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PREFACE


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, Katherine Sahmel, Textile Specialty Group Vice Chair for 2014-2015, are published as submitted by the authors. Editing of papers was done according to the Journal of the American Institute for Conservation’s “Guidelines for Authors” and the “Best Practices for Online PDF Publication: AIC Specialty Group Annuals & Postprints,” 2015 version. 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. Thanks are also extended to Translation Cloud for translating the abstracts into Spanish, and Aptara Inc. for copyediting and layout.
ABSTRACT—Selecting a light-emitting diode (LED) lamp for lighting a textile exhibition, like one for 19th-century calico and chintz quilts, could be a gamble. Because these lamps mix specific color regions to produce a white light, accurate color rendering is a particular concern with LEDs. Different “white” LEDs can change the appearance of colors: a purple might appear bluer and a red, browner; even indigo blue can be skewed. Quilts may be particularly challenging to light since a single calico can contain a variety of colors and shades. The “best” LED light would render all colors as accurately as possible with the least change in appearance.

To evaluate the likelihood of such color shifts, reflectance curve readings were taken of representative dyed and printed swatches found in William Crookes’ *A Practical Handbook of Dyeing and Calico-Printing* (Crookes 1874) and inserted into the Color Quality Scale (CQS) simulation program at the National Institute of Standards and Technology to predict the effect of different LEDs already in the program. In the future, the CQS program could evaluate the effect of LEDs on any color palette of textiles slated for exhibition, using their reflectance spectra to determine the best options for lighting.

1. INTRODUCTION

In a previous study (Bolin and Ballard 2014a, 2014b), the surprising and profound effects of light-emitting diode (LED) lamps to the colors of representative dyes on cotton and silk textiles were described, to both natural and early synthetic dye colorants. On visual inspection, these color distortions were greater for textile colorants than for comparable paper-printed color reference standards used commercially to characterize color fidelity. This current article seeks to answer two questions: How can textile conservators and curators avoid flare or other ugly color distortions in future exhibitions? What if they do not know the precise colorant formulas for the textiles being displayed (Saltzman 1986)?

Different cultures at different epochs produced distinct color palettes. In this study, we considered the colorways of late 19th century Anglo-American cotton calicoes and chintzes for a theoretical case study. Quilts from this general period contained natural dyes on cotton, mineral dyes on cotton, and early synthetic dyes on cotton. Would the 1996–97 exhibition *Calico and Chintz: Antique Quilts from the Collection of Patricia S. Smith*, held at the Renwick Gallery of the Smithsonian Institution’s National Museum of American Art, look the same under LEDs (Adamson and Smith 1997)? Is there a way to evaluate the color-rendering potential of various LED lamps? Once the considerable investment in the LED lighting assembly is made, a gallery may not easily be retrofitted during the installation and final inspection (Miller and Druzik 2012.).

Theoretically, with a knowledge of the spectral power distribution (SPD) or energy per wavelength across the visible spectrum of the LED, it is possible to determine which physical colors might be short changed (table 1, fig. 1). Light shining on a colorant in a textile will or will not be absorbed; the viewer sees only what is reflected (i.e., the light that is not absorbed). With conventional daylight, wavelengths emitted in the violet and blue will allow green-yellow and yellow colors to look vibrant. With LEDs, violets particularly are hard to render accurately, as violets absorb in the yellow and green regions of the visible spectrum strongly, yet some
THE EFFECT OF LIGHT-EMITTING DIODE LAMPS ON 19TH-CENTURY DYED AND PRINTED COTTON FABRICS

Table 1: Relationship of Colors Seen to Wavelengths of Light Absorbed (Allen, 1971)

<table>
<thead>
<tr>
<th>Light absorbed Wavelength (nm)</th>
<th>Color</th>
<th>Complementary Color Seen (reflected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400-435</td>
<td>Violet</td>
<td>Green-Yellow</td>
</tr>
<tr>
<td>435-480</td>
<td>Blue</td>
<td>Yellow</td>
</tr>
<tr>
<td>480-490</td>
<td>Green-Blue</td>
<td>Orange</td>
</tr>
<tr>
<td>490-500</td>
<td>Blue-Green</td>
<td>Red</td>
</tr>
<tr>
<td>500-560</td>
<td>Green</td>
<td>Purple</td>
</tr>
<tr>
<td>560-580</td>
<td>Yellow-Green</td>
<td>Violet</td>
</tr>
<tr>
<td>580-595</td>
<td>Yellow</td>
<td>Blue</td>
</tr>
<tr>
<td>595-605</td>
<td>Orange</td>
<td>Green-Blue</td>
</tr>
<tr>
<td>605-750</td>
<td>Red</td>
<td>Blue-Green</td>
</tr>
</tbody>
</table>

Fig. 1. A comparison of SPDs based on radiometric measurements equalized for lumen output at correlated color temperatures of 3,000 and 6,500 K. The red line charts the black body radiation roughly comparable to incandescent light and daylight, respectively, whereas the blue line depicts blue-pump phosphor converted LEDs. In each graph, the green line represents the SPD of a different standard fluorescent lighting systems. (Adapted from US Department of Energy 2014)

LEDs do not emit those wavelengths with equal strength. Unlike natural daylight, there may be no corresponding wavelength to be reflected, and hence the appearance may be skewed. Similarly, oranges and reds are sensitive to different SPDs (Bolin and Ballard 2014). Fluorescent lights were prone to these problems of color fidelity and distortion.

2. MATERIALS AND EXPERIMENTAL METHOD

The samples in Crookes’ book used mineral, natural, and synthetic dyes, so it included a broad range of distinct, popular colorants that would have been used to dye 19th-century cotton textiles made on or before 1874.
Each sample in the text was labeled with the dye used and had been analyzed non-destructively by XRF spectrometry for its elemental composition; the description of the dye and auxiliaries of each swatch matched these inorganic constituents. Table 2 (presented at the end of this article) references each sample utilized. Thus, Crookes’ book serves as a valuable resource of representative dyes for that period and culture, when the actual catalogued calico and chintz fabrics or quilts are not easily accessed for documentation by spectrophotometry (Doroszczyk et al. 2013).

To simulate the effect of viewing colored samples under a range of light sources, different evaluation methods have been developed that include printed color references. The Color Rendering Index (CRI) was developed some decades ago to categorize color distortions created by fluorescent lighting. The color

<table>
<thead>
<tr>
<th>CQS Designation</th>
<th>Name(s) of Dye and Discoverer</th>
<th>Chemical Composition</th>
<th>Color Index and Color Constitution Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>VHS1</td>
<td>Iron buff, Nankeen, Nankin</td>
<td>Hydrated ferric oxide (FeO(OