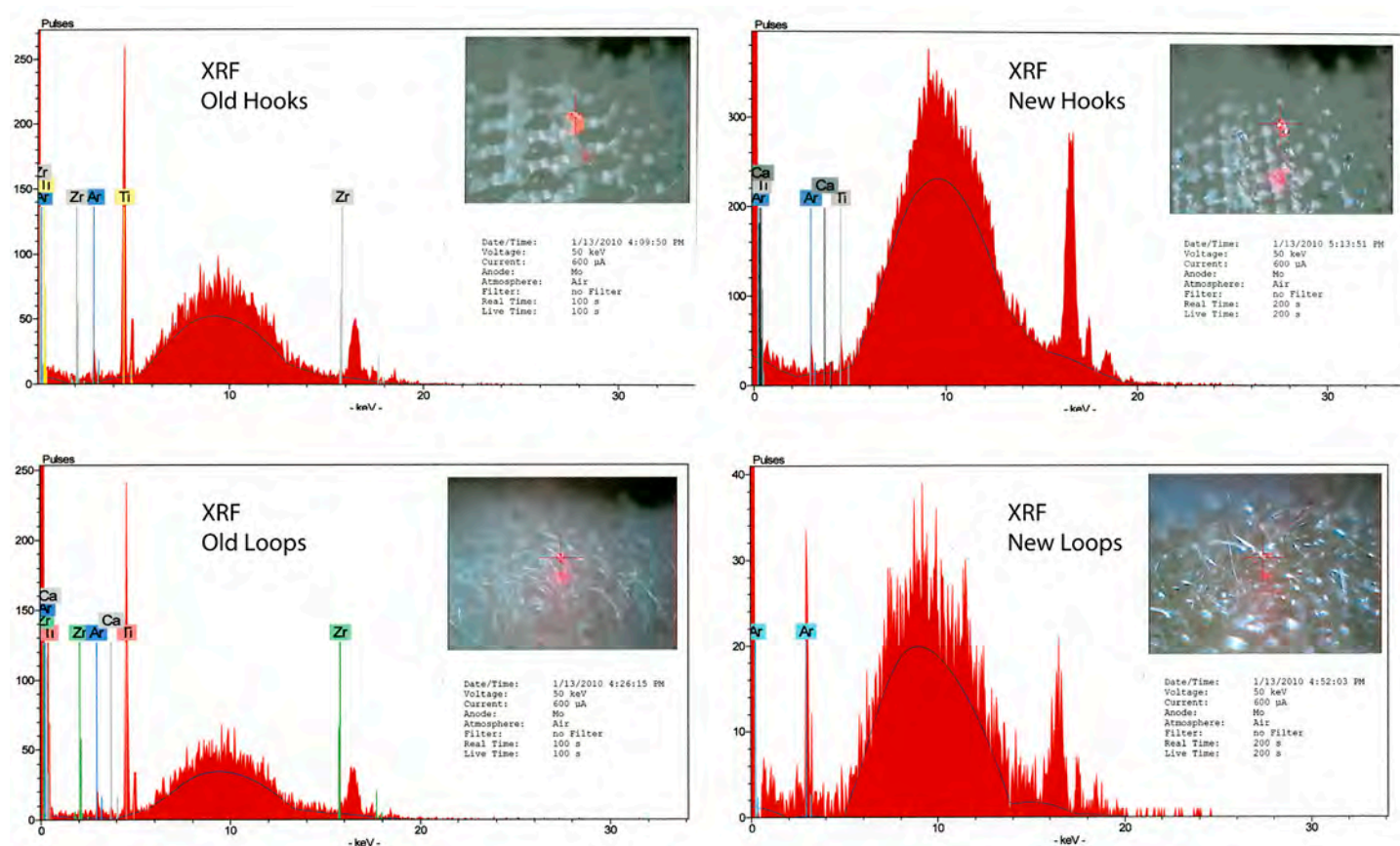


Figure 5. XRF spectra of old versus new fasteners (Rontec ArtTAX micro-XRF Spectrometer with a molybdenum x-ray source operating at 50 keV with collection times of 100 or 200 sec in air with no filter.)

In the new hook and loop fasteners a relatively small amount of Ti was found. This would have been added in the form of  $\text{TiO}_2$ , which in this quantity, would have served to control crystallization during spinning. No copper was detected, which would indicate the absence of copper halide (bromide and iodine) stabilizers. These halides are a very effective anti-oxidant for the fibers and their absence leaves the fibers very susceptible to oxidation.

## 5. TENSILE TESTING

A 3” overlap of different combinations of the hook and loop sides of the new and the old fasteners were pulled in the length-wise direction to determine shear strength on a Chatillon TCM 201® (fig. 6).

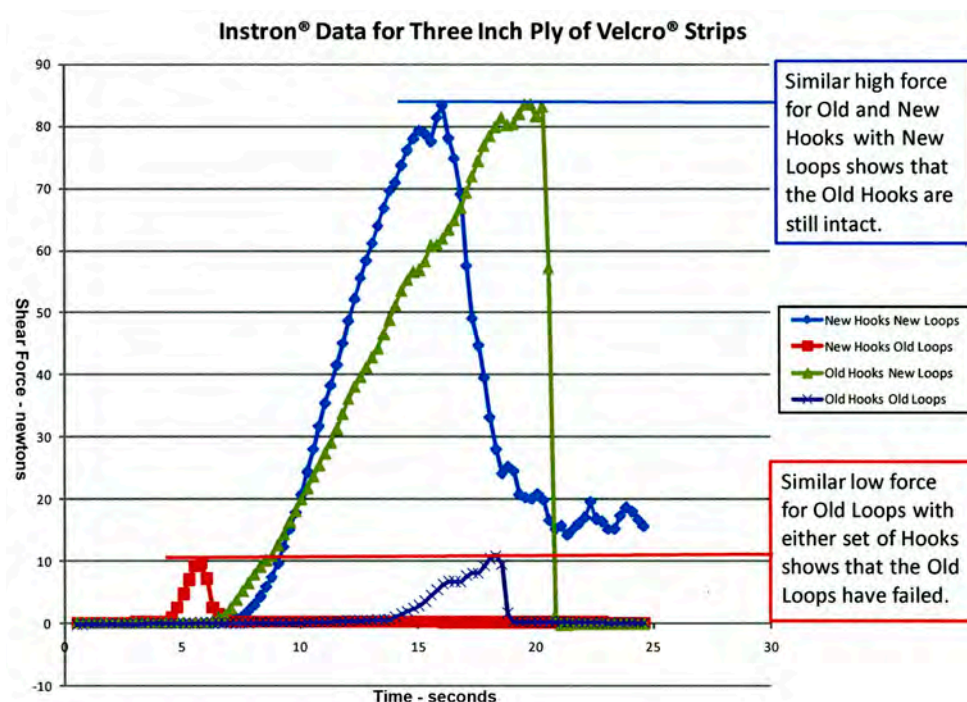


Figure 6. Tensile testing and data – R. Wolbers, graph – J. Weber.

There is a dramatic difference in shear strength of the old versus new loops independent of which age of hook was used. This further demonstrates that although there has been degradation to the old hooks as evidenced by their change to a softer texture, the mechanical failure of the system was due mainly to the more complete breakdown of the old loop side.

## 6. CONCLUSION

The brief analysis of the samples of failed hook and loop fasteners clearly illustrate that they do have limitations. This study supports the hypothesis that the cause of the malfunction was the degradation failure of the fibers which resulted in the mechanical failure of the support system. The hanging textiles in Winterthur's collection are being surveyed and those found to be attached with hook and loop applied more than ten to fifteen years ago will be systematically replaced. It is hoped that this will serve as a call to those with objects on long term display with this method of attachment to assess the potential need for careful monitoring and/or periodically scheduled replacement of the fasteners.

## ACKNOWLEDGEMENTS

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## FAILURE TO BIND: A RE-EXAMINATION OF THE AGEING OF HOOK AND LOOP FASTENERS

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**WEAVERS PROTECTING THEIR OWN HERITAGE:  
A CONSERVATOR'S EXPERIENCE IN THE COMMUNITY MUSEUM OF  
TEOTITLÁN DEL VALLE, OAXACA, MEXICO**

**HECTOR MANUEL MENESES LOZANO**

**ABSTRACT** – Mexican textile heritage is enormous, both in terms of tangible and intangible aspects. Moreover, textiles are not only housed in museum collections or galleries, but they are still an active part of different communities throughout the country. Since these objects do not always belong to institutions where conservation is an area of expertise, many textiles are vulnerable to damage due to lack of information on how they need to be stored and exhibited. The *Museo Textil de Oaxaca*, with its aim to collaborate with indigenous groups, is currently working together with the community museum of Teotitlán del Valle, a town of weavers. The project involves basic training in preventive conservation and treatment of damaged weavings carried out by interns of the *Escuela Nacional de Conservación, Restauración y Museografía “Manuel del Castillo Negrete”* (National School of Conservation).

**TEJEDORES GUARDIANES DE SU PATRIMONIO – LA EXPERIENCIA DE UN CONSERVADOR EN EL MUSEO COMUNITARIO DE TEOTITLÁN DEL VALLE, OAXACA, MÉXICO: RESUMEN** – La herencia textil de México es muy vasta, tanto en aspectos tangibles como intangibles. Es importante mencionar que los textiles no se encuentran únicamente resguardados en colecciones de museos o galerías, sino que aún forman parte importante en diferentes comunidades de todo el país. Puesto que estos objetos no siempre se encuentran en instituciones donde se cuente con suficiente conocimiento en el área de conservación, muchos textiles son vulnerables al deterioro provocado por la falta de información sobre cómo exhibir y almacenar este tipo de bienes. El Museo Textil de Oaxaca trabaja actualmente con el museo comunitario de Teotitlán del Valle – un pueblo de tejedores – como parte de su misión: colaborar con comunidades indígenas. El proyecto consta de entrenamiento básico en aspectos de conservación preventiva e intervención directa sobre tejidos deteriorados. Esto último se ha logrado gracias a la participación de alumnos practicantes de la Escuela Nacional de Conservación, Restauración y Museografía “Manuel del Castillo Negrete”.

## 1. INTRODUCTION

Teotitlán del Valle is a Zapotec community located 28 km from the city of Oaxaca, in southern Mexico. This community is best known for its wool weavings made on the treadle loom. Almost everyone in Teotitlán is involved in the textile production, and most of the time this weaving tradition is passed on from father to son. Traditional weavings are represented by *sarapes* and rugs; however, weavers have more recently been exploring ways to diversify their production by creating hand-bags, haversacks, purses, and ornamental articles. The use of natural dyes for wool has also been rising since the 1970's.

The Community Museum of Teotitlán del Valle – *Balaa Tee Guech Gulal* (home of the ancient village) – was established in 1993. The museum presents the history of the town, including pottery from pre-Columbian times to the present and the rituals that surround traditional weddings. Since Teotitlán is a town of weavers, textiles are also included in the museum. The textiles on display are mainly *sarapes* and blankets woven between 1950 and 1970 (fig. 1). The textiles were donated to the museum by different community members. These textiles, however, were never taken off display, which is why the museum's board got in touch with the *Museo Textil de Oaxaca* (Textile Museum of Oaxaca – MTO) in August 2009 to ask for guidance in taking care of their textiles. The project consisted of three different phases: a diagnosis of both the building and the textiles; preventive conservation actions; and treatment of damaged textiles.



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Figure 1. Textiles on display at the Community Museum, August 2009.

## 2. PHASE 1 – DIAGNOSIS

The moment the project started, I learned that the Museum's Board was planning on restoring the actual building, mainly due to issues including leaks, infested wood by woodworm, and the lack of a storage area, to name a few. The MTO will assess the building and try to adapt the building to meet conservation requirements using regionally available resources. For example, an air conditioning system might not be necessary if the building is built with traditional techniques (such as *adobe*), since adobe buildings tend to create and maintain stable environments. Additionally, the use of adobe for the restoration of the museum would blend the building with the rest of the village.



Figure 2. Mounting system – reed and polyester thread.

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The *sarapes* and blankets had been on display at the museum for 16 consecutive years, with no regard to their conservation. The mounting system was made of a piece of reed to which the *sarape* or blanket was stitched with white polyester thread (fig. 2). The reed was then hung from the ceiling using nylon thread and tied to the wood beams from the ceiling, directly under fluorescent lights (fig. 3). The evidence of damage after such a long time and in these conditions was obvious: all of the textiles showed a heavy coat of dust and infestation from insects, which caused rips and holes of different dimensions (fig. 4). Even with such holes (the biggest ones measuring up to 7" by 5"), the textiles were on display. The mounting system did not provide the textiles with a full support, which distorted the original weaving at the stitching points. Moreover, a piece of cardboard with the information of the donor typed onto it was sewn to all the textiles using the same polyester thread (fig. 5).

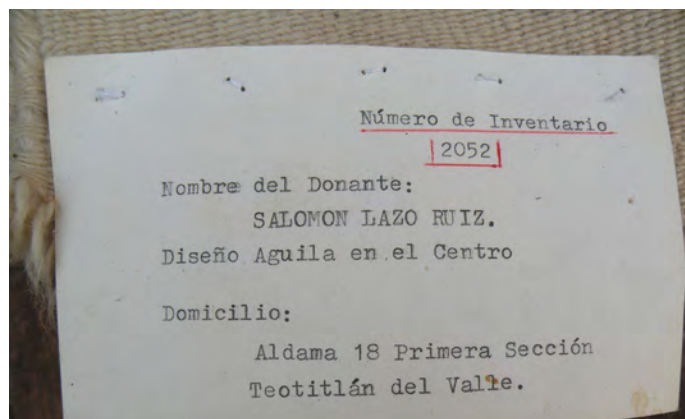


Figure 3 (top left). Fluorescent lights. Figure 4 (right). Holes and rips on blankets.  
Figure 5 (bottom left). Cardboard with registration data sewn onto the textiles.

### 3. PHASE 2 – PREVENTIVE CONSERVATION

After the initial diagnosis, the second phase began. I proposed to the Community Museum of Teotitlán to work on-site with them one day a week, leaving them a couple of activities to do during my absence. They agreed to this and, interestingly enough, they proposed to rotate members each time I was there. This allowed them to communicate to each other all new information at their weekly meetings so that everyone would be aware of the situation. This also gave me the opportunity to interact with the whole Board.



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The first step was to de-install all the textiles on display and look for signals of active moth infestation. None were found, which was quite a relief. Afterwards, the basic documentation of the textiles was written down: type of object, author (if applicable), dimensions, description of the designs (in Spanish and also in Zapotec), materials, date, name of donor, date of donation, and a conservation survey (presence of dust, moth attack, rips, holes, fading, bleeding of dyes). Since the Board members are all weavers, a suggestion was made to emphasize aspects of the weaving process for new acquisitions, including information about the wool, yarns, dyes, and weaving technique (fig. 6).



Figure 6. Documentation of textiles with Board Members.

### 3.1 SURFACE CLEANING

Since there was no active infestation, we proceeded to surface clean the blankets. After explaining to the Board the importance of surface cleaning and the benefits of regular cleaning while an object is on display, they judged it a good investment to buy a vacuum with suction regulation. I showed them the wood frame covered with net that we use at the MTO to vacuum textiles and they had one made for themselves. Once all the equipment was ready and the demonstration was made on how to surface clean a textile, different Board members were in charge of vacuuming all *sarapes* and blankets (fig. 7). After this process was done, all the Board members were fascinated by the aesthetic improvement and the enriching texture their blankets showed. One blanket in particular (woven with natural brown wool) caught their attention for the subtle shine of the fiber; a detail that was totally hidden by the heavy coat of dust that previously covered the yarns.

### 3.2 DISPLAY

The Board decided they did not want to put all blankets on display at the same time. Therefore, the best-conserved blanket was chosen for exhibition. Even though the colors are a bit faded, it does not show any rips or holes. After choosing the blanket for display, I invited the whole Board to the MTO to show them different mounting systems we have used in our exhibits, not only for flat textiles, but also for garments. I explained the advantages of the most common systems that could be useful for their textiles (passive systems, Velcro®)

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support systems, attachment of textiles to framed canvas) and encouraged a discussion on what system could work better for their purposes. It was decided to use a framed canvas of sufficient dimensions to display most of their blankets. They realized this would also come in handy for rotating textiles on display.



Figure 7. Surface cleaning of textiles with low-suction vacuum.

The Board wanted a neutral background, so I suggested using cotton muslin, a widely available, inexpensive, fabric. One of the Board members was in charge of washing the fabric prior to use, and once the wooden frame was ready, the task of preparing the support system began. The Museum's Board borrowed an adequate stapler to stretch the fabric onto the frame (fig. 8) and then we began to hand sew the blanket onto the stretched fabric (fig. 9). They learned that this requires time and effort, but they were really satisfied when they looked at their textile on display.



Figure 8 (left). Stretching the fabric onto the display wooden frame. Figure 9 (right). Stitching the textile onto the stretched fabric.



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Even though they chose to use a framed canvas on which to exhibit their blanket, I considered it necessary to also show them the way the Velcro® support system works. In the event that they one day house a temporary exhibit of *sarapes*, the Velcro® support system would be quicker and cheaper, and still not compromise the textiles' integrity. I decided to have a hands-on demonstration of this kind of support system and asked them to get a small stock of needed materials: Velcro®, scissors, nylon thread, pins, needles, metric tape, and washed cotton muslin. The Chair of the Board brought a couple of small carpets he wove so different Board members could practice this method (fig. 10). They found this activity difficult at first, but judged it to be a good option in the long run. They even contemplated doing this to display some of their most esteemed textiles within their homes so tourists and buyers could get a better sense of their work.



Figure 10. Velcro®-mounting-system practice.

### 4. PHASE 3 – INTERVENTION

The Community Museum's Board wanted a qualified person to treat their damaged textiles. However, they were aware that they did not have the resources to pay for such a project. Since the Conservation staff at the MTO is quite small (only two people), treating their textiles on our time was not possible. For that reason, I got in touch with the National School of Conservation, Restoration, and Museum Studies – “Manuel del Castillo Negrete” (ENCRyM), in Mexico City. Since 2008, the MTO had received textile conservation students for three- to four-week internships as part of their professional training. I proposed to the director of the Conservation program to change the location of the textile conservation internship to Teotitlán del Valle for 2010. After explaining the project to her, she was really excited about it. There was one issue to resolve though: the school could only pay for the transportation of the students from Mexico City to Teotitlán, but could not afford lodging and meals. After negotiations with the Board, it was decided that the ENCRyM would send a couple of students to treat some of the blankets, the MTO would guide the process, and Teotitlán would provide accommodation and meals for interns. This last aspect presents an extra appeal, since interns will get in touch with local traditions by staying at home with families from Teotitlán. The MTO and Teotitlán's community would also provide the required materials for treatment.

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### 5. CONCLUSIONS

The project with the Community Museum of Teotitlán del Valle is on-going. We still need to solve issues about storage in the short and long run. I would like to stress the importance of teamwork as a vital factor in achieving good results. Moreover, this particular case demonstrates how the initiative of the community to preserve their own heritage has been a key element for this project's success. Active participation of the community will have a long-term, positive impact on the conservation of their textiles, even without a full-time conservator on their side. Since the textile heritage in Oaxaca is so rich, I hope that more communities will get involved in preserving their heritage... our heritage.

### ACKNOWLEDGMENTS

I would like to thank the Board of the Community Museum of Teotitlán del Valle – particularly the Chair of the Board, Florentino Gutiérrez, for giving me the chance to closely appreciate the aggregated value of textiles beyond the conservation lab. I would also like to thank Ana Paula Fuentes, director of the MTO, for supporting this project. Thanks also to Eric Chávez, Education Coordinator at the MTO, for helping me during this project. I would also like to express my gratitude to Ilse Cimadevilla, Director of the Conservation Programme at the National School of Conservation, in Mexico City, for embracing this project. Finally, thanks to Camille Breeze for reviewing and editing my text.

HECTOR MANUEL MENESES LOZANO has been the Textile Conservator at Museo Textil de Oaxaca, Oaxaca, Mexico, since its opening in April 2008. He has set up the Conservation Lab as well as the Storage Area. Hector has also worked with indigenous communities in different workshops, particularly those related to the use of feathers in textiles. He just completed a two-months internship at the *Musée du quai Branly* in Paris, France. He has been collaborating with the School of Art and Design in Oaxaca, both as advisor and professor of Textile Design. Hector has been a member of the North American Textile Conservation Conference Board since 2008.

# THE CONSERVATION OF A HISTORICAL OBJECT: THE FLAG ON WHICH CHILEAN INDEPENDENCE WAS SWORN IN 1818

CATALINA RIVERA AND FRANCISCA CAMPOS

**ABSTRACT** - In November of 2007, the project “Value enhancement of the flag of Independence” was presented to Chile’s National History Museum (Museo Histórico Nacional or MHN). The object was approached from different directions: material and technique, history and aesthetics, symbolism, and finally its restoration and exhibition. Here, the historical background and physical description of the flag are reviewed, detailing the state of conservation, the treatment proposal and the intervention that was ultimately realized, involving various procedures dictated by the needs of the object.

**LA CONSERVACIÓN DE UN OBJETO HISTÓRICO: LA BANDERA DONDE FUE JURADA LA INDEPENDENCIA DE CHILE EN 1818: RESUMEN**- En noviembre del año 2007, el proyecto “Puesta en valor de la Bandera de la Independencia” fue presentado al Museo Histórico Nacional (MHN). El objeto se abordó en sus distintas dimensiones: matériaca y técnica, histórica, estética y simbólica, y finalmente su restauración y exhibición. Aquí, son revisados los antecedentes históricos y descripción física de la bandera, detallando el estado de conservación, el tratamiento propuesto y por último la intervención realizada, que involucró diferentes tipos de procedimientos en virtud de las necesidades del objeto.

## 1. HISTORICAL BACKGROUND

Attributed to being present at the swearing of Chilean Independence on February 12, 1818 in the Plaza de Armas in Santiago, the flag underwent restoration by the Poor Clare Sisters of Puente Alto in 1975. In 1980, while the flag was on exhibition, it was stolen by the Revolutionary Left Movement (Movimiento de Izquierda Revolucionaria or MIR) in protest of the military dictatorship. It was returned 23 years later as part of a demand for the release of information regarding detainees of the Movement who had been disappeared (Gómez et al.: 2003). The flag did not sustain damage during the time it was stolen.



Figure 1 (left). The flag front. Figure 2 (right). The flag reverse. Photos courtesy of J. Godoy.

## 2. DESCRIPTION OF THE FLAG

The flag measures 240 cm long x 143 cm wide (96 x 57.2 in) and the emblem is 40 cm long x 55 cm wide (16 x

22 in). It is made of blue, white and red silk satin fabric, and has two faces or layers. In the center of each face, there is white silk oval with a painted emblem. Both blue areas are appliquéd with a white five-pointed star bordered with golden sequins (figs. 1, 2).

Fiber samples were taken from each of the fabrics that compose the flag and were observed under an optical microscope with 200X magnification. The fibers from the warp and weft of the original fabrics were silk but those from the white fabric from the earlier restoration were synthetic. The weaves of the original fabrics were plain weave for the emblems and satin weave for the white, blue and red fields.

## 2.1 PREVIOUS RESTORATION

As part of the previous restoration by the Poor Clare Sisters, the seam of the flag's superior border was opened and a synthetic white fabric that served as a support was inserted between the two faces. The red fields and the emblems were secured to this fabric by numerous machine and hand stitches using red cotton thread that covered the entirety of the surface. This application resulted in an undulation in the fabric and created gathers over extensive areas. The blue field was reinforced with machine stitching around the contour of the star. Despite the problems generated by the previous intervention, this repair ultimately helped maintain the order of the loose weft threads, preventing their total loss (figs. 3-5).



Figure 3 (left) Photo courtesy of J. Godoy. Figure 4 (top right). Figure 5 (bottom right).

## 2.2 CURRENT CONDITION

Damage from dry conditions are found in both emblems and white and blue fields of Face A. There are dry, brittle fibers, the product of prolonged exposure to light, or environments with low relative humidity. The fabric has the appearance of paper (Espinoza and Grünzacher 2002). There are many worn folds, which show that it was folded for a long time causing the weakening and subsequent rupture of the fibers.



## THE CONSERVATION OF A HISTORICAL OBJECT: THE FLAG ON WHICH CHILEAN INDEPENDENCE WAS SWORN IN 1818

Warp thread deterioration is observed in the red field of the flag, on both sides, almost entirely, leaving only some isolated areas with presence of warp. The white fields have some lack of warps. The complete loss of the fabrics are found on Face A in the middle and the emblem and on Face B in the top of the red field and center of the white field and bottom edge.

The flag is discolored overall from fading, although Face A has more discoloration than Face B. The original colors of the flag can still be determined. Some staining of the fabric can be seen mainly in the red field of Face A, with smaller stains found in the blue and white fields.

### 3. METHODOLOGY

The project was completed by a multidisciplinary team composed of historians and conservators. To determine the best treatment, the flag was examined and treatment protocols were researched. The research areas included the flag's history, materials and construction techniques, similar works of restoration realized by other professionals, and a proposal for the flag's treatment written by Yadin Larochette in 2004 during an internship in the Textile Conservation laboratory of the MHN. Test treatments on prototypes were carried out in order to obtain empirical information about the efficiency of the proposed methods.

	<b>Test 1:</b> 1:3 Lascaux 360 HV/ 498 HV 1:3 Adhesive/Water	<b>Test 2:</b> 1:3 Lascaux 360 HV/ 498 HV 1:8 Adhesive/Water	<b>Test 3:</b> 1:2 Lascaux 360 HV/ 498 HV 1:10 Adhesive/Water
Adherence	High	Medium	Medium
Flexibility	Medium	Medium	High
Darkening	None	None	None

Table 1: Results of adhesives among test samples.

Adhesives were chosen according to the following considerations: reversibility (relative), chemical compatibility with the piece being treated, chemical stability, resistance to environmental factors, dimensional stability, maintenance of flexibility over time, low sealing temperature, heat resistant bonds, that it should not change the physical appearance of the piece being treated, that the method of application should not pose a risk to the textile, that it adheres strongly to the substrate, and that it does not change the texture or appearance of the fiber. Results are listed in table 1.

Color tests were performed with dyes specially made for textile conservation. After these tests, the material that was to be used as support fabric in the restoration was dyed. The design of the display case was based on the requirements established by the conservators, after an analysis of the conditions most appropriate for the exhibition of a historic textile.

A visual registry of photographs was made for the restoration process as well as for objects historically related to the flag (paintings, medallions, uniforms, etc.). A documentary was filmed by the television network Televisión Nacional de Chile (TVN), which made monthly recordings to document the progress of the restoration.

#### 4. TREATMENT

Many machine and hand stitches made by the Clare Sisters, which were secured tightly to the original fabric and synthetic fabric, were removed carefully with tweezers and scissors. This process took about one month and a half, due to the large number and small size of the stitches.

The degree of deterioration of the flag did not allow a wet or dry cleaning. To remove the particulate materials in the fibers we used a microsuction vacuum, using a mesh net to avoid further loss of weakened areas of fabric. As for the dirt that was attached to the fibers and could not be removed by the microaspiration, this was removed with a latex sponge.

The metal sequins around the edge of the star were cleaned with enzymes. The enzymes removed much of the dirt, but did not remove the patina.

Silk support fabrics were inserted into the interior of the flag for each face. These fabrics were colored using dyes made specifically for textile conservation (CIBA) (fig. 6 ). Loose and misaligned threads were realigned (fig. 7). The pleats and wrinkles of the fabrics were relaxed through the application of cold vapor and then weighted to retain the realignment (fig. 8).

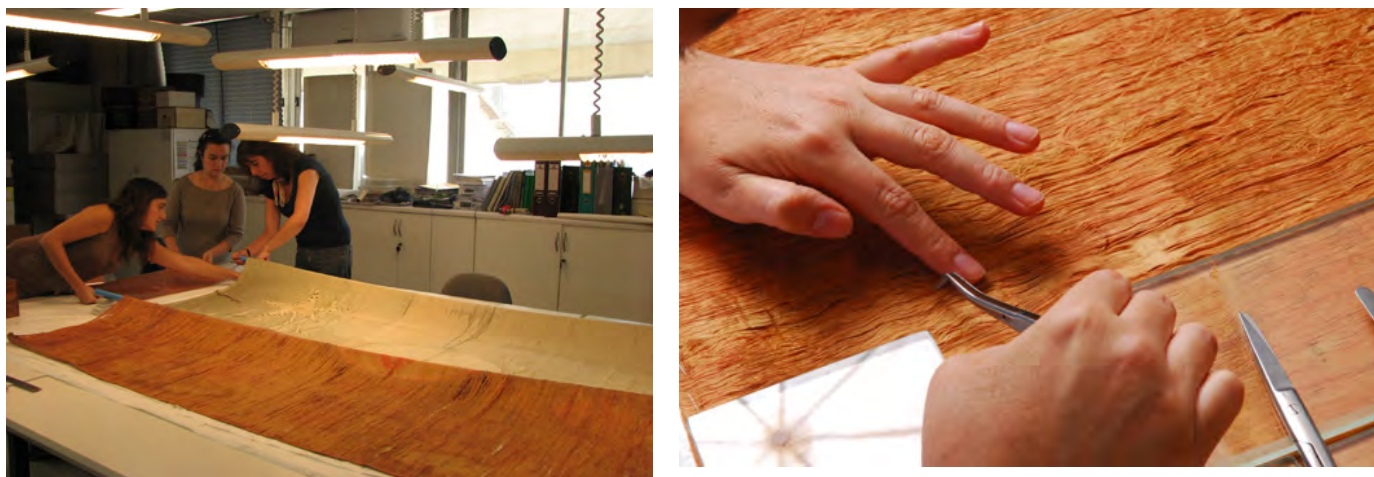


Figure 6 (left). Figure 7 (right). Alignment of loose and misaligned threads. Photo courtesy of J. Godoy.

Both red fields and the white field of Face B were stabilized by covering their entire areas with silk crepeline (fig. 9). This provided a protective cover that would prevent the threads from catching on handling and did not interfere visually with the original. The crepeline was fixed with silk thread of the same color by equidistant seams using patterns of 10 cm x 5 cm (4 x 2 in). The original material was encapsulated between the silk support fabric and crepeline.

The blue fields and the white field of Face A were stabilized with couching stitches using silk thread. However, as the treatment progressed, it wasn't possible to use couching stitches on Face A due to the high friability of the fibers. Couching stitches could produce more damage, because eventually they tend to tear along the lines of the holes produced by the needle. So, it was decided to cover the white field with crepeline dyed to match and then fixed with stitching as with the other areas of crepeline. These stitches were more widely spaced than the couching stitches and fewer stitches were needed, avoiding the risk of tearing.

## THE CONSERVATION OF A HISTORICAL OBJECT: THE FLAG ON WHICH CHILEAN INDEPENDENCE WAS SWORN IN 1818



Figure 8 (left). Figure 9 (top right). Photos courtesy of J. Godoy. Figure 10 (bottom right).

The treatment for the emblems required their removal from the flag (fig. 10). In order to document their original position before being removed, the position was mapped on a mylar film. The mylar film was slowly introduced between the emblem and the flag, once they had unpicked the seams of the prior repairs. This was an extremely slow and delicate process as it must ensure that the loose fibers and numerous fragments stay in their original position. After removing the emblem from the flag, the pleats and wrinkles of the silk were relaxed.

To consolidate the emblems, a piece of crepeline, 70 cm x 75 cm (30 in x 30 in) for each emblem, was dyed in the same tone as the emblems. The crepeline was placed on mylar and impregnated with the adhesive mixture of 1:3 Lascaux 360 HV/ 498 HV and 1:3 Adhesive/Water by using brush and roller, leaving it to dry for 3 hours, forming a film. Once dry, the crepeline was separated from the Mylar film. Then the emblems were placed on the adhesive film and was realigned on it. Then, on the front of the emblem, the adhesive was activated by applying heat with a heat spatula (65 ° C) only at certain points isolating the spatula with a mylar so as not to apply heat directly to original. Once the points were set, the emblem and crepeline were turned over and the entire area was heat-set from the back (fig. 11).

To neutralize the losses, a support of silk previously dyed in color of the emblem was placed behind the emblem. This support of silk was joined to the emblem with silk thread stitches outlining the fragments of the emblem. Finally, the emblems were placed in their original position (fig. 12) and secured with hand stitches using white silk.

A display case was constructed of heat-sealed aluminum and laminated glass with built-in lighting that is adjustable and has a UV filter. It was decided to construct a display case that showed the flag in an almost horizontal, slightly inclined plane, as due to its fragility, the flag required a staging that does not exert gravity. As the flag has two sides, one side will be on display for a period of three months and then the other side will be displayed.





Figure 11 (left). Figure 12 (right). Photos courtesy of J. Godoy.

## 5. CONCLUSION

This conservation treatment halted deterioration and stabilized the flag without reducing its value or authenticity. This newfound stability enables the object to be manipulated gently without risk of it suffering new damage and allows it to be safely exhibited. The aesthetics of the flag have improved considerably (fig. 13, 14).



Figure 13 (left). Front of the flag after treatment. Figure 14 (right). Reverse of the flag after treatment. Photos courtesy of J. Godoy.



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Creative solutions were applied to the problems that the flag presented, which demonstrates how conservation must respond to the distinct needs of each object. This interdisciplinary project generated an exchange of ideas among conservators as well as with other professionals in heritage-related fields. Thanks to the diffusion of the project through different media sources, the work that conservators do was made known to the general public. The conservation of the flag now contributes to the community by allowing this patriotic emblem to be viewed by the public.

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# Oriel Microfading Tester (MFT): A Brief Description

JAMES DRUZIK

**ABSTRACT**– The Oriel Microfading Tester was developed by Paul Whitmore at Carnegie Mellon University in the period 1994 to 1996 and has since been implemented in more than a dozen institutions worldwide. The technique, using an intense light source, employs a user-selected time interval to automatically collect a series of reflectance spectra, and derive from them a full complement of colorimetric quantities. These quantities may then be plotted to show the color change kinetics of selected colorants on artifacts. Thus it combines the features of fiber-optic reflectance spectrophotometry (FORS) with traditional accelerated light aging. This article will describe how the method works and how data is interpreted to identify particularly light-sensitive areas and inform decisions on risk assessment and management. Other strengths and weakness of the technique will be suggested that need be kept in mind during interpretation.

**TESTER DE MICRODECOLORACIÓN (MFT) ORIEL: UNA BREVE DESCRIPCIÓN: RESUMEN** – El Tester de Microdecoloración Oriel fue desarrollado por Paul Whitmore en Carnegie Mellon University durante el periodo de 1994 a 1996 y desde entonces se ha utilizado en más de una decena de institutos en todo el mundo. La técnica, de aplicar una fuente de luz intensa, utiliza un intervalo de tiempo seleccionado por el usuario para recolectar automáticamente una serie de espectros de reflectancia y obtener de ellos un complemento completo de valores colorimétricos. Estos valores luego pueden graficarse para indicar la cinética del cambio de color de los colorantes seleccionados en los objetos. De este modo se combinan las características de la espectrofotometría de reflectancia de fibra óptica (FORS, por sus siglas en inglés) con el envejecimiento acelerado tradicional por exposición a la luz. En este artículo se describirá cómo funciona el método y cómo se interpretan los datos para identificar áreas particularmente sensibles a la luz y para informar decisiones sobre evaluación y gestión de riesgos. Se sugerirán otras fortalezas y debilidades de la técnica para tener en cuenta durante la interpretación.

## 1. INTRODUCTION

The long history of light-fastness testing has been briefly compiled elsewhere (Druzik and Eshoj 2007), but dates from as early as 1733. By the late 19th century artists' materials were a serious topic of scientific study and reference (Church 1892). Yet the first study that took on a decidedly modern approach was the work of Russell and Abney in 1888 with their monumental work *Action of Light on Watercolours* (Russell and Abney 1888). By the 1930's recommendations on illumination levels for works of art began to appear in the literature (Feller 1964), and testing became common. Ultimately, natural light exposures were augmented by accelerated light aging derived from industrial applications and a review of the work of Robert Feller and Ruth Johnston-Feller illustrate this very well (Whitmore 2002). If one is prepared to give accelerated light aging enough time, any colorant except for those that are fully inert, can be induced into change and placed within a range of light stabilities that range over 3-4 orders of magnitude. For simplification and control, these studies are typically carried out on newly prepared materials. But for a number of reasons, testing newly prepared materials will not accurately predict naturally-aged samples even when they are of identical chemical composition. So a method is needed that could test colorant systems on real artifacts, of any age, in a "virtually" non-destructive manner, do it reasonably fast, and focus on the most vulnerable examples. Two approaches were described independently by Pretzel (Pretzel 2008) and jointly by Costain (Costain, Michalski et al. 1995) and Michalski (Michalski 1997), but the first identification of a technique that would later be called "microfading" appeared in a lab book entry written by Paul Whitmore and dated, September 21, 1994. The method was formally published several years later (Whitmore, Pan et al. 1999).

This article will describe the operation of the microfading tester and how it has evolved since then. Because 12 of 14 working instruments have been built from the Oriel implementation and are packaged as a system for

## Oriel Microfading Tester (MFT): A BRIEF DESCRIPTION

purchase we shall be discussing primarily that system and important modifications to it.

### 2. HARDWARE DESCRIPTION

The fundamental components of a microfading technique are rather straightforward to deduce. A powerful, yet compact light source is needed. It must be inherently stable or contain a feed-back loop to insure that stability. It requires a means to filter the light path to match certain requirements. It must have a convenient method to convey its light output to nearly any geometric surface orientation. The reflected light must then be collected and passed to a spectrophotometer, and the spectrophotometer should save its spectra to a file structure on a computer. This is illustrated in figure 1.

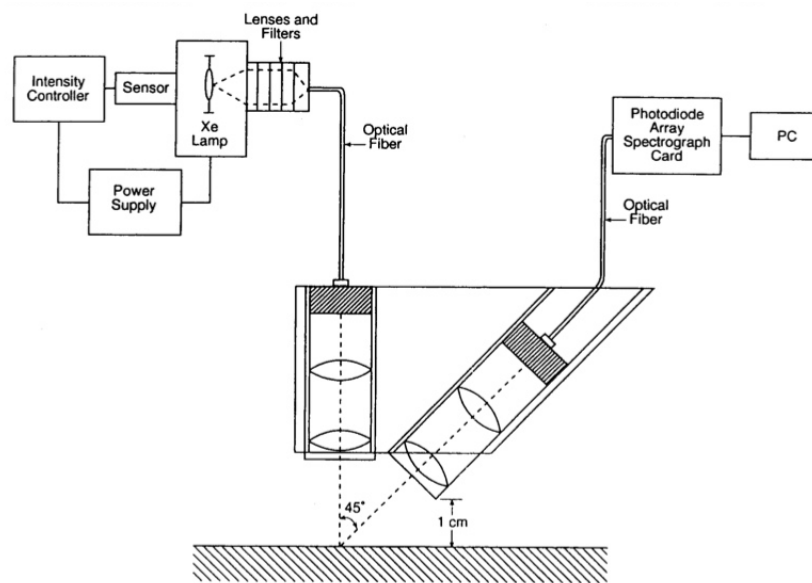


Figure 1. Schematic of the Oriel Microfading Tester. Shown with permission of the Journal of the American Institute for Conservation, Vol. 38, No. 8.

#### 2.1 LIGHT SOURCE

The Microfading Tester (MFT) light source should be as compact and intense as possible. This limits the options to a spark source xenon lamp (fig. 2). The lamp has no integrated reflector but a mirror behind increases the output that will exit the lamp housing by 60%. Light passes through a condenser lens assembly, water filter, hot mirror and UV filter, exiting through a quartz fiber (fig. 3). All these filters may be used in combination, only some of them used, or even others not specified. The water filter and hot mirror remove most infrared wavelengths and reduce the thermal transmission from the source to the fiber. Since a xenon source is richer in shorter wavelengths than common museum illuminants intended for the display of light-sensitive objects, a third filter insures that these ultraviolet wavelengths are cut off.

The xenon lamp is nominally operated at 75 watts but is automatically adjusted for stability. The user may also adjust lamp wattage – a feature Christopher Maines has exploited at the National Gallery of Art by dropping the lamp to 40 watts for artifacts considered to be especially sensitive.

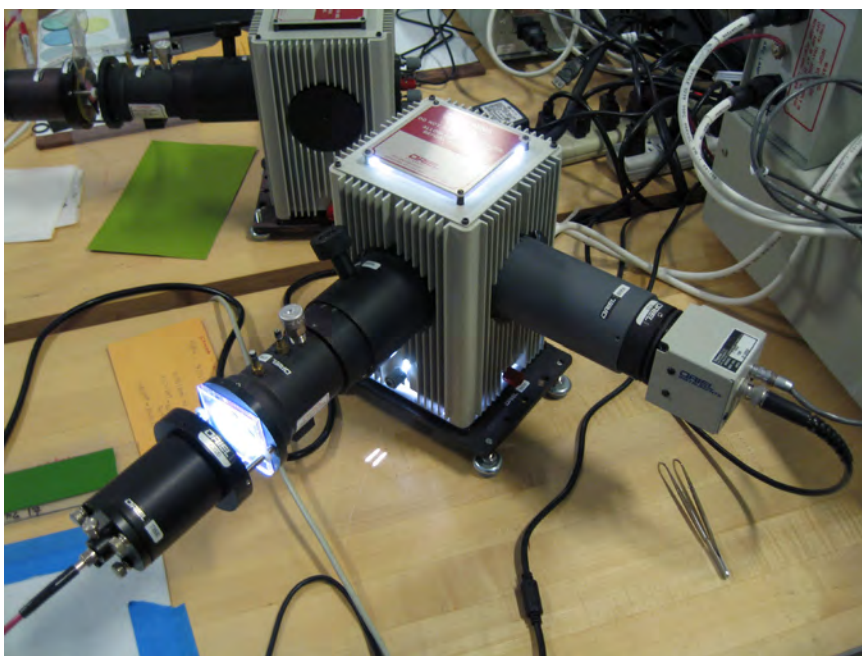


Figure 2 (left). 75 watt xenon lamp. Figure 3 (right). The xenon lamp housing with filter assembly (left tube assembly). The right side tube terminates with a photodiode array detector used to provide feed-back luminosity to the power supply.

## 2.2 MAIN FRAME ELECTRONIC

To the right side in figure 3 a second tube is seen exiting the lamp housing. This contains a photodiode array detector and a small aperture which, when combined with control electronics insures the highest luminous flux stability feasible during daily operations. It also provides stability during periods when a series of related materials may be tested together and the data needs to be kept as comparable as possible. Lamp wattage and amperage are modified with this feed-back loop as the digital exposure controller interfaces and controls the lamp power supply. Three portable implementations of the MFT at the Netherlands Institute for Cultural Heritage (ICN), the Getty Conservation Institute (GCI), and the Canadian Conservation Institute (CCI) have been built to eliminate the lamp stabilization electronics and use a simpler power supply with the same xenon lamp. This compromise works adequately for short studies but has no mechanism to hold lamp output stable for longer periods of time.

## 2.3 PROBE

The probe directs light from the source to the tested surface in a non-contact,  $0/45^\circ$  geometry. Figure 1 illustrates two convex lenses for each lens tube. In actual practice three possibilities have been used. Planoconvex, achromat doublets, and in a method first used at the Museum of Modern Art (MOMA) by Christopher McGlinchey, with no lenses at all. In the MOMA probe a single 100 micron fiber applies light normal to the surface and a cluster of six pick-up fibers return scattered and reflected light back to the spectrophotometer. Figure 4 a-c show three variations of the probe with and without a pen camera to monitor focus. Figure 4a is most common, figure 4b shows the lensless probe, and figure 4c is the probe built by Bruce Ford, Australian National Museum (ANM), where the camera can be located at right angles on either side of the source/spectrometer axis. The luminous flux from the source can vary from about 250-1100 millilumens for spot diameters estimated to be from 0.2 to 0.4 mm. Since lux is defined as lumens per meter squared, these produce rather high lux exposure



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equivalents but to vanishingly small areas. Five to over 16 megalux can be delivered producing meaningful data in as little as 10 minutes.

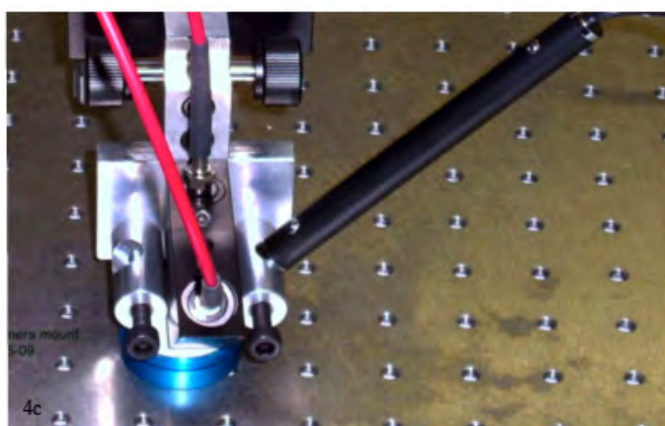


Figure 4a-c. Various probe designs to direct the xenon light to the surface being measured.

### 2.4 INTERNAL STANDARDS

With such high light fluxes it is not unreasonable to assume that the rate of color change would proceed faster than during ambient levels of exposure. For this reason attempting to calculate dose/effect (lux hours) and applying it directly to objects and their most sensitive colorant regions is not realistic and may lead to bizarre results. Rather, calibration is achieved by running internal standards and assuming that a colorant that changes similarly to a particular standard under these conditions will do the same under ambient ones. There are conditions when this assumption may be false and we shall outline them briefly in Section 5. For the time being suffice it to say that the internal standards used most often are the ISO Blue Wools. Michalski has frequently published the light-induced responses of these standards in the dose needed to achieve a “just noticeable change”. Just noticeable difference is used here to mean, in a simplified manner, the equivalent to a just perceptible color change (fade, darkening, hue shift) visible to an observer with average color perception under ideal viewing daylight conditions. The term is more formally defined by the CIE but is outside the scope of the present paper. Two technical reports often cited that embody these data have been published by CIE and IES

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(IESNA 1996; CIE 2004). As is the case for nearly all manufactured products, the ISO Blue Wools may need to be checked from time to time to determine if any manufacturing changes have impacted their performance.

### 2.5 SPECTROPHOTOMETER

The light reflected back from the surface is passed via a second quartz fiber to the spectrophotometer designed to handle fibers input. The instrument selected by Whitmore was, and still is, built by Control Development although it has gone through at least three major hardware re-designs. It is still employed by most users.

### 3. SOFTWARE DESCRIPTION

There are two levels of software control. The first operates the spectrophotometer spectral acquisition and conversion into colorimetric parameters that are then included and saved in a special header with each spectral file. The second level has tended to be written by individual users and takes portions of the colorimetry for plotting and subsequent interpretation. The user selects the colorimetry and data acquisition parameters. This is usually, but not necessarily limited to an illuminant of D65, 2° or 10° standard observers, CIELAB color space. In addition one or more of the three color difference equations may be utilized during interpretation. Spectral acquisition intervals at 1 or 2 minute intervals are most common.

### 4. INTERPRETATION

The original intent was to create an instrument that would identify objects containing light sensitivity on some portion of the artifact that is equivalent to ISO blue wool 1-3. In most discussions of preventive conservation and risk management, the most sensitive category comprise these three (CIE 2004). For ISO blue wool 1 a “just noticeable difference” is expected under typical museum light levels at a dose on or about 300,000 lux hours; ISO blue wool 2 at 900,000 lux hours; and ISO blue wool 3 at 2.7 million lux hours. Except for blue wool 1 these are often rounded up. These data are averaged values Michalski derived from work conducted in the 1950’s and 1960’s. Current work at GCI and CCI are seeking to establish if those values are still relevant for currently manufacturer ISO Blue Wool products. Those sound like large doses of light exposure, and indeed that might be, but they are tiny compared to the exposures that can accumulate over decades and centuries, not at 50 lux but at hundreds or even thousands of lux. It is remarkable that any colorant that is equivalent to ISO blue wool 1 could ever have survived from the 19th century let alone earlier. But the tendency to sequester hand-colored prints, drawing and early photographs in albums where many of them never literally “saw the light of day” has insured their survival with minimal modification. Finding them and providing highly restrictive loan and exhibition limits, even creating a category of minimal tolerance for exposure damage (Brokerhof 2008) has become a high value operation in some institutions.

The MFT can easily detect a colorant located within the ISO blue wool 1-3 range. Figure 5 illustrates an example of a blue pastel stick taken from the studio of Georgia O’Keeffe applied to Whatman filter paper and graciously provided by the Georgia O’Keeffe Museum in Santa Fe, New Mexico. Previously, ISO blue wools 1-3 were run and  $\Delta E$  is plotted versus time and represented by square symbols. Blue wool 1 is the highest, blue wool 2 is intermediate, and blue wool 3 the lowest. Mengs blue is represented by the dark circles. Measurements were taken at 60 second intervals for 30 minutes. Depending on what one wants to achieve in the interpretation, Mengs blue may be classified as equivalent to blue wool 2 because it shows a just noticeable fade

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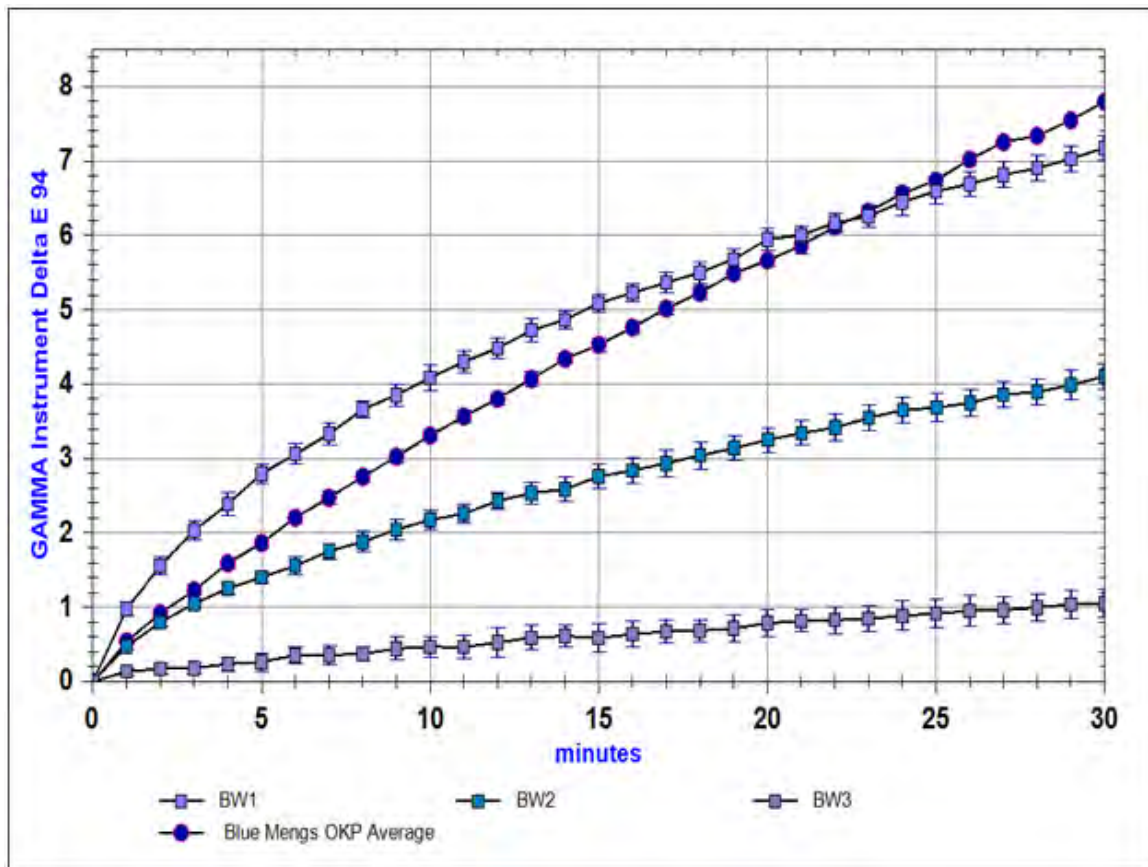


Figure 5. Mengs blue soft pastel from the studio of Georgia O'Keeffe compared to ISO Blue Wools 1-3.

*under ideal laboratory viewing conditions* closest to that standard after 2-3 minutes or as blue wool 1 because *under gallery lighting in complex compositions* color change is much harder to see and closer to blue wool 1 after 15 minutes. Regardless, blue wool 1 or 2 means that Mengs blue is highly vulnerable to light-induced damage. It is beyond the scope of this short article to further analyze this example but we shall suggest for the time being that because  $\Delta E$  for Mengs blue is also nearly a straight line and its overall chroma, as  $\Delta C^*$ , is regressing to  $a^*=b^*=0$ , its vulnerability is best served by assuming the higher sensitivity possible under all exposure conditions. These are the kinds of clues we look for during light aging.

Figure 5 shows that the color difference of Mengs blue was plotted using the 1994 CIE color difference equation. More commonly the 1976 equations are employed because it is easier to correlated  $\Delta E^*$  or  $DE_{76}$ , with older literature but there are advocates suggesting that both the  $DE_{94}$  and  $DE_{2000}$  equations should be used in preference to the old approach. In a following article by Druzik and Pesme this subject will be more thoroughly explored.

It is a matter of personal philosophy whether or not users of MFT-derived information are content using it to spot light-sensitivity and leave it at that, or take the next step and build exhibition display and loan restrictions policy around it. Both positions can be easily defended. The next section will outline just a few of the possible conditions under which MFT results could significantly over – or under-estimate light sensitivity.

## 5. LIMITATION AND STRENGTHS

When might the MFT under – or over-predict light sensitivity? The MFT compares favorably with other accelerated light aging instruments (Whitmore, Pan et al. 1999), yet it does have unique attributes the user should frequently take into consideration. The MFT is very precise and virtually invisible because the location for testing is so small. This means it is vulnerable to the same non-representationality as any other micro-sampling technique. This is particularly easy to see with watercolors. The density of pigment particle distribution will influence the apparent sensitivity. Both light washes and heavier body color will be capable of displaying smaller increases in  $\Delta E^*$  than a mid-density particle distribution.

Secondly, one must consider the testing location as an *entire system* not an isolated pigment with any single part, or all parts, capable of independent or inter-related changes. It is not uncommon for the paper substrate to show a spectral increase in the 400-500 nm range due to cellulose “bleaching”. The author has even seen “bleaching” in 100-years only white, presumably inert soft pastels, on Whatman filter paper. From testing we know lightening reactions on fresh Whatman filter paper are almost non-existent leaving one with the hypothesis that it is the aged pastel binder that may be lightening. As good as the ISO Blue Wool samples are, they are a woven textile and the position of the light beam and its geometry with respect to the weave may influence the outcome for the internal standard and hence all the assessments based upon it.

The MFT was created to locate the presence of sensitive colorant systems on artifacts. As sensitivity increases predictability becomes more problematic. Some colorants used towards the late 19th century for hand-tinting photographs are aromatic compounds with highly delocalized electrons that take very little energy to instigate transitions. It is not improbable for the energy of a single absorbed photon to participate several times between primary photo-induced and secondary reactions. If the photon flux is high this could accelerate overall change, keeping to the original ambient light aging mechanisms. Thus there is a risk of assuming a higher sensitivity than there may be for chromophoric systems like these.

We assume that light damage follows a reciprocity-type relationship but almost every known photographic process exhibits some reciprocity “failure” at the exposure extremes. The use of the term “failure” is traditional but regrettable, since the only thing that is really failing is the expectations of the photographer. There is no reason why, for pigments and dyes, reciprocity cannot behave more or less linearly over small line segments of a greater dose/effect *curve* and what we should be looking for ultimately are calibration curves that express these dose/effect relationships rather than a purely linear simplification.

Local environmental conditions modify fading behaviors. We know from the work of David Saunders (Saunders and Kirby 2004) that for some materials relative humidity plays an important role in their light-sensitivity. Some researchers have reported elevated temperatures at the spot and these are bound to have an influence on secondary reactions that may play out over time. Patricia Cox Crews in her work on dyes fading has called attention to the role of the particle’s physical state of agglomeration which impacts the rates of oxygen diffusion (Cox Crews 1987). Feller pointed out that reactions proportional to the square root of intensity, while never having been reported in conservation, nevertheless remains something to keep in mind (Feller 1994).

Lastly, we’ll remind the reader that the spectral power distribution of the MFT xenon lamp is not the same as that used to illuminate most light-sensitive artifacts. The source is filtered to remove wavelengths shorter than 400 nm but it is still a light source with a correlated color temperature between 5500 and 5700K. This gives it a



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higher proportion of shorter visible wavelengths than tungsten and halogen sources.

Given these limited observations, one could question how reliable MFT methods are for prediction. Preventive conservation often takes the position that risk management decision-making is nearly always limited by the concept of “bounded rationality”. That we, as humans, seek at all times to make rational decisions that are frequently beyond the computational scope of our abilities and are too complex to reliably predict anything with accuracy. Our decisions then evolve over time in the form of successively better approximations as the tools for making such approximations improve. Knowing these weaknesses, the MFT can still be validly used to set and enforce policy that may have had even less rationality afford for setting limits in the past. We all know that once paper-based objects were considered universally light-sensitive when almost nothing about their fiber or media selection pointed to unusually high irreversible light interaction. Taking a careful materials-oriented approach allowed us to partition out the more sensitive from the lesser sensitive ones. Perhaps, in the future the major limits of MFT will be better understood and give us more precision than we now have.

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# COMPARISON OF FIVE MICROFADING TESTER (MFT) DESIGNS

JAMES DRUZIK AND CHRISTEL PESME

**ABSTRACT** - In April 2009, the Netherlands Institute for Cultural Heritage (ICN) convened a meeting in Amsterdam to discuss the status of microfading research. It was clear that while approximately 12 of the 14 microfaders worldwide were built using the Whitmore design, considerable innovation had also taken place. In the absence of round robin testing at the time, concerns over the comparability of these innovations led the authors to purchase the parts needed to recreate five instruments for a side-by-side comparison. In this manner the instruments could be tested holding variables related to user experience and protocols constant. A set of seventeen test colorants were selected that included both new and historical materials. All three CIE color difference equations used in making color change assessments were evaluated. The question was asked, "How often would the microfaders facilitate an assessment to within  $\frac{1}{2}$  step of an ISO blue wool step in equivalent lightfastness?" As a result of those tests more than 12,000 spectra were collected and analyzed. The results stood out in good agreement and our  $\frac{1}{2}$  step criterion was matched or exceeded 70% of the time and was matched or exceeded to 1 full step 95% of the time. This paper describes the details of those experiments.

**COMPARACIÓN DE CINCO MODELOS DE TESTER DE MICRODECOLORACIÓN (MFT): RESUMEN** – En abril de 2009, el Netherlands Institute for Cultural Heritage (ICN) convocó a una reunión en Amsterdam para discutir el estado de la investigación sobre microdecoloración. Estaba claro que si bien aproximadamente 12 de los 14 microdecolorantes mundiales se construyeron utilizando el modelo Whitmore, también se había desarrollado una innovación significativa. Ante la ausencia de la planificación round robin en ese entonces, la preocupación de poder comparar estas innovaciones hizo que los autores adquirieran las partes necesarias para recrear cinco instrumentos para realizar una comparación paralela. De esta manera los instrumentos podrían ser probados manteniendo variables relacionadas con la constante de la experiencia del usuario y los protocolos. Se seleccionó un conjunto de diecisiete colorantes de prueba que contenían materiales nuevos e históricos. Se analizaron las tres ecuaciones de diferencia de color CIE utilizadas para realizar las evaluaciones de cambio de color. Se formuló la pregunta: "¿Con qué frecuencia los microdecolorantes posibilitarían realizar una evaluación a  $\frac{1}{2}$  paso de un paso ISO blue wool con una resistencia a la luz equivalente?" Como resultado de esas pruebas se recolectaron y analizaron más de 12.000 espectros. Los resultados concordaron bien y nuestro criterio de  $\frac{1}{2}$  paso coincidió o excedió en el 70% de las veces y coincidió con 1 paso completo o lo excedió en el 95% de las veces. Este ensayo describe los detalles de dichos experimentos.

## 1. INSTRUMENTS

The operations of the Oriel-based Microfading Tester (MFT) are described fully in the introductory paper to this series by Druzik and need not be repeated here. We shall only define the nature of the differences in the MFT "models" we tested. Readers who want more information may also refer to Whitmore's earlier article (Whitmore, Pan et al. 1999). Consider the MFT as having two distinct versions. A bench top version with a full-featured power supply, separate lamp housing, filter assembly, and light output control electronics, and a portable model which combines the lamp with a simplified power supply in one box, adds a limited filter package to one side and drops the need for light stability and control altogether. The possibility of a functional portable MFT was shown by Han Neevel at the Netherlands Institute for Cultural Heritage (ICN) using an Ocean Optics Miko-pack HPX-2000 light source. At GCI we modeled ours around a Newport 70529 Apex Fiber Illuminator. Figure 1 is a schematic illustration of the differences between the Whitmore bench top instruments and the portable variants.

Each of these two versions uses the same spectrophotometer and software but they may have three significantly different probes that focus the light to the surface that will be measured. One probe design uses the original

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four planoconvex lenses, the second probe substitutes four doublet achromat lenses, and the third does away with all lenses and employs a 6/1 bifurcated fiber optic. The first two probes employ a normal/45° reflectance geometry and the lensless probe is used for surface contact measurement. The lensless system was first used by Christopher McGlinchey at the Museum of Modern Art. The bifurcated fiber optic has a single 100 micron fiber channeling light from the lamp and joins with six other fibers in a cluster at the flat end of the fiber cable. Light passes through the central fiber, is reflected from, absorbed by, and scattered around the substrate and enters the adjacent six fibers that connect to the spectrophotometer – all within an area less than one half a millimeter in diameter.

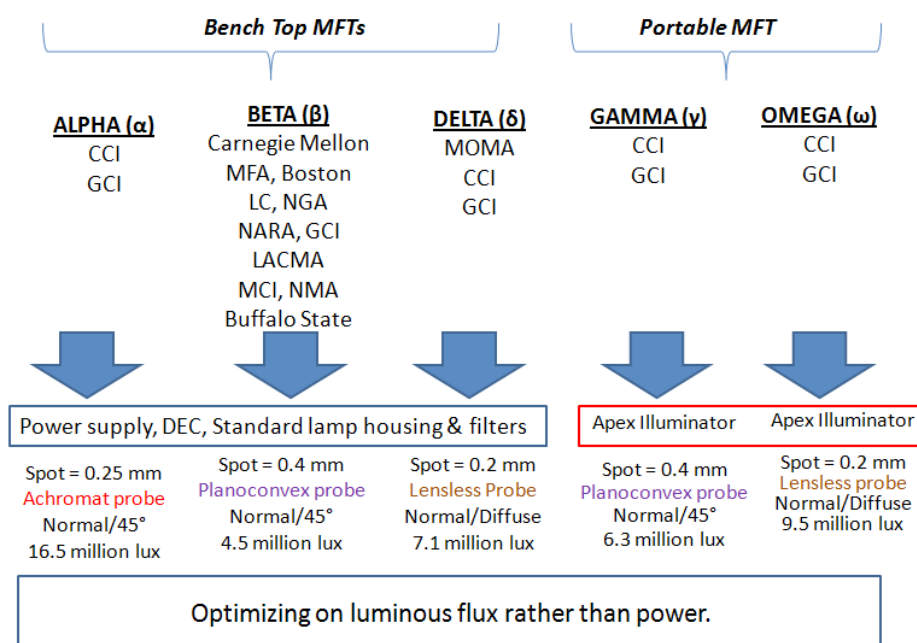


Figure 1. Schematic illustrating the five different instruments, which institutions uses each variation, and a comparison of spot size, luminous flux, and measurement geometry.

These probe modifications are not without unique optical ramifications. Achromat lens are designed to solve a problem with chromatic and spherical aberration. With chromatic aberration a normal lens fails to bring all wavelengths into focus at a single point. The phenomenon is called, in optics, dispersion, in which the phase velocity of a wave depends upon its frequency. The solution is often to create lenses of balancing dispersions. In this case the achromat selected is a doublet made by cementing two different types of glass together. This design results in a tighter focus. Both the planoconvex and achromat spots appear white but if they are enlarged one actually sees minor colored rings with the planoconvex lenses. The smaller spot size with these achromats result in a reduced spot area and thus higher lux equivalent exposures. At equal luminous flux, all else being equal, the planoconvex lenses will deliver about 40% the lux intensity of the achromats.

The situation is a little more complicated for the bifurcated fiber having no lenses. The Apex illuminator positions only a single pair of aspherical lenses between the xenon arc and the UV filter, hot mirror, and quartz fiber. The standard bench top configuration sports an adjustable aperture condenser lens. For the same 200 micron fiber used with the lensed probes this would not present a problem, but the bifurcated probe is only 100 microns in diameter. This insures some loss of bandwidth. The correlated color temperature measured with a PR-670 spectroradiometer from Photo Research ranges from 5000-5600K for the bench top instruments but only 3000-3300K for the Apex illuminator coupled with the bifurcated fiber. The difference in the spectral power



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distribution was expected to manifest itself in the final classifications of light sensitivity.

The five instruments were named Alpha, Beta, Gamma, Delta and Omega. Because the light apertures have three different diameters from instrument to instrument and lamps of different ages and performances - given that lux is defined as lumens per square meter - the five had different photon flux outputs in lux. We also varied the operating wattage as might occur under realistic operations. The output in lux for these evaluations were then: Alpha: 16.5 Mlux, Beta: 4.8 Mlux, Gamma: 6.3 Mlux, Delta: 7.1 Mlux, and Omega: 9.5 Mlux. Figure 2 shows a probe with planoconvex or achromat lens locations indicated.

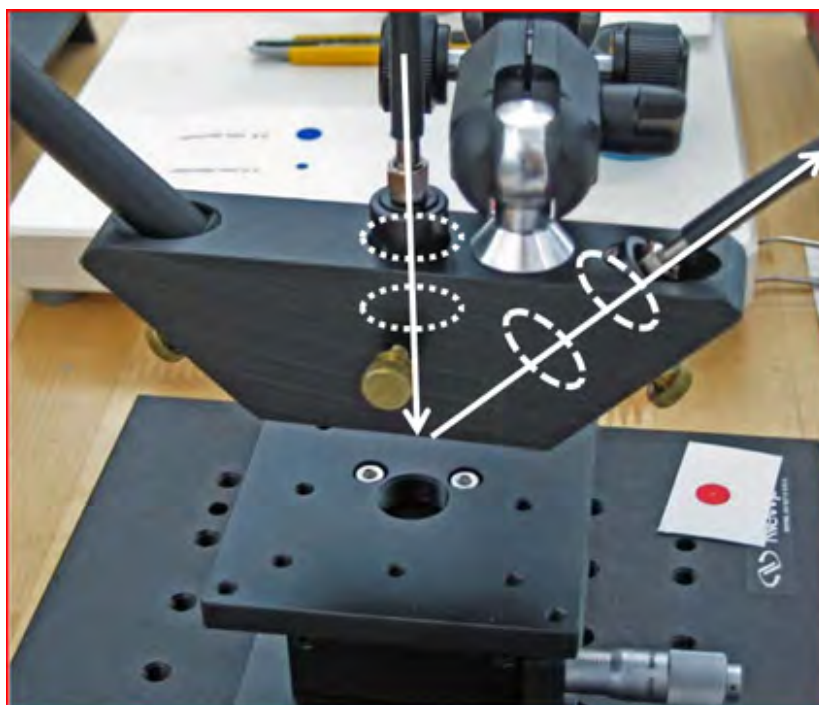


Figure 2. The probe is a solid machined block with one hole drilled vertically in the center and two holes at 45° angles. The dotted white circles show lens locations for the incident light path and the dashed circles are lens location for reflected light. The tube at the opposite 45° hole is for a small medical camera used for alignment and focus.

## 2. TEST MATERIALS

Table 1 lists the materials to be tested interspersed with copious runs of ISO Blue Wools 1-3 as internal standards. All samples were run with four replicates on each instrument of 30 spectra each at collection intervals of 60 seconds for a total of 30 minutes per run. The first eight colorant systems were taken from the GCI reference collection and contained two watercolors, two gouaches, and both pre-faded and unfaded black and purple construction paper. We had previously microfaded 100+ soft pastels left in Georgia O’Keeffe’s studio after the estate passed to the Georgia O’Keeffe Museum in Santa Fe, New Mexico that had been applied to Whatman #1 filter paper. We pick three of the most light-sensitive from the manufacturers, Weber (USA), Le Franc (France), and Mengs (Germany). Concluding the list was three early 20th century dyes on silk from a sample dye book in the collection of the Getty Research Institute from J.R. Geigy A.-G., and three dyes on cotton from a similar dye book produced by Agfa-Griescheum. Table 2 is the expected distribution of light sensitivities prior to testing.

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Materials	Preparation	Origin
Wild Rose (Martin Watercolors)	Wash on Whatman #1	GCI Ref. Coll.
Rose Bengal (Winsor & Newton, Gouache)	Airbrush on drawing paper Rhodamine/aluminum lake Fluorescent dye	GCI Ref. Coll.
“Rose Malmaison” (Winsor & Newton, Gouache) NMA	Wash on drawing paper BON arylamide red 1,2-dihydroxyanthraquinone	GCI Ref. Coll.
Alizarin Crimson (Winsor & Newton, Watercolors)	Airbrush on drawing paper BON arylamide red 1,2-dihydroxyanthraquinone	GCI Ref. Coll.
Purple construction paper	Dyed “construction paper”	GCI Ref. Coll.
Faded Purple construction paper	Dyed “construction paper”	GCI Ref. Coll.
Black construction paper	Dyed “construction paper”	GCI Ref. Coll.
Faded Black construction paper	Dyed “construction paper”	GCI Ref. Coll.
O’Keeffe Pastel: Emerald Green, Weber (USA)	Dry application on Whatman #1	GOK studio
O’Keeffe Pastel: Granance Cramoise, Le Franc (France)	Dry application on Whatman #1	GOK studio
O’Keeffe Pastel: Blue, Mengs (Germany)	Dry application on Whatman #1	GOK studio
J.R Geigy A-G. Acid Green	Dyeing on weighted crepe de Chine	GRI circa 1930’s
J. R Geigy A-G. Erio Cyanine A	Dyeing on weighted crepe de Chine	GRI circa 1930’s
J. R. Geigy A-G. Violet Diphenyl TS 0.5%	Dyeing on weighted crepe de Chine	GRI circa 1930’s
Agfa-Griescheum. Zambesi Red B 2.5%	Dyeing on cotton	GRI ca. Early 20 <sup>th</sup> c.
Agfa-Griescheum. Primulin 1, 1%	Dyeing on cotton. (Flavonoid)	GRI ca. Early 20 <sup>th</sup> c.
Agfa-Griescheum. Primulin 1. 5%	Dyeing on cotton (Flavonoid)	GRI ca. Early 20 <sup>th</sup> c.

Table 1. List of materials tested.

### Expected Sensitivity Distribution

≥ISO Blue Wool 1	ISO Blue Wool 2-3	≥ISO Blue Wool 3
Rose Bengal	Rose Malmaison (New)	Alizarin Crimson
Unfaded Black Construction Paper	GOK Le Franc Granance Cramoise	GOK Weber Emerald Green
Unfaded Purple Construction Paper	Agfa Zambesi Red	Agfa Primulin 1%
Wild Rose	Faded Black Construction Paper	Agfa Primulin 5%
GOK Mengs Blue	Faded Purple Construction Paper	
	Geigy Acid Green	
	Geigy Erio Cyanine	
	Geigy Violet Diphenyl TS	

Table 2. Expected distribution of light sensitivities for the 17 test materials prior to microfading.

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### 3. ANTICIPATED CURVE SHAPES

Patricia Cox Crews reviews various types of curves from the work of Giles and relates his hypotheses for their shapes (Cox Crews 1987). Three curves shown in figure 3 are seen an estimated 95% of the time in microfading. Type I curves are thought to be dyes molecularly disperses throughout a substrate. Type II, which shows a rapid fall-off is attributed to dye/pigment aggregates with some molecularly dispersed colorant responsible for the initial rapid loss. Type III curves are attributed to larger aggregates with a fixed constant visual change that is oxygen diffusion limited. Whether or not the reasons for these shapes reported by Cox Crews apply to microfading behavior is unknown and outside the scope of this investigation. But when we encounter them, we expect their shapes to remain similar from instrument to instrument. Likewise we would theorize that if the behavior remained the same regardless of light intensity, the fundamental chemistry, in the limited way it can be tracked though kinetic colorimetry would also remain the same or similar. Figure 4 shows CIELAB color data  $a^*$  and  $b^*$  for unfaded purple construction paper confirming the similarity of the dose responses for four series of runs between 4.8 million and 16.5 million lux. Figure 5 illustrates where the curves would occur if we had internal standards that represented blue wools 3, 2.5, 2, 2.5, 2, 1.5, 1, and two levels above 1. In reality we have only 1, 2, 3 (and unfaded purple construction paper which will serve as our most light sensitive calibration standard). We call unfaded purple construction paper “>>BW1” and the halfway point “>BW1” although we could also have used the terminology BW0 and BW0.5 as well. There were potential candidates for standards that are more sensitive than BW1 but at the time of the study all were far too sensitive to be used. We shall designate a tested material’s ISO blue wool equivalency as its “nearest neighbor” curve after 30 minutes of exposure.

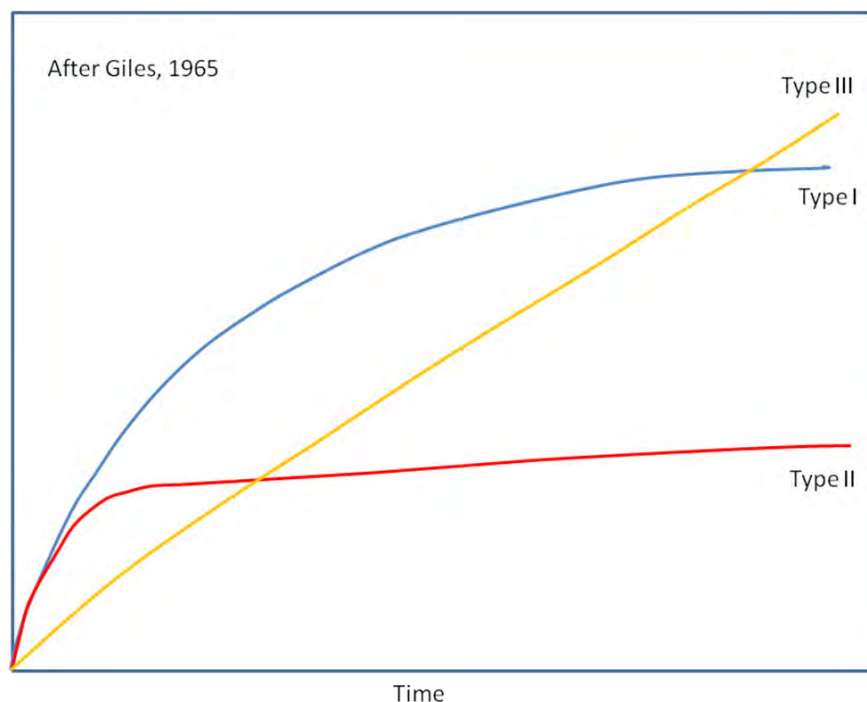


Figure 3. Expected curve shapes for colorant systems (Patricia Cox Crews after Giles).

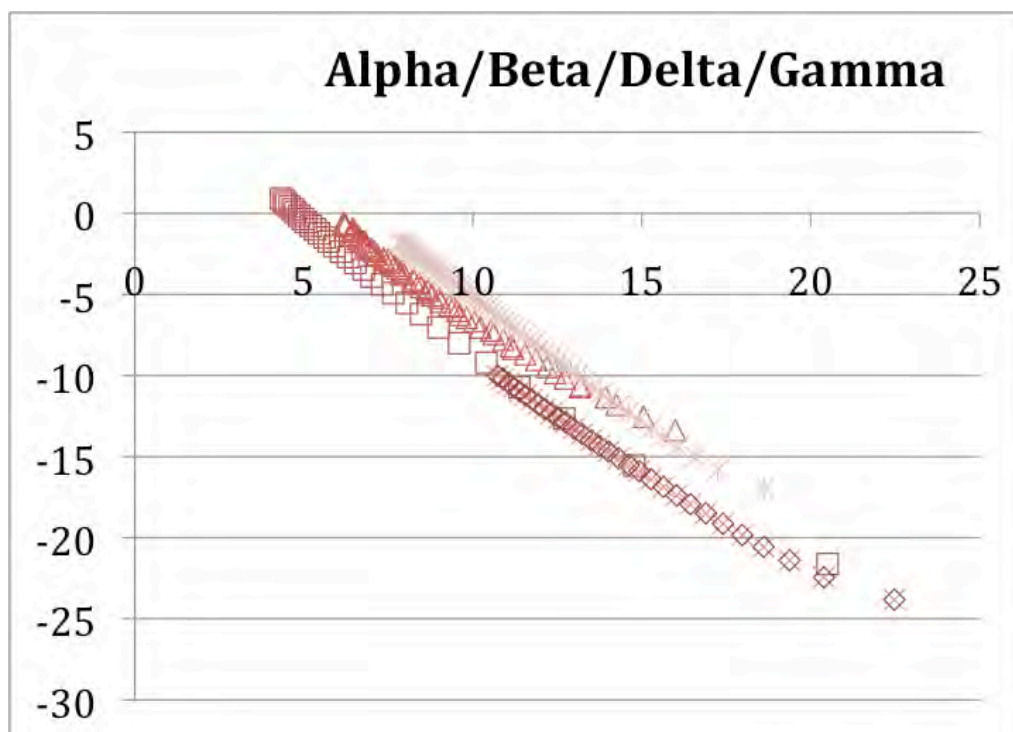


Figure 4. CIELAB  $a^*$  (y axis) plotted versus  $b^*$  (x axis) for unfaded purple construction paper at luminous fluxes ranging from 4.8 to 16.5 million lux.

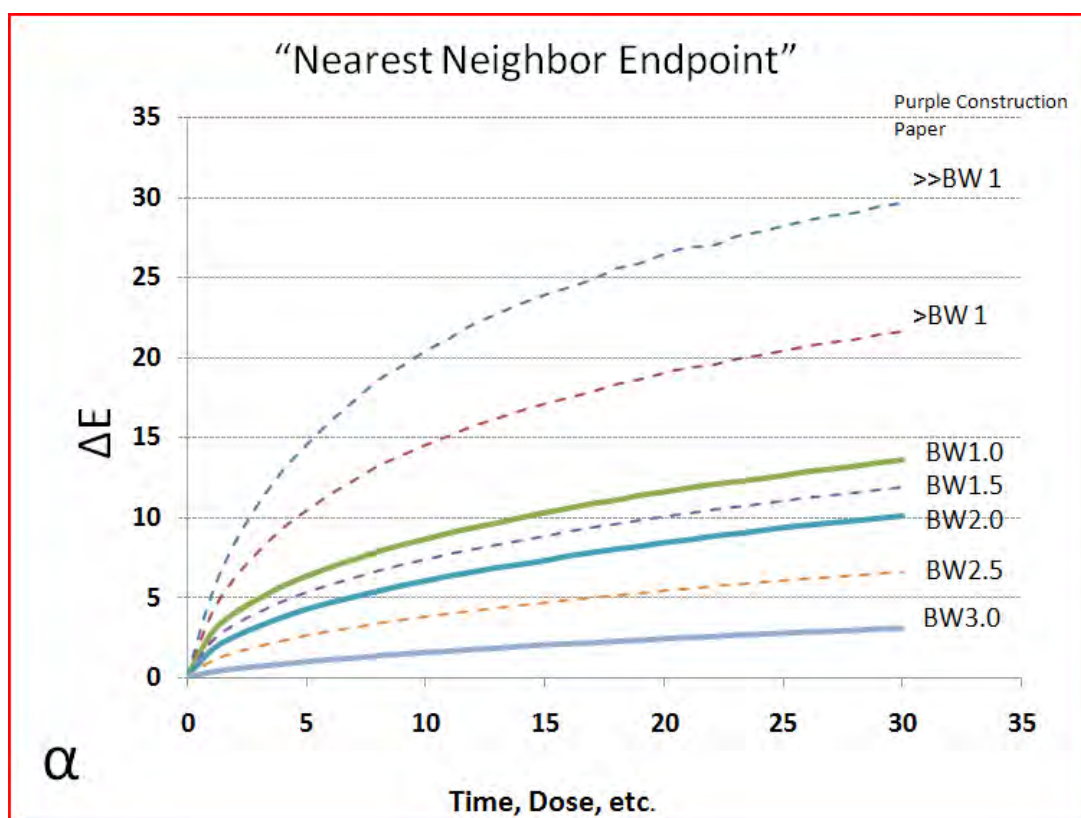


Figure 5. Endpoints for establishing ISO Blue Wool equivalency with tested materials.



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### 4. RESULTS

#### 4.1 AGREEMENT BETWEEN CIELAB COLOR DIFFERENCE EQUATIONS

It is assumed that the reader has a familiarity with basic colorimetry and CIELAB color space. Since it is beyond the scope of this paper to describe those topics fully, excellent discussions can be found in the literature (Berger-Schunn 1994; Berns 2000; Fairchild 2005). In 1976 the CIE published their first color difference equation to express the Euclidean distance between the  $L^*$ ,  $a^*$  and  $b^*$  coordinates.

$$\Delta E_{ab}^* = [\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}]^{1/2}$$

CIELAB color space was intended to be perceptually uniform but this goal in its creation was not strictly achieved (Fairchild 2005). To improve the uniformity of color difference measurements the CIE approved a modified equation, CIEDE94 that was recommended to replace CIEDE76 for industrial use in 1994.

Still more recently in 2000, a far more complex CIEDE2000 equation has been developed and Pretzel and Saunders have both begun using it in their conservation research (Saunders and Kirby 2004; Pretzel 2008). Notwithstanding these two researchers, for microfading color difference assessments there has been a general hesitancy to relinquish CIEDE76. The older equation has been a mainstay in conservation research making the idea of “backward compatibility” very attractive. Our study allowed CIEDE76 to float as the method *de rigueur* and asked if CIEDE94 or CIEDE2000 offered sufficient improvement to be recommended as a replacement.

Table 3 compares the assessments based on the three equations against four instruments and all seventeen colorants. The fifth instrument was added late in the study after we had already drawn our conclusions concerning the relative merits of the three equations from the first four instruments. The absence of DE76 and DE2000 in the column under the Omega instrument does not alter these conclusions but those conclusions do explain why we subsequently used DE94 when we included the Omega assessments in the final analysis.

It is probably not justified to go further than to draw general trends. The reasons are the following. We calculated color change kinetics on three equations, rounding up or down ISO blue wool sensitivity to  $\frac{1}{2}$  step intervals when comparing samples to their nearest blue wool internal standard. This was a subjective decision and influenced strongly by the cut-off time for the exposures. We chose 30 minutes because it appeared to treat the three most important curves shapes seen in figure 3 more accurately, but others may have chosen a shorter or longer exposure period. The nuances of the two more precise equations are blunted by the uncertainties in the risk assessment process. The two other restrictions are that the ISO blue wool scales are limited at the most sensitive end and several of our samples, as in real life, exceeded their range, and the MFT has restricted range below BW3.

Still, by assigning the values 0, 0.5, 1, 1.5, 2, 2.5, 3, and 4, we can draw some numerical inferences. Within a  $\frac{1}{2}$  blue wool step range, 95% of the assessments averaged over four instruments are in agreement whether based on curves derived from DE94 or DE2000. Assessment based on all three equations grouped within a range of  $\frac{1}{2}$  step averaged over four of the instruments, about half the time. For those instances where DE76-based assessments exceeded that  $\frac{1}{2}$  step range, the tendency was for DE76 to rank the samples as less sensitive than assessments based on either of the other two equations. The reason for this is not difficult to understand. DE94 and DE2000 calculate lower values for  $\Delta E$  than does DE76 for most colors and in the case of blue colors this can be a large difference. When chroma is low, all three equations converge to similar values. Examining results in Table 3 for faded black construction paper one easily sees this effect. The curves for faded black paper did not change with color difference equation but the curve position relative to the blue wool curves did change

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resulting in an average DE76-based assessment of 2.3 while DE94 and DE2000 were 1.0 and 0.9 respectively. For this reason we choose to recommend the use of DE94 because it is easier to implement than DE2000 and because for a small but significant number of samples it will render a more conservative evaluation of light sensitivity.

Colorant		$\alpha$	$\beta$	$\gamma$	$\delta$	$\omega$
Estimated luminous flux for each instrument as lux (in millions)		16.5	4.8	6.3	7.1	9.5
Rose Malmaison (New Formulation), Winsor & Newton Designers Gouache	$\Delta E_{76}$ $\Delta E_{94}$ $\Delta E_{00}$	BW3 BW2.5 BW2.5	BW2 BW1.5 BW1	BW2.5 BW2 BW1.5	BW2 BW2 BW2	BW2
Weber: Emerald Green (Pastel)	$\Delta E_{76}$ $\Delta E_{94}$ $\Delta E_{00}$	<BW3 <BW3 <BW3	BW3 <BW3 <BW3	<BW3 <BW3 <BW3	BW3 BW3 BW3	<BW3
Le Franc: Garance Cramoisie (Pastel)	$\Delta E_{76}$ $\Delta E_{94}$ $\Delta E_{00}$	BW3 BW3 BW3	BW2.5 BW2.5 BW2.5	BW3 BW2.5 BW2.5	BW2.5 BW2.5 BW2.5	BW2.5
Mengs Blue (Pastel)	$\Delta E_{76}$ $\Delta E_{94}$ $\Delta E_{00}$	>BW1 >BW1 >BW1	BW1 BW1 BW1	BW1 BW1 BW1	BW1 BW1 >BW1	BW1
AGFA: Primulin1 @1% (Dye)	$\Delta E_{76}$ $\Delta E_{94}$ $\Delta E_{00}$	<BW3 BW3 BW3	BW2.5 BW3 BW2.5	BW2.5 BW3 BW3	BW2.5 BW2.5 BW2.5	BW2.5
AGFA: Primulin 1 @5% (Dye)	$\Delta E_{76}$ $\Delta E_{94}$ $\Delta E_{00}$	BW2.5 BW2.5 BW2.5	BW2 BW2 BW1.5	BW2.5 BW3 BW3	BW2 BW2 BW1.5	BW2.5
AGFA: Zambesi RED B @ 2.5% (Dye)	$\Delta E_{76}$ $\Delta E_{94}$ $\Delta E_{00}$	BW2.5 BW2.5 BW2.5	BW2.5 BW2.5 BW2.5	BW1.5 BW2.5 BW2.5	BW1.5 BW2.5 BW2.5	BW2.5
Rose Bengal, Winsor & Newton Designers Gouache	$\Delta E_{76}$ $\Delta E_{94}$ $\Delta E_{00}$	>BW1 BW1 BW1	>>BW1 >BW1 BW1	>>BW1 >BW1 >BW1	>>BW1 BW1.5 >>BW1	>BW1
Alizarin Crimson, Winsor & Newton Watercolors	$\Delta E_{76}$ $\Delta E_{94}$ $\Delta E_{00}$	$\leq$ BW4 $\leq$ BW3 $\leq$ BW4	BW3 <BW3 BW3	<BW3 < BW3 BW3	BW3 BW3 BW3	<BW3
Black Construction Paper (Unfaded)	$\Delta E_{76}$ $\Delta E_{94}$ $\Delta E_{00}$	BW1 >BW1 >BW1	BW2 BW1 >BW1	BW2 BW1 >BW1	BW1 >BW1 >BW1	BW1
Black Construction Paper (Faded)	$\Delta E_{76}$ $\Delta E_{94}$ $\Delta E_{00}$	BW2.5 BW1 BW1	BW2 BW1 BW1	BW2 BW1 >BW1	BW2.5 BW1 BW1	BW1
Purple Construction Paper (Unfaded)	$\Delta E_{76}$ $\Delta E_{94}$ $\Delta E_{00}$	>BW1 >>BW1 >BW1	>>BW1 >>BW1 >>BW1	>>BW1 >>BW1 >>BW1	>BW1 >>BW1 >>BW1	>>BW1
Purple Construction Paper (Faded)	$\Delta E_{76}$ $\Delta E_{94}$ $\Delta E_{00}$	BW2.5 BW1.5 BW1	BW1 BW1 BW1	BW2 BW1 >BW1	BW2.5 BW2 BW1.5	BW1.5

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<b>Wild Rose, Ph Martin's Watercolors</b>	$\Delta E$ 76 $\Delta E$ 94 $\Delta E$ 00	>>BW1 >>BW1 >>BW1	BW1 BW1 BW1	BW1.5 BW1.5 BW1	>>BW1 >BW1 >BW1	>BW1
<b>GIEGY: Acid Green (Dye)</b>	$\Delta E$ 76 $\Delta E$ 94 $\Delta E$ 00	BW2.5 BW2.5 BW2	BW2.5 BW2.5 BW2	BW2.5 BW2.5 BW2	BW2 BW2 BW2.5	BW2
<b>GIEGY: Erio Cyanine A @0.5% (Dye)</b>	$\Delta E$ 76 $\Delta E$ 94 $\Delta E$ 00	<BW3 BW2.5 BW2.5	BW2.5 BW2.5 BW2.5	BW2.5 BW2.5 BW2	BW2.5 BW2 BW2.5	BW2.5
<b>GIEGY: Violet Diphenyl TS @ 0.5% (Dye)</b>	$\Delta E$ 76 $\Delta E$ 94 $\Delta E$ 00	BW3 BW3 BW3	BW3 BW2.5 BW2	BW3 BW2.5 BW2	BW3 BW2.5 BW2.5	BW2.5

Table 3. Comparison of ISO Blue Wool assessments based upon light sensitivity calculated from three color difference equations. >BW1 means the sample possessed a sensitivity to light greater than BW1. <BW3 means the sample possessed a light sensitivity less than BW3.

### 4.2 AGREEMENT BETWEEN INSTRUMENTS ISO BLUE WOOL ASSIGNMENTS

Figure 6 presents the agreement between all five instruments when DE94 was used to assign ISO blue wool equivalency to the seventeen test materials. Four of the seventeen materials were assigned identical sensitivities. Eight agreed to within  $\frac{1}{2}$  of a blue wool step making 71% of the materials achieving  $\frac{1}{2}$  step agreement or better. Four samples were within 1 full step and one sample ranged over  $1\frac{1}{2}$  steps. No material was misclassified as insensitive. In addition thirteen of seventeen samples agreed over three of the five instruments perfectly, and eight agreed over four of five.

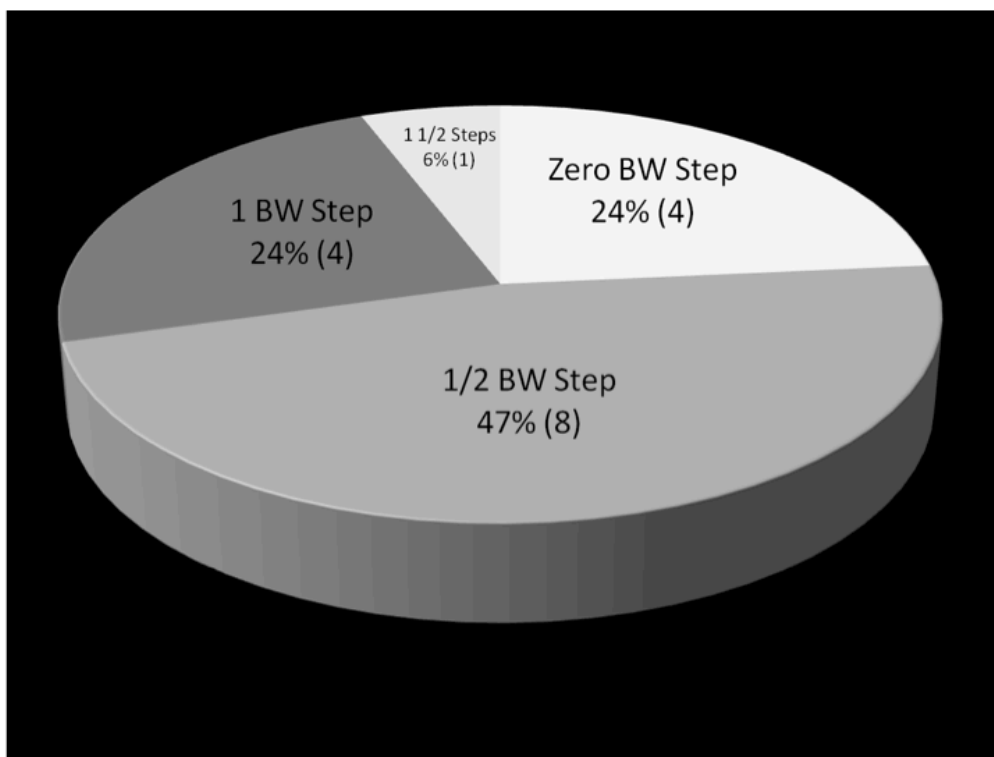


Figure 6. Agreement between instruments for assessments based upon the DE94 color difference equation.

While we recommend DE94 for making light sensitivity assessments, either DE94 or DE2000 can be used to examine the changes in colorimetry because of their similarity. Figure 7 shows how much color change was produced after 30 minutes for the most sensitive materials tested and figure 8 for the remainder. Both of these use DE2000 for the y-axis. In general, the microfader with the highest flux produced the most extreme color changes and the one with the lowest flux produced the smallest color changes. Figure 7 shows this very well. But not all materials behaved in this manner. Figure 8 shows that for the three Agfa dyes on cotton the more powerful Alpha instrument produced a lower color change than the Delta instrument which was significantly less powerful. This cannot be attributed simply to Delta's more efficient lensless probe because even the Beta instrument which had Whitmore original probe design produced larger color changes than the achromat-equipped probe of Alpha. At this point the reason for this apparently anomalous behavior is a mystery. Nevertheless, the degree of agreement with assessments based on DE94 given these large differences in luminous flux suggests that the technique is robust and similarly captures the behavior of these colorant systems with all the modifications made here to Whitmore's original design. The level of disparity that remains is probably consistent with the types of uncertainties attendant with risk assessment techniques in general.

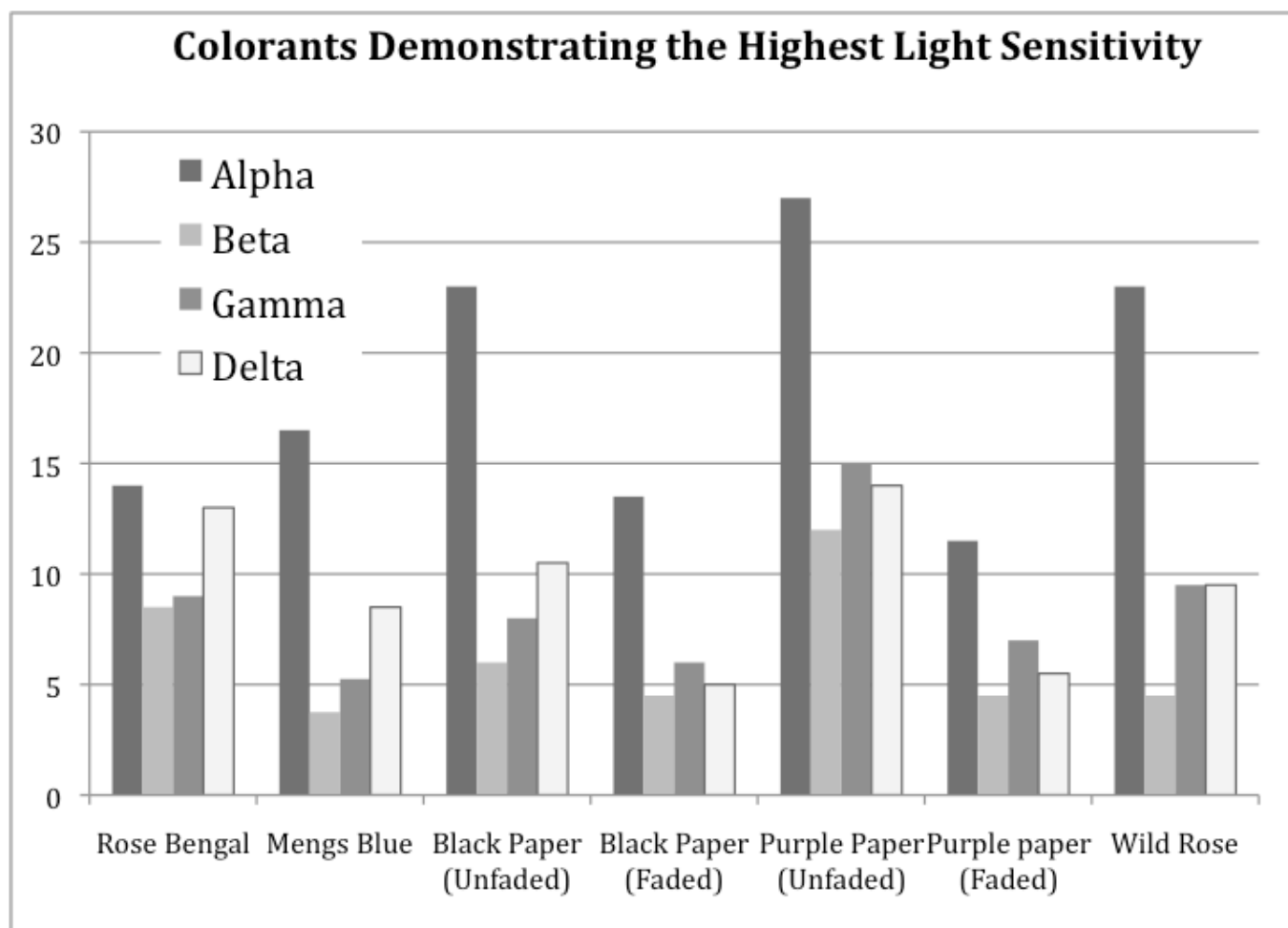


Figure 7. Plot of DE2000 after 30 minutes for seven of the most light sensitive colorants tested. Alpha represented 16.5 million lux exposures. Beta produced 4.8 million lux. Gamma produced 6.3 million lux. And Delta produced 7.1 million lux.



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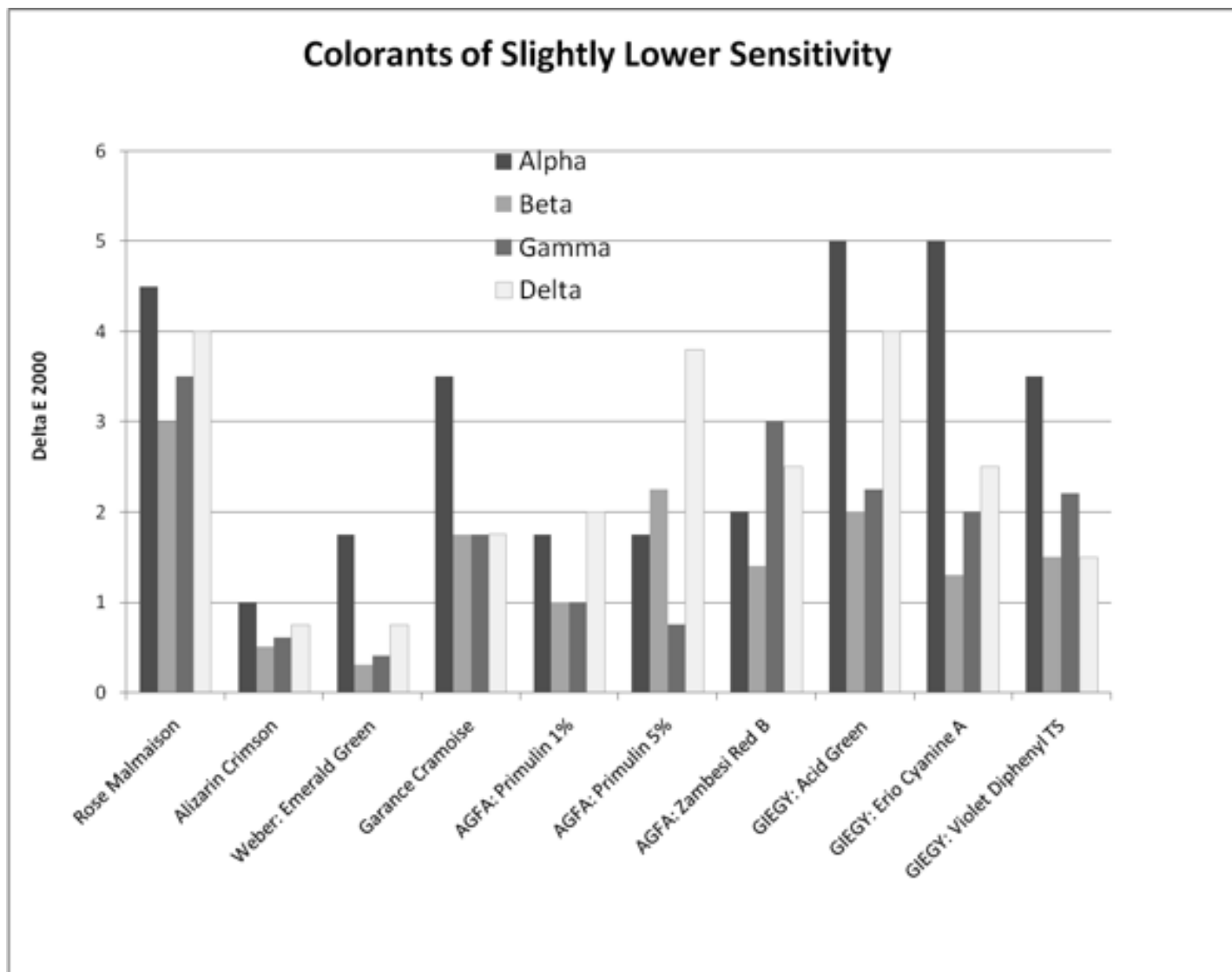


Figure 8. Plot of DE2000 for the materials with lower sensitivity.

## 5. CONCLUSIONS

After a meeting of users of the microfading technique in April 2009 at the ICN we became apprehensive at the range of experimental freedom users were taking in modifying and creating whole new designs for these tools. Since the majority of instruments were built upon the core design of Whitmore the decision was made to duplicate the innovations in our lab and test their reliability on a common set of materials. In the absence of a real round robin series of testing with a dozen institutions participating, we set out to test their equipment ourselves. Five instruments were created and assessments made on seventeen materials, running 4 replicates for each. Replicates for the blue wools were run frequently over the period of the study. Testing all three color difference equations it was determined that the any one of the equations, if used consistently, would provide reliable results but that DE94 had certain advantages justifying its recommendation.

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Four of the seventeen materials were assigned identical sensitivities by all five instruments. Eight agreed to within  $\frac{1}{2}$  of a blue wool step making 71% of the materials being assigned a  $\frac{1}{2}$  step agreement or better. Four samples were within 1 full step and one sample ranged over 1  $\frac{1}{2}$  steps. No material was misclassified as insensitive, nor were any of the known sensitive materials misclassified as not. In addition thirteen of seventeen samples agreed over three of the five instruments perfectly, and eight agreed over four of five.

As a result we feel that all the microfaders now being operated in figure 1 and table 4 should be able to engage in comparisons between laboratories with reasonable consistency and that databases of light-sensitive materials can feasibly be built with different contributors. The next step is to clarify the comparability of these instruments as operated by different individuals. There was no effort to compile the protocols that different individuals and institutions employ or evaluate the assumptions they use in making their own ISO blue wool assessments. These steps must wait for a later time when a true round robin cycle of testing can be accomplished.

### ACKNOWLEDGEMENTS

The authors would like to thank Mary Reinsch Sackett, Head of Conservation and Preservation, Getty Research Institute, for providing access to their 20<sup>th</sup> century dye books used in this study; and to all our colleagues at the J. Paul Getty Museum and The Getty Conservation Institute whose unfailing encouragement has continued to push us to new challenges in museum lighting. We also would like to thank Dale Kronkright, Conservator, Georgia O’Keeffe Museum for providing access to Georgia O’Keeffe’s soft pastels that were used in this study. We owe a debt of gratitude to Han Neevel at the Netherlands Institute for Cultural Heritage who inspired our search for our own portable MFT design. And of course, we wish to acknowledge Paul Whitmore who started this whole trend with a crazy lab notebook entry in 1994 and the perseverance to follow it through.

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38: 395-409.

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# **PROTECTING THE MOST IMPORTANT, MOST EXHIBITED AND MOST FUGITIVE MUSEUM OBJECTS FROM LIGHT-FADING**

**BRUCE FORD AND NICOLA SMITH**

**ABSTRACT** – In late 2007 the authors were asked to review the National Museum of Australia’s lighting guidelines because the Conservation and Finance Managers had serious concerns about the cost of light-driven object replacements. Two underlying factors, both potentially able to be addressed, were found to be responsible for the high replacement rate. The first was a lack of reliable fading-rate data for much of the collection, leading both to conservative and inflexible display restrictions and probable over-exposure of the most fugitive colorants, which could not be reliably identified. The second was an implicit assumption that, for the purposes of setting display periods, all objects are equally likely to be displayed, and therefore equally exposed to light over time.

The Museum subsequently acquired an Oriel® Fading Test System by Spectra Physics that has proven to be a highly cost effective means of distinguishing materials at real risk of unacceptable fading from those for which exhibition times may safely be extended. The micro-fading results inform a lighting regimen in which objects of high significance to the museum, and therefore likely to be in regular demand for exhibition, are given the same or less exposure per exhibition period than before, and the majority of less-used items allowed more exposure when exhibited. This dual approach allows the museum to concentrate its resources on the most important, most displayed, most fugitive – and therefore most vulnerable – colorants in the collection.

**PROTECCIÓN DE LOS OBJETOS DE MUSEO MÁS IMPORTANTES, MÁS EXHIBIDOS Y MÁS FUGACES DE LA DECOLORACIÓN POR LA LUZ: RESUMEN** – A fines de 2007 se pidió a los autores que revisen las normas de iluminación del Museo Nacional de Australia debido a que los Gerentes de Conservación y Finanzas tenían serias preocupaciones con respecto al costo de reemplazos de objetos afectados por luz. Se determinaron dos factores subyacentes, ambos potencialmente tratables, como los responsables del alto índice de reemplazo. El primero era la falta de datos confiables sobre el índice de decoloración para gran parte de la colección, lo que causaba restricciones de conservación e inflexibilidad de la muestra y probable exposición excesiva de los colorantes más fugaces, que no podían ser confiablemente identificados. El segundo era una presunción implícita de que, a los efectos de establecer periodos de exhibición, todos los objetos se exhiben de igual manera, y por lo tanto se exponen de igual manera a la luz con el paso del tiempo.

El Museo posteriormente adquirió un Sistema de Prueba de Decoloración Oriel® de Spectra Physics que demostró ser un medio sumamente rentable para distinguir materiales en riesgo real de decoloración inaceptable de aquellos para los cuales se podría prolongar con seguridad los tiempos de exhibición. Los resultados de la microdecoloración advierten de un régimen de iluminación en el cual los objetos de mayor importancia para el museo, y que tienden a tener una demanda regular de exhibición, reciben la misma exposición o menos por cada periodo de exhibición que antes, y la mayoría de los artículos menos utilizados reciben mayor exposición al ser exhibidos. Este doble enfoque hace que el museo concentre sus recursos en los colorantes más importantes, más exhibidos, más fugaces; y por lo tanto, más vulnerables de la colección.

## **1. INTRODUCTION**

The National Museum of Australia (NMA), which first opened to the public in 2001, is a social history museum tasked with representing the continent’s long human occupation. At present this is achieved through a series of ‘permanent’ exhibitions on the themes of Land, People and Nation that are refurbished every ten years, and through temporary exhibitions, usually of less than one year’s duration, which examine particular social and historical topics. The museum has a large and varied textile and natural fibre collection covering traditional and modern indigenous Australian and Torres Strait Island items, and non-indigenous textiles from the early colonial period of the late 18th century until the present day. These include colorants predating the first synthetic dyes of



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the mid-19th century, and a range of synthetic and natural dyes employed in hand and factory fabric dyeing and printing since that period.

Published fading rate data for these textiles, and a vast range of other colored objects in the collection, is sketchy at best; nevertheless light-exposure decisions need to be made on the basis of conservators' experience and the best evidence available. In 2000 the Conservation Department adopted a slightly modified form of the exhibition lighting guidelines (Tait et al 2000) developed at the Victoria and Albert Museum (V&A) in the late 1990s (Derbyshire & Ashley-Smith 1999, Ashley-Smith et al. 2002), which built on earlier work by Colby (1992). A similar approach was subsequently taken by the International Commission on Illumination in their technical report on the control of damage to museum objects by optical radiation (CIE 2004). In the NMA's implementation of the V&A guidelines objects of (estimated or assumed) lightfastness ranging from the most unstable down to ISO Blue Wool 4 (BW4) equivalent were labelled "sensitive", and with their exposure based on an average stability of BW2, limited to two years display at 50 lux. More stable material classified "durable" (BW5-7) and "permanent" (BW8) could withstand proportionally greater or indefinite cumulative exposures. Higher light levels could be traded off against shorter display times providing cumulative exposures were tracked over time.

Like the Netherlands National Museum of Ethnology, however, the Museum found that in practice "[the] amount of work that such an extensive replacement programme would entail ... [was] ... a major problem" (Reuss et al. 2005, 693). At an estimated average cost of \$1000 per light-driven changeover, including curatorial time locating and interpreting suitable replacements, registration activities, conservation, de-installation, re-installation, relighting and so on, application of the guideline was costing the NMA hundreds of thousands of dollars a year without a clear commensurate benefit. A way was needed to reduce costs and, perhaps even more importantly over the long term, address concerns that the BW2 average exposure for the 'sensitive' range over-exposed (by definition) the most fugitive materials. Another aim was to introduce more flexibility in lighting levels, including an option to exceed the 50 lux limit that in practice applied to most colored materials, and which for reasons outlined by Michalski (1997) are often too low for adequate viewing. These include low contrast and fine detail, viewing distance, darker objects and the inevitable decline in visual acuity that accompanies age related macular degeneration.

### 2. REVIEW OF LIGHTING GUIDELINES

When the Museum's past practices and experiences as well as a range of other museums' lighting policies were reviewed, two factors emerged as contributing most to the high cost of protecting the collection from excessive light damage. Each problem related to a different aspect of a general inability or unwillingness to impose exposure restrictions selectively rather than across the board.

The first and most obvious reason was gross uncertainty about the specific or even general lightfastness of the majority of the collection, which saw nearly all colored textiles classified as "sensitive" as a matter of precaution. With relatively few exceptions relevant light fastness data in the literature is limited to generalisations based on accelerated studies of newly prepared surrogate samples of mostly European historical interest. In practice it is rarely possible or economically feasible for conservators to routinely identify dyes and pigments. Even if this were not the case a colorant's identity does not determine crucial aspects of its light-fastness. Just as important are the extent to which fading has already occurred, dye preparation and application, substrate and other constituents, mordant type and concentration, depth of shade, pollutants and contaminants, washing, and the botanical origin and growing

conditions of natural dyes.

Ideally, exposures would be based on monitoring the color change of individual objects under museum lighting conditions, however while this is sometimes feasible (Ford 1992), it is extremely time consuming and difficult or impossible in many cases for technical reasons. Accepting that accelerated techniques are necessary, Whitmore's (1999) microfade tester appeared to be the most practical way of bridging the information gap because it offered routine, rapid, and non-destructive access to object specific fading rate data.

The second factor – which none of the published guidelines addressed despite being based on hypothetical display lifetimes of several hundred years – is the underlying assumption (for the purpose of calculating exposure limits) that all objects are equally likely to be displayed, and therefore equally at risk of fading over time. In reality only a small proportion of the potentially light-sensitive objects in the Museum's collection are in such constant demand. From this it follows that equally restricting access to all objects irrespective of their likely display frequency is a costly overreaction, and if there were a way to estimate an object's "future display history" the less likely-to-be displayed part of the collection (the majority) might be left on exhibition longer without exceeding the cumulative color change targets in the existing guidelines. This idea had the merit of potentially reducing the cost of light driven replacements even without better fading rate data, although it would do nothing to identify and safeguard the most fugitive colorants.

Garry Thomson (1986, 33), who is most often cited as the authority for limiting the display of nearly all potentially fugitive materials to short periods at very low light levels, had actually addressed both of these issues when he recommended 50 lux 'for all very valuable material[s] ...that are especially sensitive to light'. He succinctly summarises the case for selectively restricting display, however the qualifier "for all very valuable material" – referring to objects for which there is most exhibition demand and for which the loss of value is potentially greatest – appears to have been largely ignored as conservators rushed to conform to unofficial international "standards" and researchers focused their attention on fading rates.

### 3. USING SIGNIFICANCE ASSESSMENTS TO REDUCE LIGHT-DRIVEN OBJECT REPLACEMENTS

Identifying and ranking significance in a consistent and meaningful way for museums has been systematically addressed by the Collection Council of Australia (CCA), whose significance assessment methodology (Russell & Winkworth 2009) is based on the 1979 ICOMOS Australia 'Burra Charter' (ICOMOS 1999) which has been used for over 30 years to prioritise and guide conservation decisions for cultural sites. Notwithstanding that some conservators were trained to believe it is unethical to base conservation decisions on value judgements (the so-called Rembrandt Rule), there is nothing new or particularly controversial about doing so, in fact it is impractical not to. The Burra Charter has evolved into an approach to heritage management called "Values Based Management (VBM)" (UNESCO 2010) and there is a growing literature on the subject for museums, particularly in relation to risk management (Michalski 2004, Waller 2003) where significance is used to measure potential loss. It is endorsed by AIC's sister organisation in Australia, the AICCM, whose code of ethics states (AICCM 2002, 4):

[i]t is recognized that the significance of cultural material may have a bearing on conservation decisions. Accordingly ... the AICCM Member shall ensure that cultural material in her/his care receives levels of conservation appropriate to its significance and available resources.

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The CCA publication breaks significance down into four overarching socio-cultural categories: historic, aesthetic, research and social or spiritual. Objects or collections are ranked in relation to one another within these categories according to comparative criteria: provenance, representativeness, rarity, condition and, importantly for a social history museum like the NMA, interpretative potential.

A statistical analysis of past exhibitions revealed that it was necessary only to sort objects into two categories, 'high use' and 'the rest', to significantly reduce light-driven changeovers by allowing those in the second category to remain on display longer. An exposure guideline was developed (table1) in which objects not considered likely to be in continuous demand for exhibition would be 'downgraded' to the next most stable category where their total color change over time remains much the same or less than their equivalent sensitivity 'high use' counterparts. An object, for example, that would be limited to 2 years display on the basis of its assessed blue wool rating (4 replacements/permanent exhibition assuming it is replaced with similar objects), could be displayed for 5 years (1 replacement) if it were not in the "high use" group – a saving of 75% in replacement costs. In developing this guideline the V&A's color change limit of 1 Just Noticeable Fade (JNF)/50 years was retained, while recognising that, for various reasons, counting JNF's may not be realistic (Ford & Smith 2009). The specific display intervals were kept in place because they were already embedded in forward work schedules incorporating 2 and 5 year changeovers.

The two tiered approach in table 1 will be trialled when the administrative and organisational arrangements, such as how significance is documented, recorded and communicated, and how frequently significance assessments should be repeated to account for changing circumstances, have been finalised. In the meantime display durations are set as if all objects are in the high significance/high use category and exposure is determined purely on the basis of microfading results. The strong intention is to avoid applying the criteria mechanically or inflexibly because fading rates and light levels are only part of the decision making process; for example the handwriting on an important historic document was determined to be relatively lightfast (BW4-3) according to microfade testing, but only because it was already very faded. With this in mind the lighting recommendation was much more conservative than the fading rate data would normally indicate because the contrast between the yellowing ink and the parchment was already very low and would likely decline seriously with any additional change.

Eventually a combination of pre-selection using significance and more valid generalisations based on previous testing should cut the proportion of objects tested, with the caveat that it is not unusual for superficially similar materials to test very differently. For this reason all high significance objects will be fade-tested individually unless there are very good grounds for not doing so.

ISO (BW#)	< about BW2	about BW2 –3	about BW3 –4	> about BW4
	about 50 lux	50-100 lux*	50-150 lux*	100 -250 lux*
Exposure of high significance (high use) objects	individually decided	2 years/decade	5 years/decade	life of exhibition
Exposure of average significance (lower use) objects	Individually decided	5 years/decade	life of exhibition max 10 years	life of exhibition max 10 years

\*as low as possible consistent with good display.

Table 1. Significance based lighting framework, where BW = ISO Blue Wool Fading Standard, based on a color change target of less than 1 Just Noticeable Fade/50 years.

## 4. MICROFADING

The V&A's exposure recommendations for colorants less stable than BW4 are based on an average fading rate of BW2. This 'underexposes' the more stable colorants according to the 1JNF/50 year criterion, imposing unnecessary and costly access restrictions, and risks over-exposing colorants whose lightfastness is less than BW2. These are the very dyes and pigments that will suffer significant damage over a relatively short period of display, even under museum conditions. The logical way to contain costs (if one is reasonably sure of relative fading rates) is to allow those at the lower end of the 'sensitive' range greater exposure than the more fugitive ones, where the increase is justified by the twofold decrease in stability for each numerical step up the ISO Blue Wool increments. This approach was adopted by the Netherlands National Museum of Ethnology, whose conservators subdivided the 'sensitive' range into 'sensitive 1' (BW1 or worse), 'sensitive 2' (BW2-3) and 'sensitive 3' (BW3-4), with an additional 'vulnerable' category containing 'sensitive 1' objects that are also pristine (Brokerhof et al. 2008). Incidentally, the last category is actually a significance judgment based on 'condition' and probably 'rarity' as well, since pristine-ness is not a common characteristic of historic materials of low lightfastness. We believed that in practice, however, sorting objects in the Museum's very diverse collection into such narrowly defined categories would often amount to little more than guesswork.

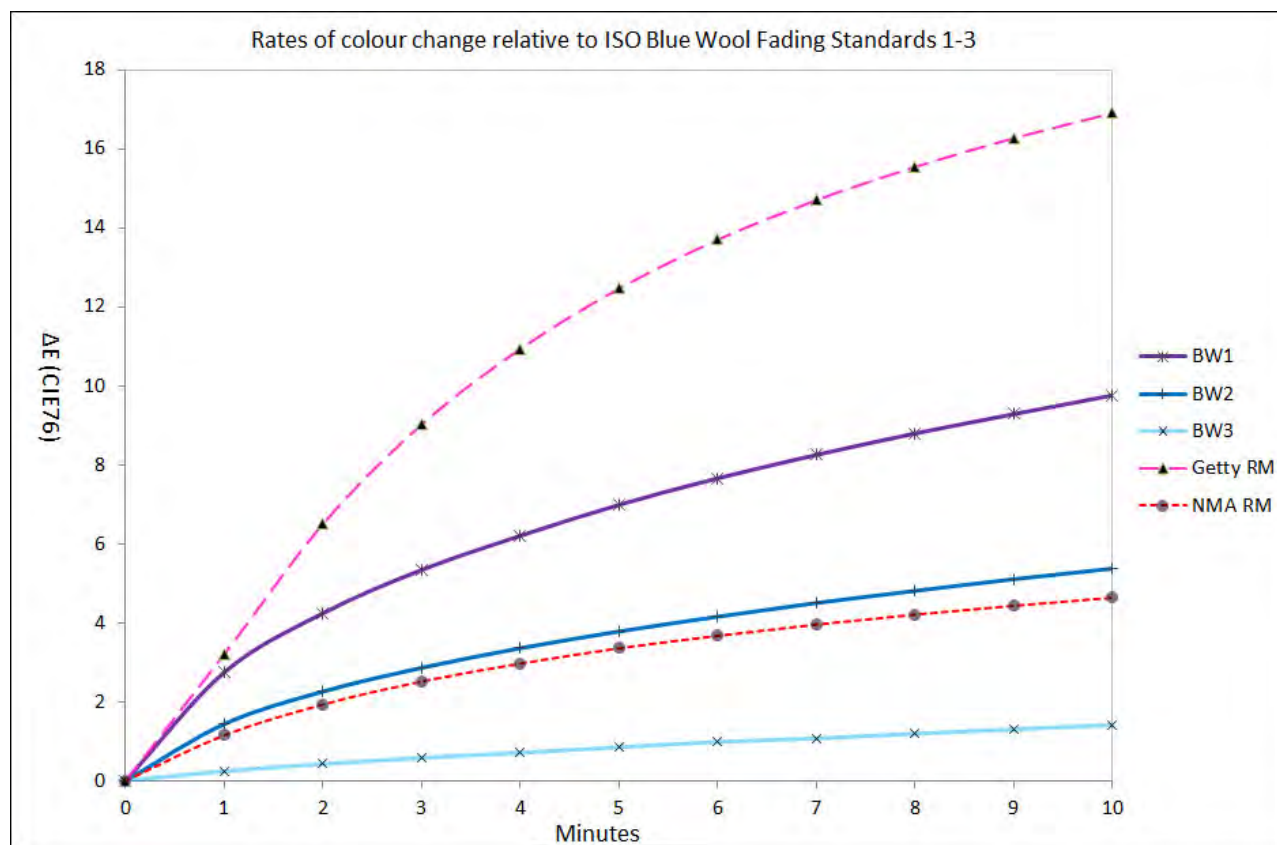


Figure 1. Fading rate curves, separate tubes of W&N Rose Malmaison purchased in the USA (Getty) and Australia (NMA).

In 2008 the Museum acquired a Newport Oriel® Micro Fade Tester and since then accelerated lightfastness measurements have been made on hundreds of objects representing well over 1000 colorants. Direct measurement approaches like Whitmore's (1999), and also Pretzel's (2000, 2008) studies of the Bullerswood and Ardabil Carpets, cut through the maze of unknowns (and unknowables) by rapidly and non-destructively quantifying – to the extent possible with accelerated ageing – the lightfastness of the item intended for display. It is completely



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unnecessary to know the identity of colorants and substrates or specific dyeing processes and subsequent history; although where this kind of information is available it provides a fascinating physical and chemical context for micro-fading results.

Conversely there is good reason to believe that with the benefit of accumulated data on relatively well characterised colorant and substrate systems, micro-fading will complement existing analytical methods on the basis of reflectance spectra and spectral and colorimetric change under test conditions. A glimpse of this potential is provided in figures 1 and 2, where two very similar paints are clearly distinguishable by their fading rates and colorimetric change. The spectral data (not shown) provides additional information.

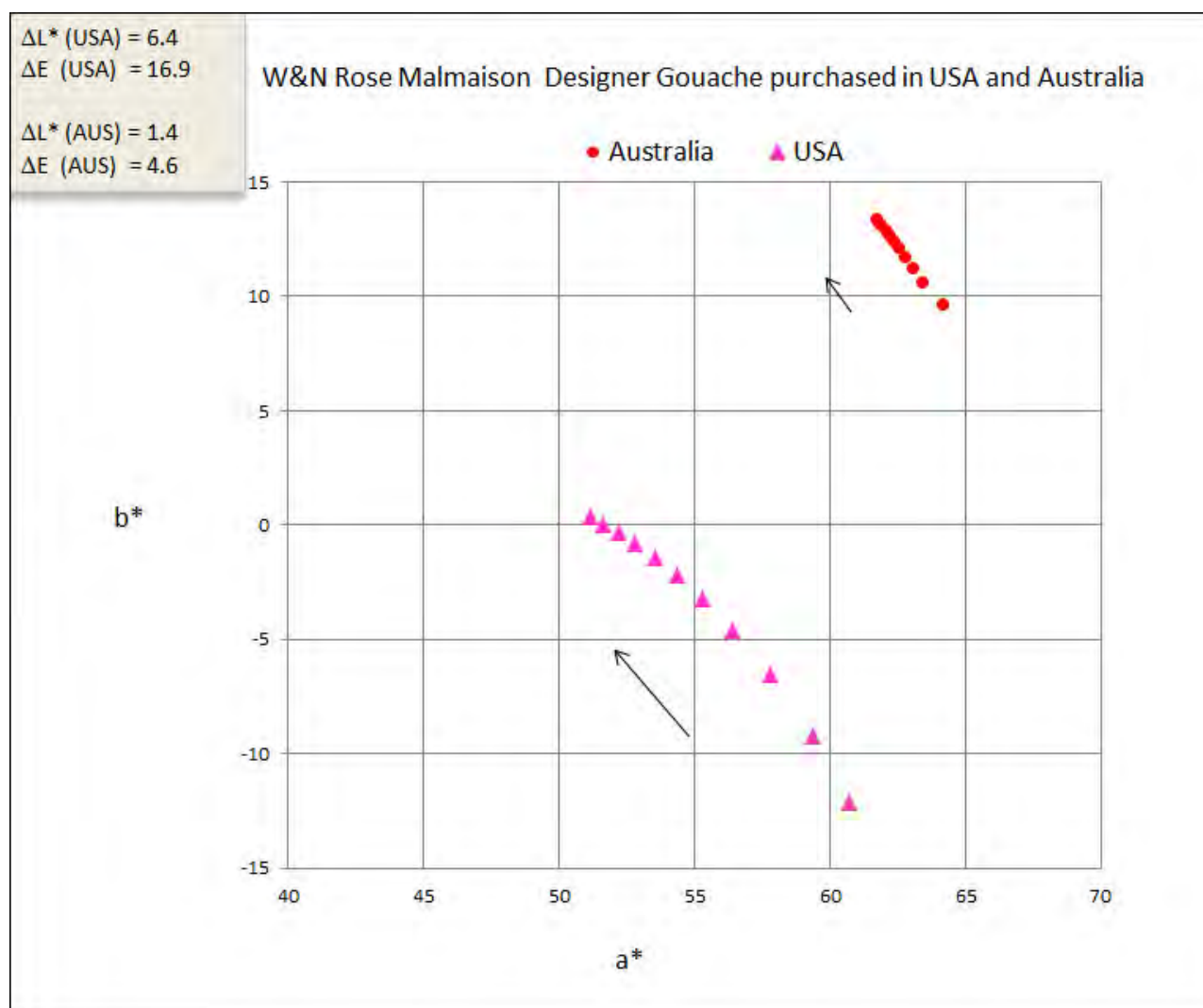


Figure 2. CIEDE76  $a^*$   $b^*$  plot, W&N Rose Malmaison USA and NMA. Clearly shows the two paints are different.

One of the difficulties with using the existing tables is that the assumed stability depends on qualifiers such as “most” (furs), “cheap” (synthetic colorants) “good quality” (acrylics, paper) or “carbon” (inks), however even leaving aside prior exposure and other factors that profoundly affect fading rates, how is the exhibition conservator to tell? In fact, one of the most consistent lessons from microfade testing is that lightfastness is often unpredictable. Winsor and Newton’s ‘Rose Malmaison’ designers’ gouache is a

good example. Two different tubes of this rhodamine based paint, which has a manufacturer's light fastness "c" rating (poor), were microfade tested by the GCI and the NMA. Its lightfastness had also been determined by microfading and published by Whitmore (1999); the labeling of the two tubes (one bought in the USA and the other Australia) were identical; both were painted out on filter paper; and neither had received prior exposure to light. Furthermore according to Winsor and Newton there had been no changes in formulation. This is the best possible scenario for using V&A or CIE type heuristic guidelines, however the paint from each of the tubes reproducibly faded at very different rates and occupied different positions on the  $a^* b^*$  plane of the CIE76  $L^*a^*b^*$  color space (figs. 1 & 2). Exposures based on the NMA's tube at BW2 would seriously overexpose paint from the GCI's tube, which was much less stable than BW1.

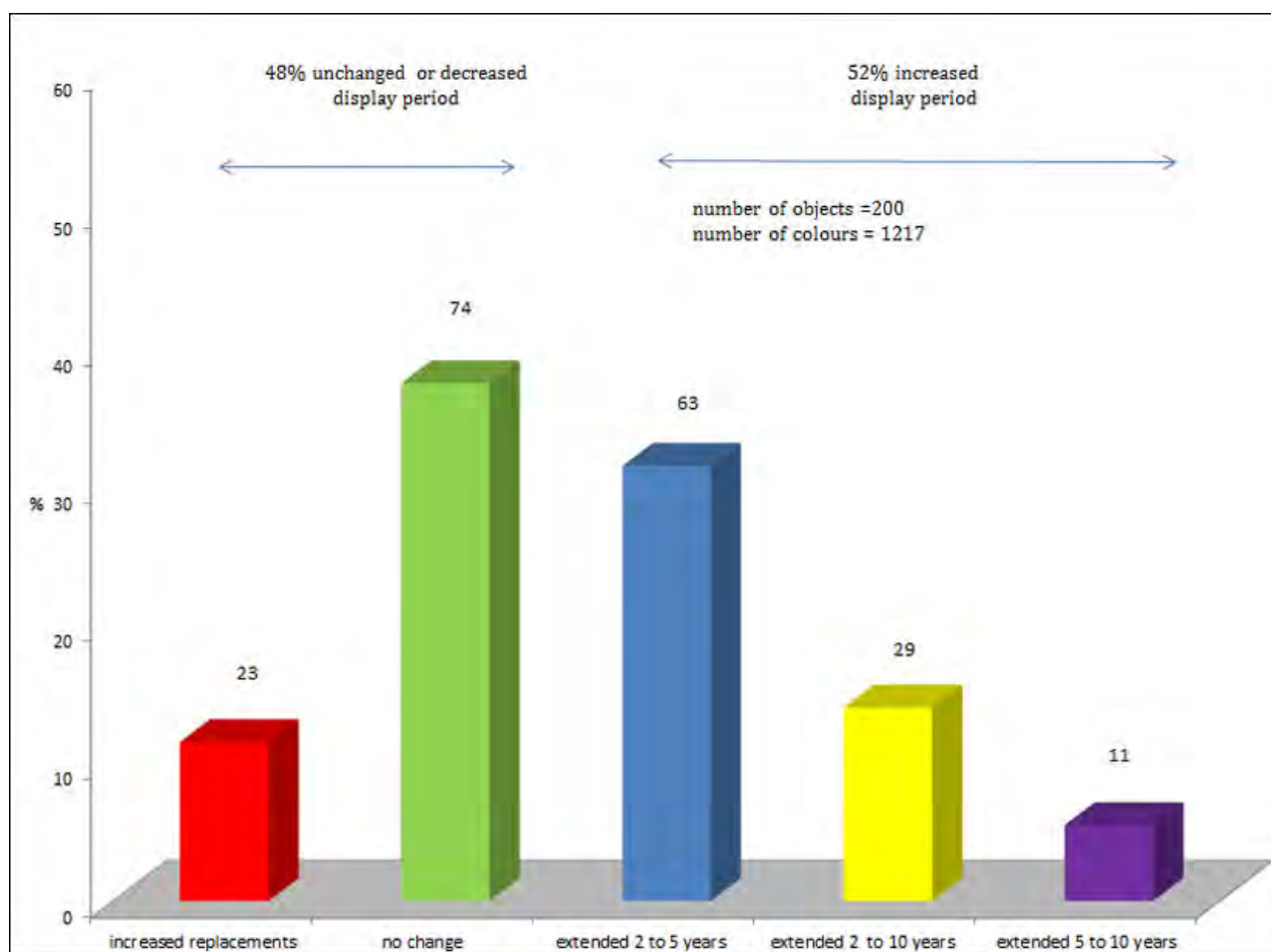


Figure 3. Changes to recommended exhibition duration based on microfade testing of 200 objects selected for exhibitions during 2009-10.

Shortly after the acquisition of the O-MFT routine microfade testing began on most colored objects destined for 'permanent' exhibition, ranking their lightfastness against the ISO Blue Wool fading standards 1-4. In most cases, the exhibitions in question were already in place; however changes to light-driven replacement rates for 200 objects in figure 3 show that if microfade testing had been carried out from the outset, 70-80% of replacements would have been avoided over the exhibitions' (10 year) display cycle. At \$1000/replacement, this would represent a saving in the order of \$700,000 to \$800,000 per year to the museum. As it is for the 200 objects tested, more than 800 changeovers have been saved over the remaining lives of the exhibitions, largely by extending

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the display of objects in the two year category out to five. According to these figures the benefit of microfading is at least an order of magnitude greater than the cost of testing.

As expected, a significant minority of objects (12%), some of them very important, would certainly have been over-exposed if they were displayed for 2 years at 50 lux according to the criteria underpinning the old heuristic guidelines. While many of them were predictable (daylight fluorescent colors for instance) others were not: for example black inks on good quality paper and even artists' acrylic paints which under the old NMA guidelines (Tait et al 2000) were all considered "durable" and eligible for permanent display at 150 lux.

### 5. CONCLUSION

Lighting decisions are often a source of tension in museums where conservators have been cast – or cast themselves – in the unfortunate role of "lighting police" (Michalski 1990, 586). It is uncomfortable to enforce rules based on inadequate data, especially when it has such a serious impact on access, other people's work, and operating costs. Collection care is increasingly defined as a process of "making well informed decisions to prioritize and allocate resources to optimize the value of our collections" (Brokerhoff 2006, 1) and in the context of light exposure, museums badly need the better data microfading affords. A significance filter will help to identify objects in high demand and therefore more exposed to light over time, and also more broadly to define the values which conservation aims to protect, whether they are physical integrity, historical and spiritual associations, information content or pristineness. In this sense the lighting project is a useful test case for the wider introduction of risk management principles based on minimizing loss of value(s) (Waller 2003). Even in relation to color alone there are factors other than light whose effects need to be weighed up against exposure related damage, for example thermal yellowing, or physical changes to feathers where color is partly or wholly structural in nature.

The Museum's old lighting guidelines resulted in well-intentioned, but unnecessary over-protection of about half of all objects in long-term displays, and over-exposure of a vulnerable minority that are not easy to predict. Their application seriously limited access to many objects and spread the available resources over the whole collection instead of concentrating on the objects at greatest risk. A greater than necessary number of sometimes fragile objects were subjected to physical interventions and handling, and unreasonably low exhibition light levels were generally adopted. While microfading is a relatively new technique, and there will always be uncertainty about the correlation between accelerated and museum fading in any particular case, there is little doubt that at worst it reliably flags very fugitive colorants. It is the best available scientific risk management tool to selectively limit light damage at this time, and it has given the NMA the confidence to display its collection to best advantage now, and to keep it for the benefit of visitors and scholars well into the future.

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# MICROFADE TESTING OF 19TH CENTURY IRON GALL INKS

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AND MARIA TROJAN-BEDYNSKI

**ABSTRACT** - The Oriel Microfade Tester (O-MFT) was used to test five sample sets of 19th century iron gall inks, with and without aqueous treatments, and after previous light exposure. The results showed that these inks belong in the category of BW1-3 which means they have 'high light sensitivity'. There are very light sensitive components in the ink which can be partially removed by aqueous treatments resulting in lower sensitivity to light. In addition, calcium phytate reacts with some inks making them less light sensitive.

**PRUEBA DE MICRODECOLORACIÓN DE TINTAS FERROGRÁFICAS DEL SIGLO 19: RESUMEN** – Se utilizó el Tester de Microdecoloración Oriel (O-MFT) para probar cinco conjuntos de muestras de tintas ferrográficas del siglo 19, con y sin tratamientos acuosos y después de exposición a la luz. Los resultados demostraron que estas tintas corresponden a la categoría de BW1-3, lo que significa que poseen una 'alta sensibilidad a la luz'. Hay muy pocos componentes sensibles a la luz en la tinta que se pueden remover parcialmente mediante tratamientos acuosos para lograr una menor sensibilidad a la luz. Asimismo, el fitato de calcio reacciona con determinadas tintas y las hace menos sensibles a la luz.

## 1. INTRODUCTION

Since 2008, the Oriel Microfade Tester (O-MFT) has been used at the Canadian Conservation Institute for direct determination of light sensitive materials. The first of two testers was built based on Paul Whitmore's original design (Whitmore 1999), and the second was built with a more portable light source. The materials tested include herbaria specimens in Catherine Parr Traill scrapbooks, Queen Victoria's written dedication and signature in iron gall ink, 19th century photographs, wool yarns with natural dyes and mordants, treatment materials such as digitally printed textiles and paper, and oil and acrylic paintings. Among the historic colorants and media tested, iron gall inks were found to be among the most light sensitive (BW1-3). Since many Canadian historic documents written in iron gall ink suffer from ink fading rather than ink corrosion, it was necessary to understand the effect of light exposure on historic iron gall inks, in order to determine exhibition protocols.

### 1.1 COLOR OF IRON GALL INKS

The color of historic iron gall inks vary from light brown to dark blue black, and their fading properties also vary. It is well known that both high (pH above 8) and low (pH below 4) pH can cause these inks to change color (Krekel 1999, Reissland 2001). Other factors that influence ink color include the type and concentration of tannin in the gallic acid source, the proportion of Fe(II) and Fe(III) in the iron source, the ratio of gallic acid to iron ions and the method of preparation (Krekel 1999, Sistach *et al* 1993, Sistach *et al* 1999, Daniels 2000). Since historical iron gall inks are made from natural products, all of these factors play a role in determining the properties of the inks, and result in the wide range of color and stability of these inks.

### 1.2 LIGHT SENSITIVITY OF IRON GALL INKS

When applied on textiles, gallotannin dyestuff with iron mordants is reported to have medium light sensitivity (BW5-6) (Hofenk de Graaff, 2004). On paper these ferro-gallotannin colorants are more light sensitive. The difference may be due to the larger size of the color complex, better adsorption and higher concentration as a dye used for textiles compared to iron gall ink used on paper.

The light sensitivity of iron gall inks has been studied by Reissland and Cowan (2002). Using laboratory

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prepared and aged inks, they systematically evaluated the degree of color change as a function of different molar ratios of iron ions and gallic acid. They found that most of the color change from the inks are a result of increase lightness ( $L^*$ ) and increase yellowness or loss of blueness ( $b^*$ ). They also observed that after exposure to an intermediate stage of oven aging, the inks that have higher ratio of iron sulphate relative to gallic acid, tend to be more light sensitive. This is attributed to iron catalyzed oxidation of ink/paper components forming light sensitive components. At the same degree of heat aging, inks that have higher proportion of gallic acid are less light sensitive, possibly because of the antioxidant qualities of gallic acid. With further oven aging this trend reversed, suggesting that the light sensitivity of inks may be a function of the stage of aging. The study confirmed that iron gall inks are light sensitive, the degree of sensitivity is a function of their composition and exposure history.

### 1.3 IRON GALL INK TREATMENTS

The treatments investigated in this study are aqueous deacidification treatment using calcium bicarbonate for neutralizing acids in iron gall inks; paper simmering – an extreme washing treatment that is very effective in removing water soluble compounds including acids and Fe(II) ions, and degradation products; and calcium phytate. Calcium phytate is one of the most effective and proven treatments for preservation of iron gall ink documents over the past 15 years. Made from naturally occurring phytic acid, calcium phytate acts as an antioxidant by forming strong complexes with excess Fe(II) ions in the ink, preventing them from catalyzing oxidation of the substrate, at the same time without destroying the ink complex (Neevel 2001). A detail background of this treatment and an optimized procedure can be found in the Ink Corrosion Website (Reissland *et al* 2007).

### 1.4 MICROFADE TESTING OF HISTORIC INKS

In this study we use historic inks instead of lab prepared inks. While this eliminates the need to extrapolate results from model inks, one should accept that the results may not be representative due to large variations in historic ink compositions and matrix. The selected ink samples are from an ongoing study evaluating the effect of aqueous treatments on iron gall inks, where five original 19th century iron gall ink documents were subjected to 18 separate treatments (Orlandini 2010). Eight of the 18 sets of treated samples were subjected to further accelerated aging by heat, high humidity and high intensity light (Tse *et al*, 2010). This study investigates the effects of selected treatments on light sensitivity of iron gall inks.

## 2. EXPERIMENTAL

The Oriel Microfade Tester (O-MFT) is shown in Figure 1. The settings and the characteristics of the light spot are summarized in Table 1. Details of the construction and operation of the tester were previously described by Whitmore (1999), and summarized by Druzik (2010). One modification was made from the Whitmore design. Two sets of doublet achromat lenses were used for illumination and collection, instead of the singlet lenses in the original design. The diameter of the light spot was estimated to be 0.3mm using image analyses of the effective faded spot (Young 2008). An Endoscope pencamera was used to locate and document the light spot on the test areas. The luminous flux of the light spot was measured using ILT900 spectroradiometer and an integrating sphere calibrated for point source.

Microfading tests were carried out for 10-minute periods, and spectral data was collected every 30 seconds. Data processing was done using the Getty Spectralviewer, software developed by Lionel Keene. Prior to testing

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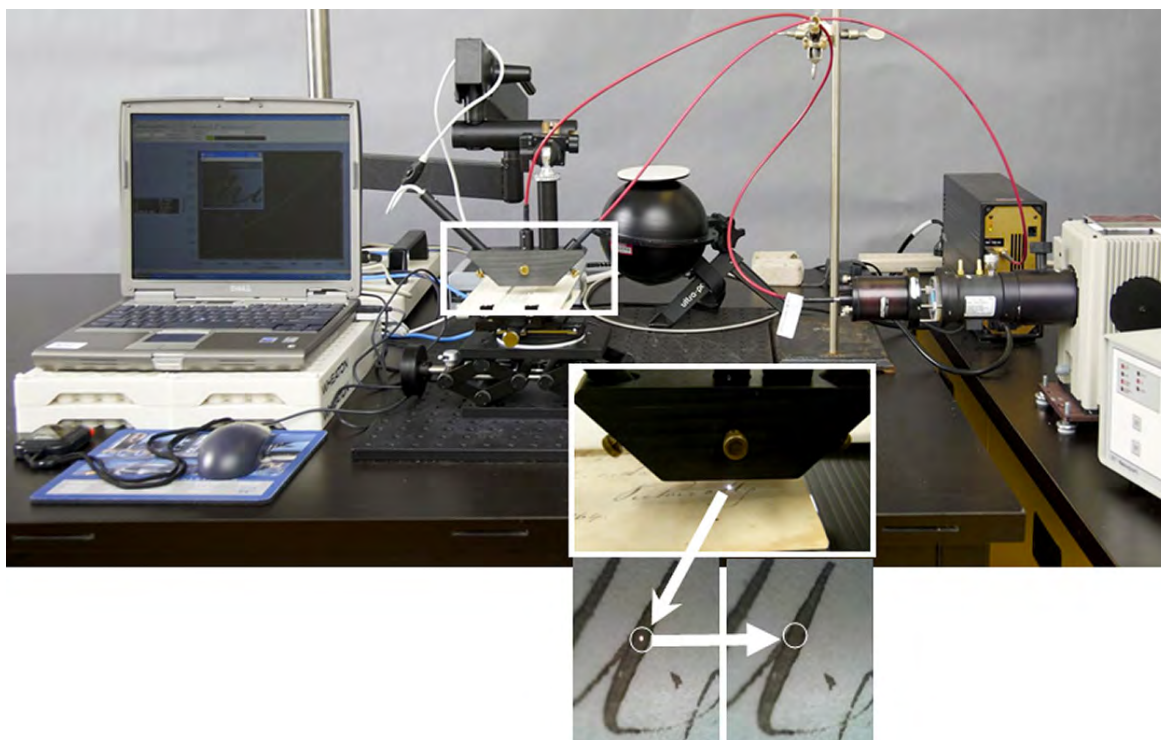


Figure 1. The CCI benchtop Oriel microfade tester. The small white spot in the magnified image of the inkline is the light spot viewed through a neutral density filter. The adjacent image showed the same area, without the light spot, after 10 minutes of fading.

of ink samples, the fading rates of ISO blue wool standards (BW1-3) were measured each day. Replicates of 4 to 6 measurements were carried out for each ink, the number of replicates was determined by the homogeneity of the inks. Fading rates are expressed as total color change (CIE dE'94) as a function of time. The light sensitivity category for the ink is determined by comparing the total color change after 10 minutes exposure, to that of the blue wool standards.

Description of treatment and light exposure conditions for ink samples selected for microfade testing are summarized in Table 2. Description of the five ink documents are summarized in Table 3 along with the results. The visible condition of the inks were documented using the Netherlands Institute for Cultural Heritage (ICN) rating system (Reissland and Hofenk de Graaff 2000). The presence and recurrence of the ferrous (Fe(II)) and ferric ions (Fe(III)) in all samples were tested using bathophenanthroline indicator strips, with and without ascorbic acid, and the numeric values are obtained by comparing test paper color to a calibrated color chart developed at CCI (Tse *et al* 2010).

### 3. RESULTS

The microfade tester allows one to carry out *in-situ* fading tests in a micro-destructive manner. The advantage of direct light sensitivity measurements of these historic inks is that the results take into account the differences in ink compositions, substrate matrices, environmental exposure histories and state of deterioration, and allow one to measure the effect of the treatments on their light stability.



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### 3.1 CHANGES OF INKS WITH MICROFADING

Figure 2 shows the fading rates of all 5 sets of inks. Table 3 summarizes the total color change ( $\Delta E^*_{94}$ ), change in lightness ( $L^*$ ), red-green ( $a^*$ ) and yellow-blue ( $b^*$ ) after 10 minute testing. An example to illustrate the progressive color change ( $\Delta E^*_{94}$ ,  $L^*$ ,  $a^*$  and  $b^*$ ) of the inks is shown in figure 3 using the untreated Sample 2 ink.

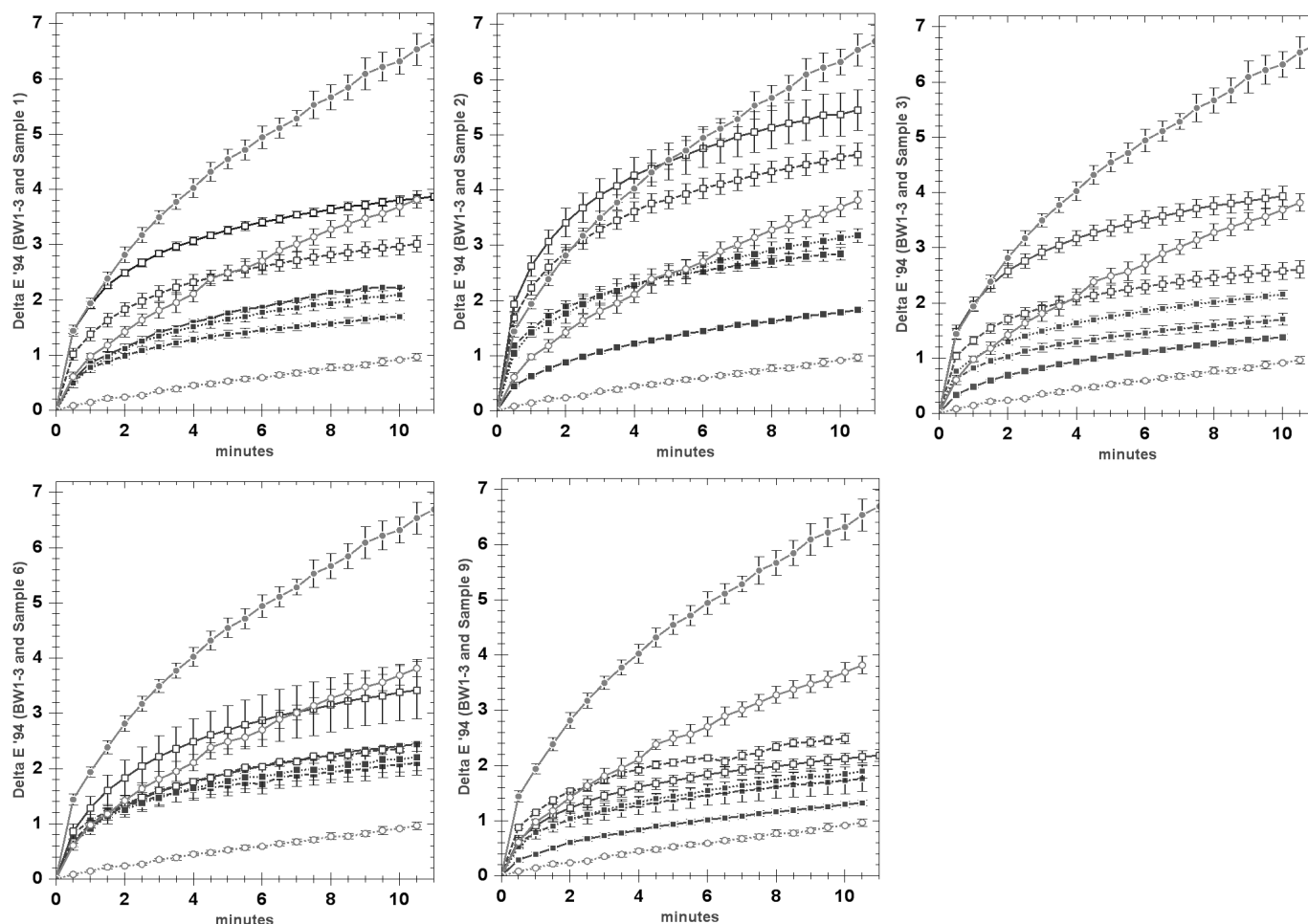


Figure 2. Fading curves of ISO Bluewool 1-3 and five iron gall inks with treatment, without treatment and with light exposure (-●- BW1, -○- BW2, ○ BW3, -□- Control, ---□--- control lightaged, ■ Calcium bicarbonate, ---■--- Simmering, -■- calcium phytate).

Based on the total color difference ( $\Delta E^*_{94}$ ) data after 10 minutes, all the inks have sensitivity equivalent to BW1-3, and they are all categorized as having “high light sensitivity”. Table 4 shows that the estimated light dose to just noticeable difference (JND) for these inks are between 0.22-1.5 Mlux-hr, with UV, and 0.3-3.0 Mlux-hr, without UV. These light dose are estimates based on averaged values obtained from literature review. The uncertainty in each dose estimate ranges approximately to the value for the adjacent Blue Wool (Michalski 1987; 2010). The time it takes to result in just noticeable difference will depend on the light intensity or lux level, and the duration of light exposure. The longer the exposure time or the higher the light intensity, the sooner visible change will occur. The CCI Light Damage Calculator, an online tool being developed by Stefan Michalski, is designed to help users visualize the impact of these lighting decisions.

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Of the five inks, Sample 2 is the most sensitive to light, and Sample 9 is the least sensitive. Most of the color change results from an increase in lightness ( $L^*$ ) and yellowness ( $b^*$ ). This is consistent with previous observations with lab-prepared inks (Reissland & Cowan 2002).

The shape of the fading curves of the five inks is consistent with Type II curves described by Giles (1968) and Cox-Crews (1987). There is an initial rapid change followed by a slower and constant change (fig. 2). Figure 4

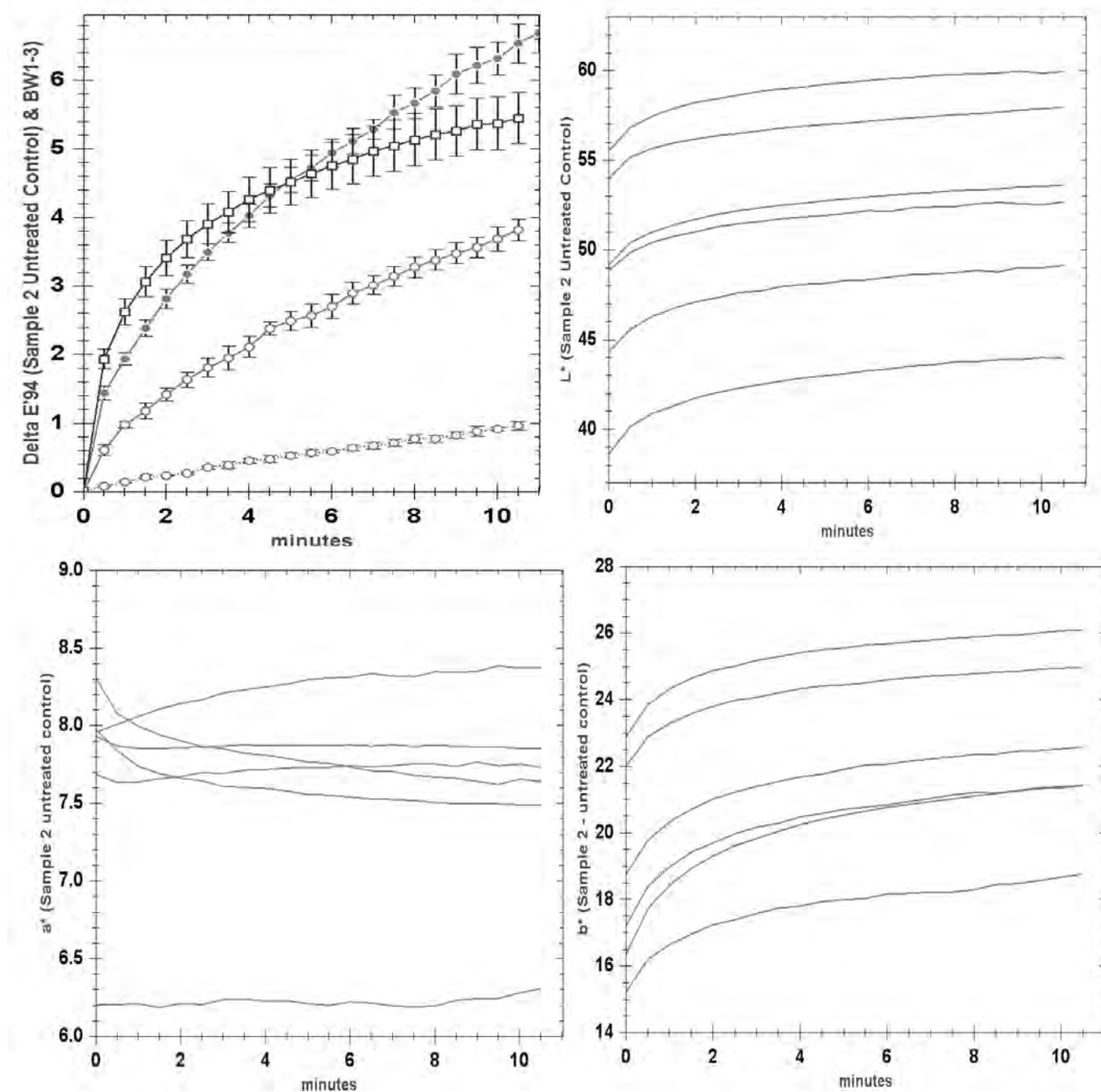


Figure 3. Sample 2 - change of  $dE^*_{94}$ ,  $L^*$  (lightness);  $a^*$  (red-green) and  $b^*$  (yellow-blue) ( $dE^*_{94}$ : -●- BW1, -○- BW2, ○ BW3, -□- Sample 2 ink untreated control).

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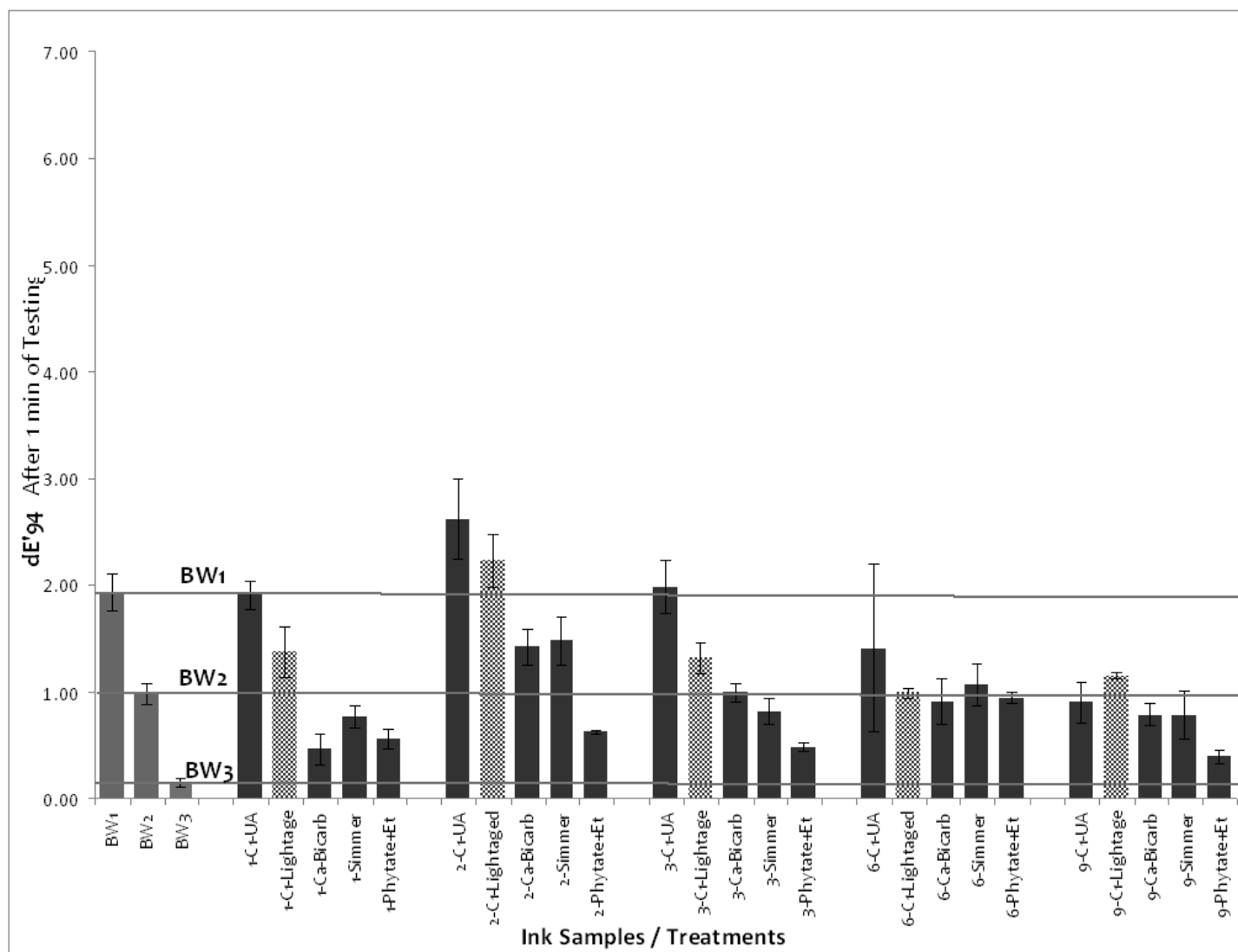


Figure 4. Total color change (dE'94) after 1 minute testing: five sets of inks.

shows the dE'94 of the inks after 1 minute testing. Samples 1, 2 and 3 have the highest initial fading rate, higher than or equal to BW1; Sample 6 and 9 are close to BW2. Fading subsequently slowed down. Figure 5 shows that after 10 minutes, inks 1, 2 and 3 are close to BW2 and inks 6 and 9 are close to BW3. This behaviour is consistent with dyes that have small portions that are molecularly dispersed and a larger portion in the form of aggregates in the substrate (Cox-Crews 1987). With these inks, the highly light sensitive components could be these smaller particles of ink complexes or degradation products on the surface of the ink line.

### 3.2 EFFECT OF TREATMENT ON LIGHT SENSITIVITY

Figure 3 and table 3 show the fading curves of the five inks with and without treatment, and with light exposure. With all the inks, the untreated control is consistently most light sensitive. Aqueous treatment and previous light exposure reduced the fading rates of the ink to different degrees for the different inks. Previous light exposure will cause break down of some of the light sensitive molecules resulting in lower concentrations of these molecules, hence slower fading rates.

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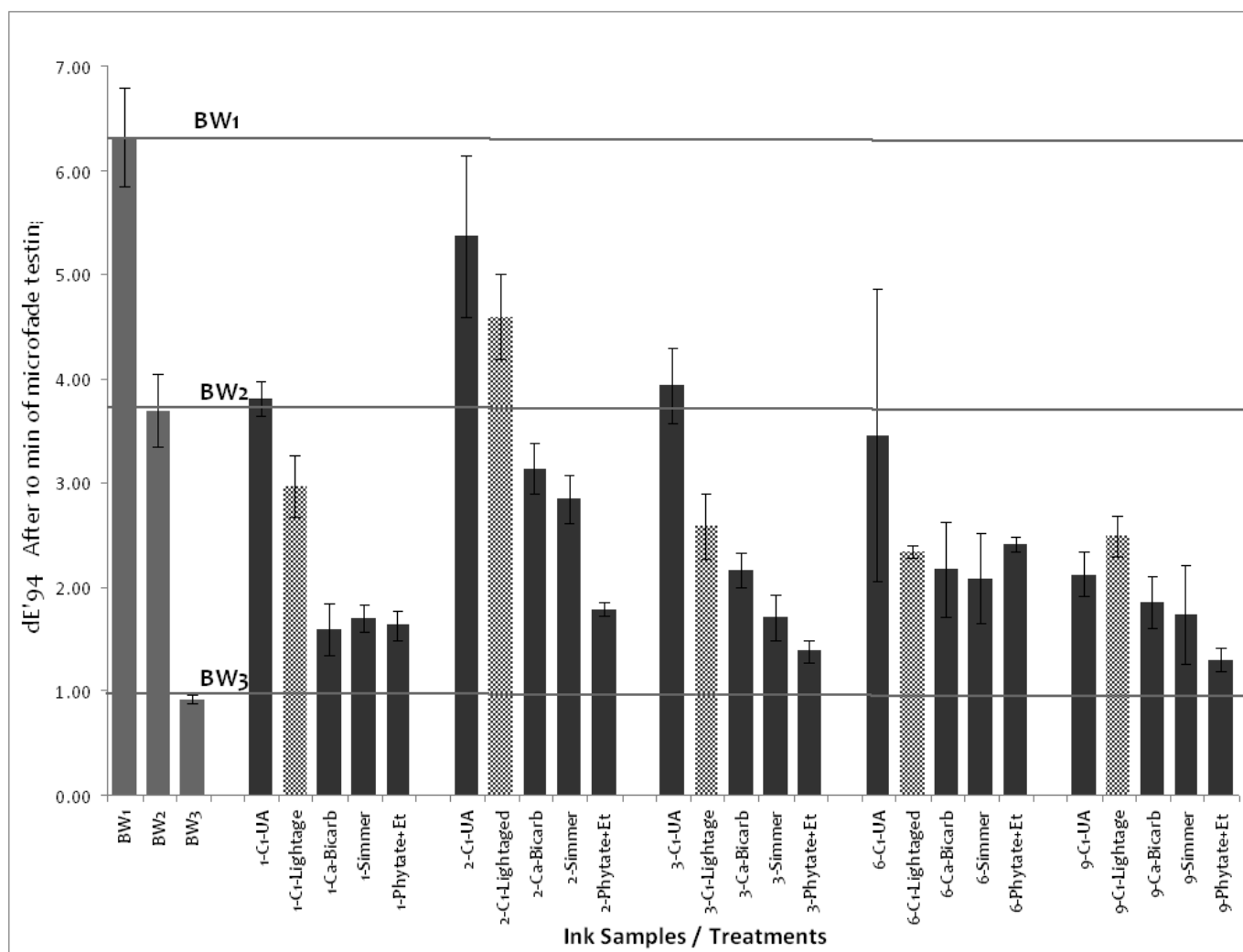


Figure 5. Total color change (dE'94) after 10 minutes testing: five sets of inks.

With aqueous treatments, the decreased fading rates is likely due to solubilization and removal of the highly light sensitive smaller particles and degradation products. Simmering, a more aggressive treatment because of its higher temperature, is expected to remove more ink components compared to calcium bicarbonate treatment, and should therefore have greater impact in light sensitivity of the ink. But the difference between the two treatments is marginal for four out of the five inks. This suggests that increasing the temperature of the treatment

bath does not remove more of these light sensitivity components, and that most of these are removed in room temperature treatments. Calcium phytate, on the other hand, is expected to have similar impact compared to calcium bicarbonate because of similar treatment temperatures. But with three out of five inks, phytate treated inks have measurably lower light sensitivities than bicarbonate. This additional benefit of calcium phytate may be due to its ability to act as an antioxidant by forming an insoluble complex with iron (II) ions, thereby stabilizing the ink complex against light damage.



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	Without Digital Exposure Control	With Digital Exposure Control
<b>Power Supply Current (A)</b>	5.6	5.2
<b>Voltage (V)</b>	15.5	15.3
<b>Power (W)</b>	86	81
<b>Digital Exposure Controller Current (<math>\mu</math>A)</b>	-	46.73
<b>Integration Time</b> on Labsphere spectralon white standard (Sec): 0.009472		
<b>Flux (ILT-900; mlm):</b>	320	
<b>Diameter of spot:</b>	0.3 mm	
<b>Illuminance (spot):</b>	4.53 Mlux	
<b>Data collection frequency:</b>	30 seconds	
<b>Duration of test:</b>	10 minutes	
<b>Dosage for 10 minute testing:</b>	755 klux-hr	

Table 1. O-MFT Instrument settings and characteristics of the light spot.

	Description of treatment and light exposure
Control	No treatment
Calcium bicarbonate	RO water + 0.011M $\text{Ca}(\text{HCO}_3)_2$ ; 20min each
Simmering	Ethanol immersion + alkaline water simmer - pH 8.3 $\text{Ca}(\text{OH})_2$ ; 90°C; 15min
Calcium phytate	Pre-wet with ethanol spray; calcium phytate + 0.011M $\text{Ca}(\text{HCO}_3)_2$ ; 20min each
Light exposure	Fluorescent light bank (14; 40-watt, 4-foot 1157 Vita-lite); vertically mounted; no UV filters; 20-25°C, 40 $\pm$ 5%RH; 10 weeks; averaged accumulated irradiance: 5564 kJ/cm <sup>2</sup> ; total light exposure: 3.71Mlux-hr.

Table 2. Description of treatment and light exposure conditions applied to ink samples.

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	<b>ID</b>	<b>dE'94</b>	<b>std. dev.</b>	<b>dL*</b>	<b>std. dev.</b>	<b>da*</b>	<b>std. dev.</b>	<b>db*</b>	<b>std. dev.</b>
	BW1	<b>5.95</b>	±0.72	<b>3.59</b>	±0.77	<b>-1.37</b>	±0.07	<b>8.98</b>	±3.59
	BW2	<b>3.71</b>	±0.25	<b>2.01</b>	±0.18	<b>0.36</b>	±0.05	<b>7.01</b>	±0.37
	BW3	<b>0.99</b>	±0.13	<b>0.73</b>	±0.10	<b>-0.35</b>	±0.10	<b>1.42</b>	±0.23
<b>Sample 1</b>	c.1856 cream colour ledger, wove cotton rag paper with thin blue lines; ink dark brown. ICN rating: 1; Fe <sup>2+</sup> : 50+ ;Fe <sup>3+</sup> :50+ ; FTIR-ATR: gelatin; μXRF-ink: Fe, K								
	Control	<b>3.80</b>	±0.17	<b>3.02</b>	±0.21	<b>-0.02</b>	±0.32	<b>2.52</b>	±0.38
	Control + lightaged	<b>2.97</b>	±0.30	<b>2.26</b>	±0.23	<b>0.14</b>	±0.28	<b>2.04</b>	±0.34
	Calcium bicarbonate	<b>1.59</b>	±0.24	<b>1.90</b>	±0.28	<b>-0.11</b>	±0.42	<b>1.22</b>	±0.31
	Simmer at 90°C	<b>1.70</b>	±0.13	<b>1.50</b>	±0.09	<b>-0.13</b>	±0.29	<b>0.80</b>	±0.45
	Calcium phytate	<b>1.63</b>	±0.14	<b>1.67</b>	±0.23	<b>-0.23</b>	±0.21	<b>0.80</b>	±0.61
	Calcium phytate + light exposed	<b>1.50</b>	±0.40	<b>1.28</b>	±0.26	<b>-0.26</b>	±0.18	<b>0.35</b>	±0.67
<b>Sample 2</b>	c.1849 greyish cream colour ledger; wove cotton rag paper with thin blue lines; ink light brown ICN rating: 1; Fe <sup>2+</sup> : ~10; Fe <sup>3+</sup> :50+; μXRF-ink: Fe, K								
	Control	<b>5.37</b>	±0.78	<b>4.39</b>	±0.62	<b>-0.11</b>	±0.39	<b>3.76</b>	±0.76
	Control + lightaged	<b>4.60</b>	±0.41	<b>3.82</b>	±0.37	<b>-0.24</b>	±0.32	<b>2.55</b>	±0.58
	Calcium bicarbonate	<b>3.13</b>	±0.25	<b>2.65</b>	±0.13	<b>-0.62</b>	±0.23	<b>1.33</b>	±0.62
	Simmer at 90°C	<b>2.84</b>	±0.23	<b>2.31</b>	±0.18	<b>-0.84</b>	±0.02	<b>0.28</b>	±0.34
	Calcium phytate	<b>1.78</b>	±0.06	<b>1.54</b>	±0.05	<b>-0.82</b>	±0.07	<b>-0.43</b>	±0.15
	Calcium phytate + light exposed	<b>1.18</b>	±0.06	<b>1.06</b>	±0.03	<b>-0.58</b>	±0.01	<b>-0.70</b>	±0.26
<b>Sample 3</b>	c.1864 blue ledger; laid cotton rag paper with visible chain and laid lines; ink light brown with dark strokes; ICN rating: 1; Fe <sup>2+</sup> : ~25; Fe <sup>3+</sup> : ~25; FTIR-ATR: gelatin; μXRF-ink: Fe, Ca, S								
	Control	<b>3.93</b>	±0.35	<b>3.22</b>	±0.30	<b>-0.49</b>	±0.36	<b>2.06</b>	±0.86
	Control + lightaged	<b>2.58</b>	±0.31	<b>2.12</b>	±0.22	<b>-0.52</b>	±0.10	<b>0.72</b>	±0.39
	Calcium bicarbonate	<b>2.15</b>	±0.16	<b>1.81</b>	±0.12	<b>-0.60</b>	±0.09	<b>0.42</b>	±0.42
	Simmer at 90°C	<b>1.77</b>	±0.25	<b>1.49</b>	±0.19	<b>-0.45</b>	±0.09	<b>0.34</b>	±0.24
	Calcium phytate	<b>1.38</b>	±0.11	<b>1.19</b>	±0.16	<b>-0.58</b>	±0.07	<b>-0.10</b>	±0.30
	Calcium phytate + light exposed	<b>0.83</b>	±0.06	<b>0.64</b>	±0.15	<b>-0.40</b>	±0.10	<b>-0.43</b>	±0.21
<b>Sample 6</b>	c.1846 cream ledger; wove cotton rag paper with no lines; ink thin dark brown strokes ICN rating: 1; Fe <sup>2+</sup> : 50; Fe <sup>3+</sup> :50+++; FTIR-ATR: gelatin; μXRF-ink: Fe, K								
	Control	<b>2.95</b>	±1.00	<b>2.30</b>	±1.19	<b>0.61</b>	±0.18	<b>2.51</b>	±1.18
	Control + lightaged	<b>2.34</b>	±0.06	<b>1.77</b>	±0.04	<b>0.19</b>	±0.20	<b>1.97</b>	±0.01
	Calcium bicarbonate	<b>2.17</b>	±0.46	<b>1.69</b>	±0.40	<b>-0.12</b>	±0.13	<b>1.55</b>	±0.22
	Simmer at 90°C	<b>2.08</b>	±0.43	<b>1.66</b>	±0.39	<b>-0.47</b>	±0.34	<b>0.74</b>	±0.32
	Calcium phytate	<b>2.41</b>	±0.08	<b>1.86</b>	±0.15	<b>-0.28</b>	±0.27	<b>1.78</b>	±0.19
	Calcium phytate + light exposed	<b>1.40</b>	±0.26	<b>1.06</b>	±0.25	<b>-0.56</b>	±0.13	<b>0.62</b>	±0.02
<b>Sample 9</b>	c.1846 green ledger; wove cotton rag paper with no lines; ink light brown ICN rating: 1; Fe <sup>2+</sup> : ~10; Fe <sup>3+</sup> :~10; μXRF-ink: Fe, Cu, Mn, Ca, Cl, K								
	Control	<b>2.06</b>	±0.02	<b>1.91</b>	±0.20	<b>-0.70</b>	±0.14	<b>0.56</b>	±0.44
	Control + lightaged	<b>2.49</b>	±0.19	<b>2.11</b>	±0.18	<b>-0.69</b>	±0.01	<b>0.77</b>	±0.32
	Calcium bicarbonate	<b>1.85</b>	±0.25	<b>1.59</b>	±0.24	<b>-0.71</b>	±0.08	<b>0.09</b>	±0.19
	Simmer at 90°C	<b>1.73</b>	±0.48	<b>1.38</b>	±0.54	<b>-0.61</b>	±0.08	<b>-0.22</b>	±0.57
	Calcium phytate	<b>1.30</b>	±0.11	<b>1.12</b>	±0.12	<b>-0.63</b>	±0.05	<b>-0.20</b>	±0.26
	Calcium phytate + light exposed	<b>1.20</b>	±0.08	<b>1.04</b>	±0.05	<b>-0.53</b>	±0.06	<b>-0.44</b>	±0.15

Table 3. Change of dE'94, L\*, a\* and b\* of inks after 10-minute testing.

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	Treatment Description	dE*94 at 10 min	std. dev.	BW equi- valence	Estimated light dose to JND ; Mlux-hr	
					with UV	no UV
	BW1	5.95	±0.72	High sen- sitivity to light	0.22	0.3
	BW2	3.71	±0.25		0.6	1
	BW3	0.99	±0.13		1.5	3
Sample 1						
	Control	3.80	±0.17	~BW2	0.6	1
	Control + lightaged	2.97	±0.30	BW2-BW3	0.6 -1.5	1 - 3
	Calcium bicarbonate	1.59	±0.24	BW2-BW3	0.6 -1.5	1 - 3
	Simmer at 90°C	1.70	±0.13	BW2-BW3	0.6 -1.5	1 - 3
	Calcium phytate	1.63	±0.14	BW2-BW3	0.6 -1.5	1 - 3
	Calcium phytate+lightaged	1.50	±0.40	BW2-BW3	0.6 -1.5	1 - 3
Sample 2						
	Control	5.37	±0.78	BW1-BW2	0.22- 0.6	0.3 - 1
	Control + lightaged	4.60	±0.41	BW1-BW2	0.22- 0.6	0.3 - 1
	Calcium bicarbonate	3.13	±0.25	BW2-BW3	0.6 -1.5	1 - 3
	Simmer at 90°C	2.84	±0.23	BW2-BW3	0.6 -1.5	1 - 3
	Calcium phytate	1.78	±0.06	BW2-BW3	0.6 -1.5	1 - 3
	Calcium phytate+lightaged	1.18	±0.06	BW2-BW3	0.6 -1.5	1 - 3
Sample 3						
	Control	3.93	±0.35	BW2	0.6	1
	Control + lightaged	2.58	±0.31	BW2-BW3	0.6 -1.5	1 - 3
	Calcium bicarbonate	2.15	±0.16	BW2-BW3	0.6 -1.5	1 - 3
	Simmer at 90°C	1.70	±0.22	BW2-BW3	0.6 -1.5	1 - 3
	Calcium phytate	1.38	±0.11	BW2-BW3	0.6 -1.5	1 - 3
	Calcium phytate+lightaged	0.83	±0.06	BW3	1.5	3
Sample 6						
	Control	3.46	±1.40	~BW2	0.6	1
	Control + lightaged	2.34	±0.06	BW2-BW3	0.6 -1.5	1 - 3
	Calcium bicarbonate	2.17	±0.46	BW2-BW3	0.6 -1.5	1 - 3
	Simmer at 90°C	2.08	±0.43	BW2-BW3	0.6 -1.5	1 - 3
	Calcium phytate	2.41	±0.08	BW2-BW3	0.6 -1.5	1 - 3
	Calcium phytate+lightaged	1.40	±0.26	BW2-BW3	0.6 -1.5	1 - 3
Sample 9						
	Control	2.12	±0.21	BW2-BW3	0.6 -1.5	1 - 3
	Control + lightaged	2.49	±0.19	BW2-BW3	0.6 -1.5	1 - 3
	Calcium bicarbonate	1.85	±0.25	BW2-BW3	0.6 -1.5	1 - 3
	Simmer at 90°C	1.73	±0.48	BW2-BW3	0.6 -1.5	1 - 3
	Calcium phytate	1.30	±0.11	BW2-BW3	0.6 -1.5	1 - 3
	Calcium phytate+lightaged	1.20	±0.08	BW2-BW3	0.6 -1.5	1 - 3

Table 4. Light sensitivity categories and light dose estimates for fading of inks.

SEASON TSE, SHERRY GUILD, VALERIA ORLANDINI  
AND MARIA TROJAN-BEDYNSKI

#### 4. CONCLUSIONS

The lightfastness of a dye (colorant), like the ferrogallotannin complex in iron gall inks, is a function of the its chemical structure and physical state (particle size and distribution on the substrate). The light sensitivity properties of these five sets of iron gall inks all belong in the category of high light sensitivity (BW1-3). The inks have a very light sensitive component that results in rapid initial color change when exposed to light, follow by a slower fade. The rapid initial change in ink color is measurable by the spectrophotometer, but it may not be visibly detectable. The amount of this light-sensitive components varies with different inks. Most of the color change is a result of increase in lightness ( $L^*$ ) and increase in yellow ( $b^*$ ). Previous light exposure or aqueous treatments can reduce the light sensitivity of iron gall inks by partially breaking down or solubilizing/removing these light sensitive components. With some inks, calcium phytate treatment is able to reduce the light sensitivity more than that of calcium bicarbonate and simmering treatments. This may be due to the antioxidant properties of phytate.

#### ACKNOWLEDGEMENT

Jim Druzik for his very generous help, ready advice especially during the initial set up of the first O-MFT - we could not have done it without his help, and for providing the Getty Spectral Viewer software, which greatly facilitates data handling. We continue to benefit from his extensive knowledge and experience on lighting and light fading research, and from the regular exchanges of ideas on research and for MFT technique improvement.

Paul Whitmore for perfecting a technique that is uniquely able to predict light fading properties of colorants *in-situ* - without his thorough research and meticulous development, the technique would not be available for our benefit; for his ready and excellent advice and guidance, especially during the initial set up of the benchtop tester.

Bruce Ford for the many exchanges of stimulating ideas, for his insights and very practical approach to research; for being so generous in sharing his knowledge and experience on every subject not just in microfading; for initiating, and organizing the round-robin testing.

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**SEASON TSE, SHERRY GUILD, VALERIA ORLANDINI  
AND MARIA TROJAN-BEDYNSKI**

**SOURCES OF MATERIALS**

Bathophenanthroline Fe(II) test strips  
Preservation Equipment Ltd  
Vinces Road  
Diss, Norfolk  
IP22 4HQ, England  
Tel. +44(0) 1379 647400  
Fax. +44 (0) 1379 650582  
<https://www2.preservationequipment.co.uk/>  
Email: [info@preservationequipment.com](mailto:info@preservationequipment.com)

Or

University Products Of Canada  
Catalogue No. 539-3000  
Bfb Sales  
2957 Inlake Court  
Mississauga, Ontario  
L5N 2A4  
Tel. (905) 858-7888  
Fax (905) 858-8586

Color charts for Fe(II) test strips  
Season Tse  
Canadian Conservation Institute  
Department of Canadian Heritage  
1030 Innes Rd. Ottawa, ON Canada K1A0M5  
Tel. (613) 998-3721  
Toll free: 1 (866) 998-3721  
Fax (613) 998-4721  
[Season.tse@pch.gc.ca](mailto:Season.tse@pch.gc.ca)

ILT900 Spectroradiometer (RPS900) and integrated sphere (INS150)  
International Light Technologies  
10 Technology Drive  
Peabody, MA 01960  
Tel. (978) 818-6180  
Fax. (978) 818-6181

ISO Standard bluewool fading cards  
Talas  
330 Morgan Ave.  
Brooklyn NY 11211 US  
Tel. (212) 219-0770  
Fax. (212) 219-0735

## MICROFADE TESTING OF 19TH CENTURY IRON GALL INKS

<http://www.talasonline.com>

Phytic acid; 40% solution

Catalogue number: 80180

Sigma-Aldrich

<http://www.sigmaaldrich.com/>

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# DEVELOPMENT OF A MICROFADING TESTER FOR LIGHT EXPOSURES INCLUDING NEAR-ULTRAVIOLET WAVELENGTHS

CHONG TAO AND PAUL M. WHITMORE

**ABSTRACT**— A new microfading tester (MFT) was developed for light exposures containing near UV wavelengths, namely 300-700nm. The required light (solar simulation) was generated from proper filtration and sampling of light from a xenon lamp. The chromatic aberrations of the simple focusing lenses were studied with microscope imaging and utilized to create the desired focus across the entire wavelength range. The effect of including the UV radiation on the fading of Blue Wools and rose madder, a known UV-sensitive pigment, was studied. A protocol is proposed for using the conventional MFT with only slight modifications to include the UV wavelengths.

**DESARROLLO DE UN TESTER DE MICRODECOLORACIÓN PARA EXPOSICIONES A LA LUZ INCLUYENDO LA LONGITUD DE ONDA ULTRAVIOLETA CERCANA. RESUMEN** – Se desarrolló un nuevo tester de microdecoloración (MFT) para las exposiciones a la luz con longitudes de onda ultravioleta cercana, es decir 300-700nm. La luz necesaria (simulación solar) se generó a partir de una debida filtración y muestra de luz de una lámpara de xenón. Se estudiaron las aberraciones cromáticas de los lentes de enfoque simple con imágenes de microscopio y se utilizaron para crear el enfoque deseado a lo largo de todo el rango de la longitud de onda. Se estudió el efecto de incluir la radiación UV en la decoloración de Blue Wools y el rojo carmesí, un reconocido pigmento sensible a la luz UV. Se propone un protocolo para utilizar el MFT convencional con leves modificaciones solamente para incluir las longitudes de onda UV.

## 1. INTRODUCTION

The microfading tester (MFT) is a tool used to characterize the light sensitivity of colored materials encountered in cultural property by performing tiny, sensitive fading tests directly on those objects (Whitmore et al. 1999). Originally aimed at identifying fugitive colorants (ISO Blue Wool 1 or 2 lightfastness grade) exhibited in indoor environments that are free of ultraviolet radiation, the MFT was designed to deliver high intensities of visible light to the test spot. While the overall performance of the original instrument design has been shown to be reasonably well correlated to other accelerated light exposures, the device has since been modified by various users to address some known shortcomings of the simple optical system, such as chromatic aberrations that slightly distort the wavelength spectrum delivered to the test area. Those improvements have generally led to very small changes in the instrument performance.

Over time users have begun to explore whether the MFT can be used to answer other questions about light sensitivity of artifact materials. Of particular interest is the characterization of the fading of more stable colorants (ISO Blue Wool 3 and greater), which tend to fade primarily from exposure to ultraviolet wavelengths. The original MFT design allows for some delivery of ultraviolet light simply by removing a UV-blocking filter. However, the relative intensity of ultraviolet (UV) wavelengths is not easily controlled, for it is sensitive to the focusing of the lenses in the device. Modified instruments that have incorporated achromatic lenses may be particularly limited in this regard, since those lenses generally do not transmit UV wavelengths.

In this paper the modification of an MFT to deliver controlled intensities of light from near-UV wavelengths through the visible spectrum is described. A new spectrometer, able to measure both visible wavelengths and the UV region, has been incorporated. Simple lenses are still used in order to keep the cost of the instrument reasonable and to allow straightforward adaptation of current devices. The chromatic aberrations inherent in those lenses have a greater impact on the spectrum of focused light, and thus on the fading results. Techniques to operate the instrument to optimize delivery of the desired wavelength spectrum are explored. The performance



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of the new instrument to measure the fading of materials having lightfastness of ISO Blue Wool 3 and greater are presented.

### 2. INSTRUMENT DEVELOPMENT AND TESTING

The new microfading tester was built as a modification of the generic Oriel type, currently available as the kit. To keep the price of the system from becoming formidably high, simple quartz lenses or lens systems that are used in the standard configuration were employed, as most commercial achromatic lenses do not transmit well for wavelength short than 400nm. In order to monitor the whole spectral region from 300-700nm, a new spectrometer (USB silicon PDA spectrometer from Control Development, Inc.) with response between 250-780nm was used. It can be controlled either by the commercial software coming with the spectrometer or by a program written with LabView. Filters used for the new system are described in the following section.

#### 2.1 LIGHT SOURCE AND FILTERS

In the development of the MFT, the most important factors are effectively delivering the light with the desired spectral power distribution to the test area and effectively focusing the light throughout the spectrum range, to create the high intensities. Chromatic aberrations in the simple lenses will tend to distort that delivered spectral power distribution, as some wavelengths are focused to a higher intensity than others. Since the desired spectral range runs from 300 to 700nm, a xenon arc lamp remained a good choice as the light source. Different filters have been used to deliver the spectral range desired. First, a borosilicate glass filter combined with a 2 in. water filter gave a spectral range of 300~1000nm. The heating at the test area was found to be up to 38°C under ambient conditions, which should not be a problem for most applications. A KG-2 glass filter was also tested, which produced a spectral window between 300nm to 800nm, and according to the specifications it also transmits less than 20% of the lamp output in the infrared region between 1  $\mu\text{m}$  and 2.5  $\mu\text{m}$ . Using this filter alone would generate the desired spectral window and cause only a slight temperature increase in the test area to 36°C under ambient conditions. The only drawback of the KG-2 glass filter is that it can only take 30w/cm<sup>2</sup> of illumination. Higher light intensities will damage the filter due to excessive heat. For all the experiments described in this paper, the combined water and borosilicate glass filters were used to generate the spectral power distributions delivered to the samples.

As mentioned in previous section, all the lenses in this modified MFT system are simple quartz lenses, which have slight chromatic aberrations. One can, however, utilize these aberrations, for they allow slight adjustments to tailor the spectral power distribution of the light delivered to the test area. In this MFT system, light from the xenon lamp is collimated with the condenser lens in the lamp housing, then focused by a lens in the optical fiber coupler onto the fiber tip, before being delivered to the illumination lens assembly in the test head. Because of the chromatic aberration in the lens in the optical fiber coupler, the spectral power distribution delivered into the fiber end is slightly altered depending on the position of the fiber end. At any given position of the fiber end, some wavelengths will be more tightly focused and thus more efficiently injected into the fiber. So adjusting the optical fiber position slightly enables the sampling of different portions of the focused light. Shown in figure 1, different spectral power distributions were obtained by adjusting the fiber position relative to the lens in the optical fiber coupler. Since this adjustment is continuous, the spectral power distribution was adjusted to achieve the best match with indoor natural sunlight, or in this case, with another commercial xenon exposure cabinet, the Atlas SunTest CPS, that was designed to simulate the solar spectrum (fig. 2). The light below 400nm accounts for 16% of the total energy. Also shown in figure 2 is the spectral power distribution of the MFT when it

is aligned for its typical use in visible-only tests. The usual optimization to maximize lumen output (i.e., maximize output at around 550nm) causes reduced intensities to be delivered at the short wavelengths.

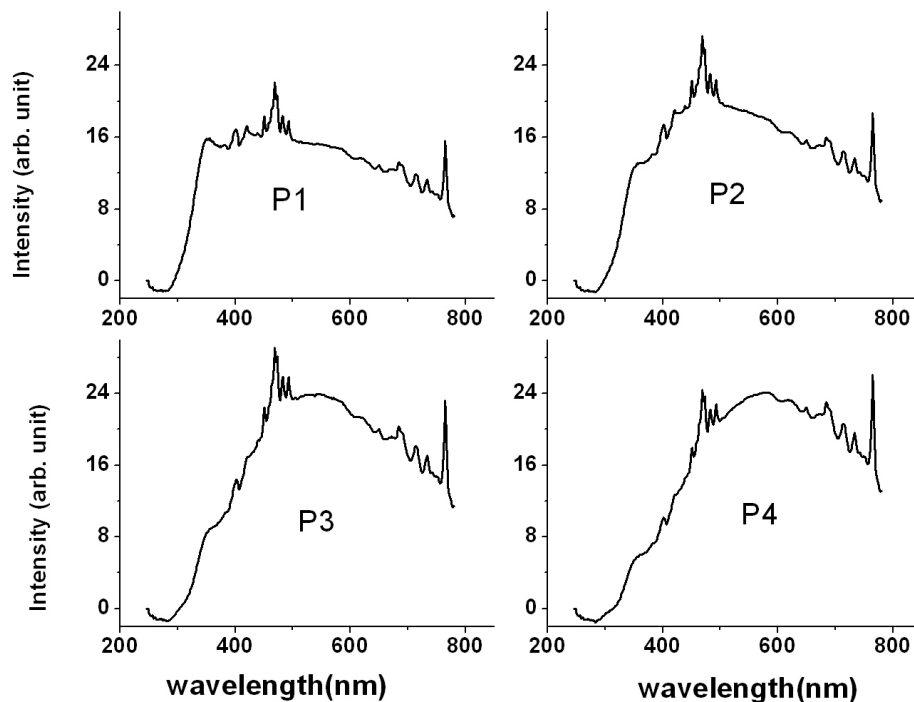


Figure 1. Spectral power distributions of the Xe light exiting the optical fiber for 4 different optical fiber coupler input positions. The relative intensities of the UV wavelengths can be increased or decreased significantly by this adjustment due to the chromatic aberrations of the lens in the optical fiber coupler.

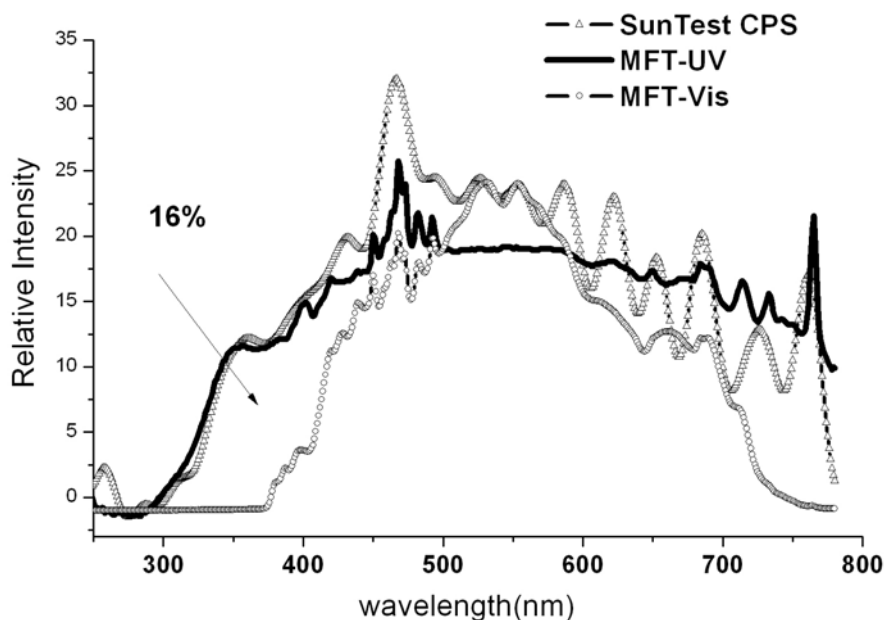


Figure 2. Spectral power distributions delivered through the fiber optic of the MFT in its conventional alignment for performing visible-only tests (MFT-Vis), and in its alignment to simulate natural daylight indoors, including the UV portion of the spectrum (MFT-UV). The spectral power distribution of the Atlas SunTest CPS, another xenon arc lamp exposure apparatus designed to simulate solar UV spectral power distributions, is also included for comparison.

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### 2.2 ILLUMINATION SPOT INTENSITY DISTRIBUTION AND CHROMATIC ABERRATION

As shown in figure 2, the desired spectral power distribution can be delivered to the illumination spot. Once that spectrum of light exits the fiber, it is focused with another set of simple lenses, and chromatic aberrations will also come into play. Focusing the various wavelengths to differing degrees can result in the high intensities being created unevenly across the spectrum. The position of the fiber optic connector with respect to the first lens in the focusing lens assembly determines the degree of focus for the light exiting the lens assembly. Adjusting that connector position, the shape and size of the focused spot could be altered, as well as the wavelength of light that was most nearly in tight focus. That adjustment allowed the exploration of the range of illumination conditions that could be produced in the small, intense focused spot on the sample. The focusing that occurred with the final lenses needed to be studied in order to make the adjustment that allows reproducible delivery of focused light across the entire spectral range.

The focusing of the different wavelengths with the focusing lens assembly at the test head has been examined by measuring directly the size of the focused spot at selected wavelengths. By placing a bandpass filter into the beam, different wavelength regions were selected. A total of 6 filters—400, 450, 500, 600, and 700nm bandpass filters with a 70nm bandwidth, and a HOYA U-340 visible absorbing glass filter—were used to cover the UV-Vis region. These narrow-wavelength light beams were directed through the optical fiber, focused by the focusing lens assembly in the test head, and directed upward into the 10X objective of an optical microscope (Olympus BX61). The black-and-white image recorded by the microscope camera (Hamamatsu C10600) documented the size and shape of the beam as it traversed the focal plane of the microscope optics. One of those images for 400nm light is shown in figure 3a. That image can be analyzed to create a 3-D representation of the intensity distribution in the spot (fig. 3b), or a line scan can trace the intensity across the diameter of the spot (fig. 3c). The ratio of the area within full width at half maximum (FWHM) and the total area of the intensity for the entire spot measures how much light was spread at the edges of the main spot. This metric describes the tightness of the focus. All these image processing procedures and area calculations were carried out using Matlab program.

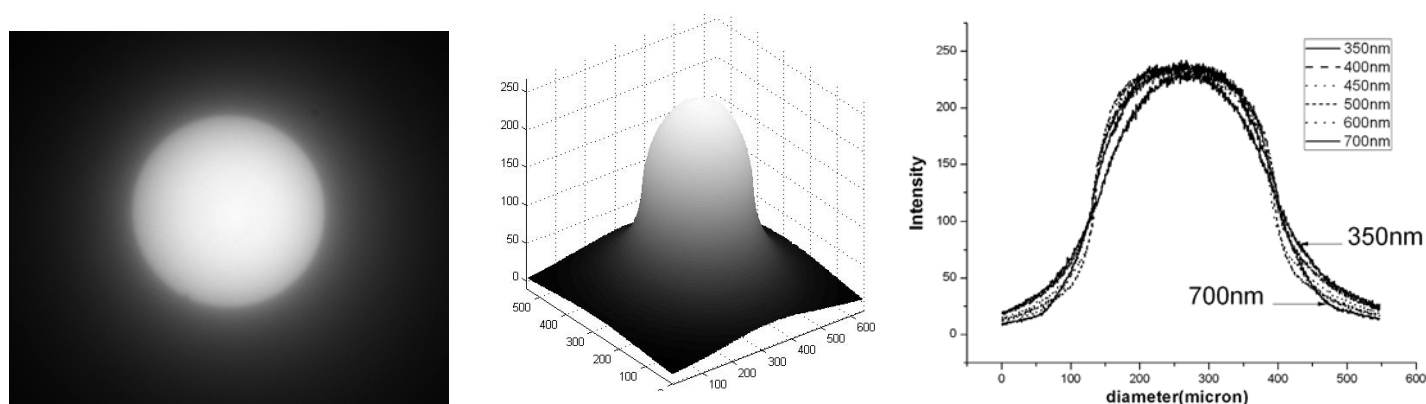


Figure 3. 3a (left). Photomicrograph of the illumination spot with a 400nm bandpass filter. 3b (center). An intensity profile of the image shown in (a), showing the intensity distribution of the 400nm light. 3c (right). Line scans of the intensity distributions measured from photomicrographs obtained for different wavelengths. Despite the chromatic aberrations and the slightly different focus of the different wavelengths, the congruence of the focused areas is very close.

The results of the intensity distributions at the various wavelengths are shown in figure 3c. While there is some spreading of the beam at the very high and low ends of the 300-700 nm spectral range, the deviation is reasonably small: measured ratios between the area within FWHM and the total area range from 78% for 350nm to 83% for 500nm. This indicates that under this specific focus condition the illumination spot was focused almost

uniformly throughout the whole spectral region. Other focus conditions—for example, tightly focusing at a wavelength in the red or in the UV—would lead to substantially poorer focus at the other end of the spectrum. Focusing the light around 450nm, then, near the midpoint of the UV-Vis region, tends to focus the entire spectral range reasonably well, and thus that focus will produce uniformly high intensities without distortion of the spectral power distribution that was delivered through the fiber.

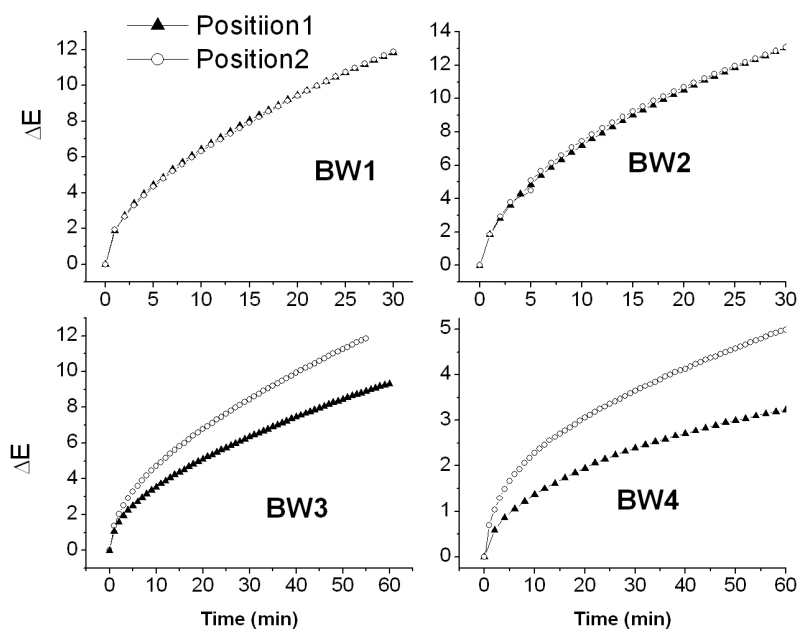
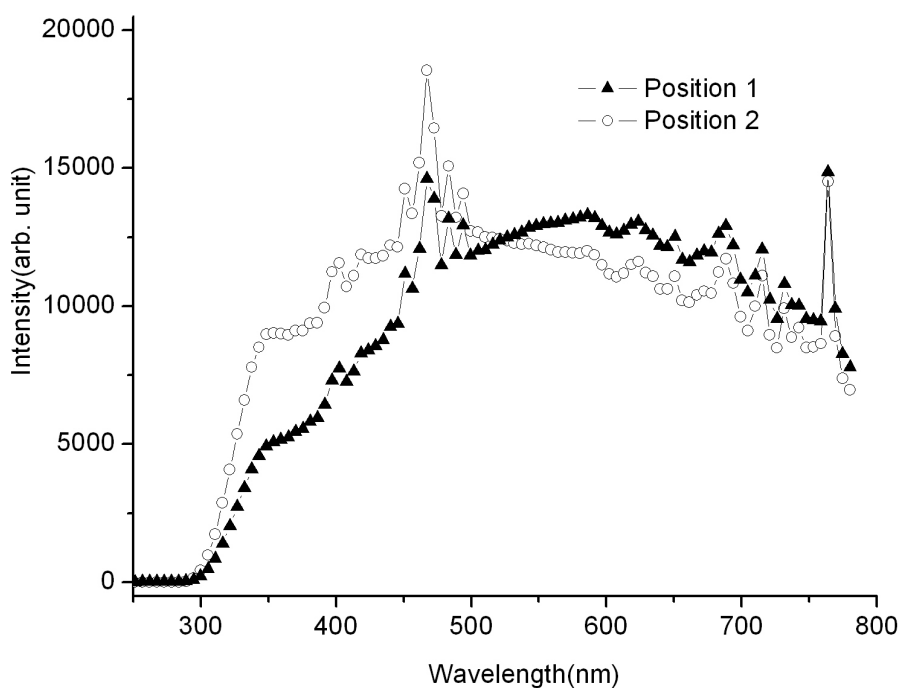


Figure 4. 4a (top). Spectral power distributions delivered for two different alignments of the lens in the fiber optic coupler. 4b (bottom). Blue Wool 1 to 4 fading curves for the corresponding two positions. The greater proportion of UV causes more rapid fading of the Blue Wools 3 and 4, while the fading of Blue Wools 1 and 2 is unaffected by the short wavelengths.



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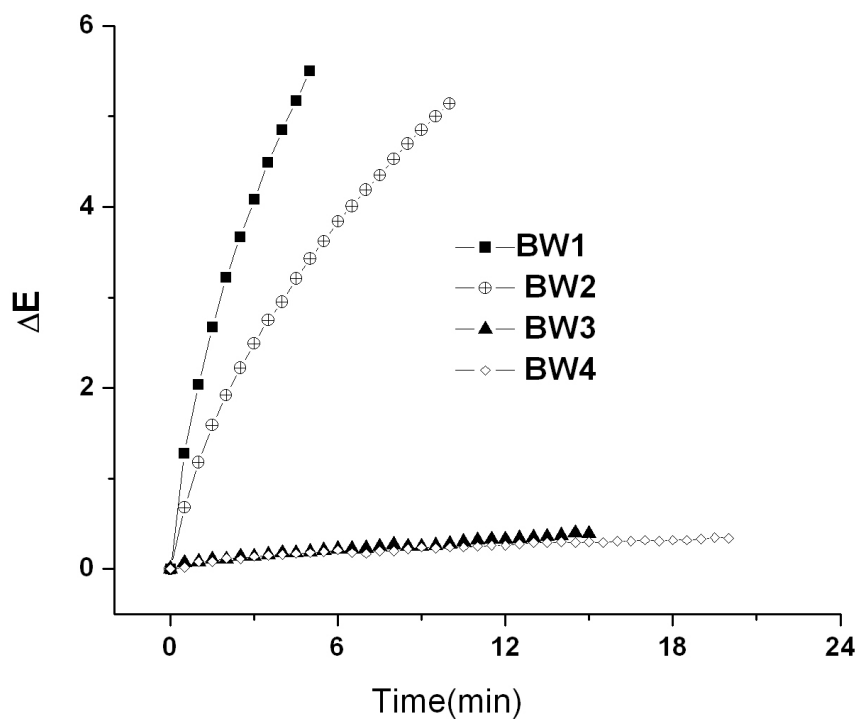


Figure 5. Fading curves for Blue Wools 1 to 4 measured with the MFT using only visible light.

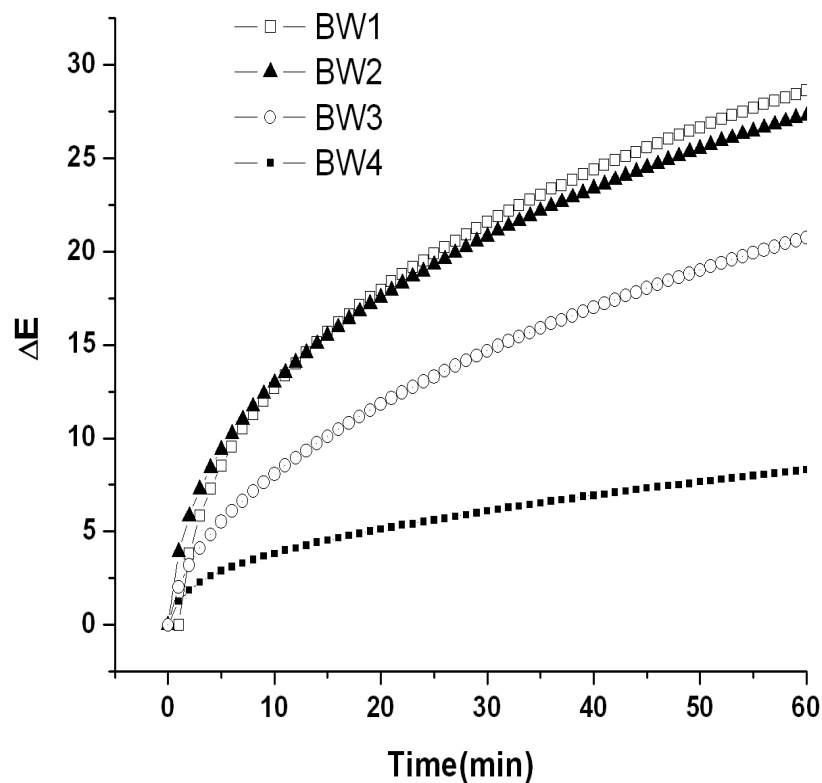


Figure 6. Fading curves for Blue Wools 1 to 4 measured with the MFT with light including UV wavelengths.

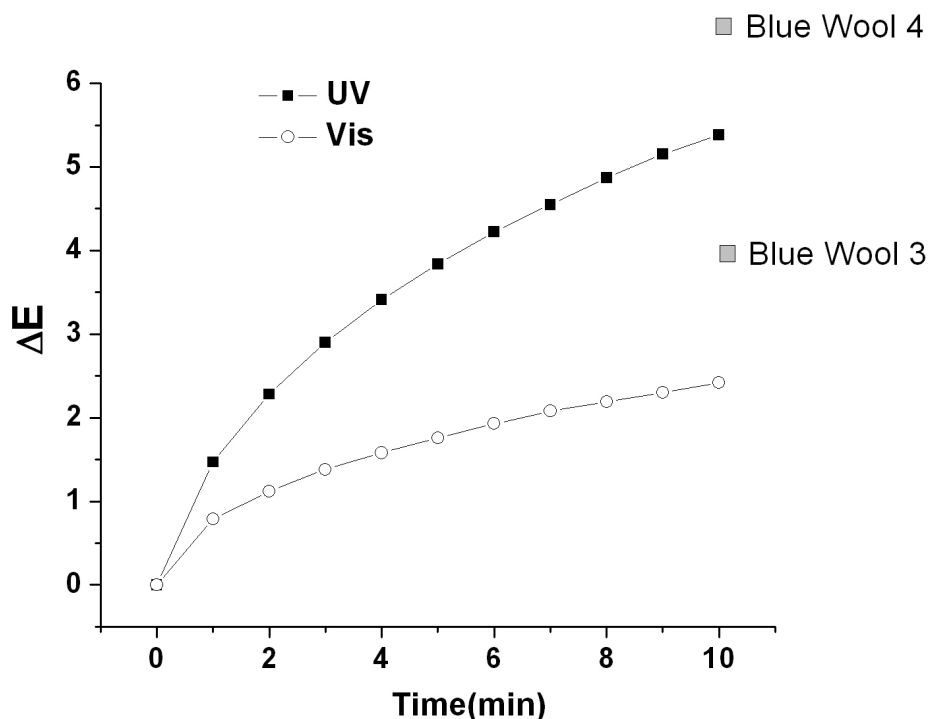


Figure 7. Fading curves of Rose Madder tested with the conventional instrument that excludes UV wavelengths (Visible) and the modified device that includes the UV portion of the spectrum (UV). The  $\Delta E$  reached by Blue Wools 3 and 4 after 10 minutes are also indicated on the figure by the square symbols.

### 3. PERFORMANCE OF NEW INSTRUMENT CONFIGURATION

#### 3.1 FADING RESULTS OF BLUE WOOL STANDARDS AND ROSE MADDER PIGMENT

For all the fading experiments carried out in this study, the luminous flux delivered by the fiber optic was set at 600 millilumens, and this light was then focused to a 0.28mm spot for both UV-Vis and Visible light exposures. This produced intensities of about 9.7 MLux in the focused spot. Fading tests were performed in the usual way (Whitmore et al. 1999), with the light-induced color changes ( $\Delta E$ ) calculated using the 1976 CIE equation.

Pigments fade because of chemical reactions that follow absorption of photochemically active wavelengths. Different pigments react differently to light at different wavelength regions. It is well established that the ISO Blue Wools 1 and 2 are more sensitive to visible light, while Blue Wool 3 and higher are more susceptible to UV radiation (McLaren 1956). His wavelength dependence can be demonstrated by performing two fading tests, with two spectral power distributions that differed in the relative intensities of the UV and the visible. Shown in figure 4a, alignment position 1 had higher intensity in visible region ( $> 500\text{nm}$ ) than that of position 2, while position 2 contained more intensity in the UV region. The fading curves of Blue Wools 1 to 4 exposed to these two spectral power distributions are shown in figure 4b. The fading rates for Blue Wools 1 and 2 did not change with the alignments. However, for Blue Wools 3 and 4, the fading rates increased dramatically when the UV content of the light was increased. These results are consistent with earlier measurements (McLaren 1956).

This UV sensitivity of the Blue Wools 3 and higher is illustrated in the tests with the MFT using either visible light only (i.e., the typical configuration that excludes UV wavelengths with a cutoff filter) or with visible plus

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UV wavelengths. Figure 5 shows the typical fading curves for Blue Wools 1-4 using visible light only in the MFT system. The fading rates of Blue Wools 3 and 4 are very slow, because these dyes are much less sensitive to visible light. When the Blue Wools were exposed to light that included the UV wavelengths, the fading rates of both Blue Wools 1 and 2 increased moderately, while the Blue Wools 3 and 4 faded according to relative rates that are closer to those expected for the standards. In these tests Blue Wool 2 faded slightly faster with the UV included, and this brought its fading curve almost coincident with that of Blue Wool 1 under the same conditions. The reasons for this discrepancy are still being explored. Nevertheless, the dramatic fading rate increase due to UV light for both Blue Wool 3 and 4 makes them comparable to other measurements, for example, those reported by Feller and Johnston-Feller (1979).

To test the performance of the UV-MFT on other colorants, fading tests with and without the UV portion of the spectrum were done on a commercial genuine Rose Madder watercolor paint (Winsor & Newton) painted on a hot-pressed watercolor paper. As shown in figure 7, rose madder is very sensitive to UV radiation. The fading rate doubled with the inclusion of UV wavelengths. Under the experimental condition, the fading rate of Rose Madder fell in between Blue Wool 3 and Blue Wool 4, which is reasonable for this particular pigment.

### 3.2 PROPOSED PROTOCOLS FOR FADING INCLUDING NEAR-UV WAVELENGTHS

In order to get consistent results for fading tests containing UV radiation, it is important to follow the proposed protocols, especially for the microfading systems without UV-sensitive spectrometers. First, an appropriate filter, such as KG-2 glass or borosilicate glass with a water filter, is required to generate the desired spectral window. Then, the illumination fiber coupler end is adjusted to intercept the light beam at the position having the desired spectrum. This adjustment can also be made by delicate movement of the lamp condenser lens. (Using the condenser lens for this spectral tuning will require re-optimizing the focus of the lenses at the test head.) The spectrum of near-UV wavelengths in the beam should be similar to that of daylight indoors or the Suntest CPS. For systems with spectrometers sensitive only to the visible region, this UV spectrum can be roughly achieved by tuning the visible spectrum to have an intensity at 400 nm about 65% of the intensity at 500nm. After that, a bandpass filter to allow only 450nm light into the fiber is placed into the filter holder on the lamp and the test head lenses are adjusted to optimize the focus at that wavelength. This condition should then produce reasonably good focus across the entire 300-700nm region. Finally, Blue Wool standards 1-4 are tested to ensure the correct relative fading rates.

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Whitmore, P. M., X. Pan, and C. Bailie. 1999. Predicting the fading of objects: identification of fugitive colorants through direct nondestructive lightfastness measurements. *Journal of American Institute for Conservation* 38: 395-409.

### SOURCES OF MATERIALS

Diode array spectrometer (PDA USB-512 element) and software  
Control Development Inc.  
2633 Foundation Drive  
South Bend, IN 46628

KG2 glass, cat. no. FSQ-KG2, HOYA U-340 glass, cat. No. FSQ-U340  
Newport Corp.  
1791 Deere Avenue  
Irvine, CA 92606

Borosilicate glass, cat. no. WG-305  
Edmund Scientific  
101 East Gloucester Pike  
Barrington, NJ 08007

Olympus BX61 Microscope, Hamamatsu C 10600 camera  
B&B Microscopes, Ltd.  
535 Rochester Road  
Pittsburgh, PA 15237

Rose madder watercolor paint  
Art supply stores

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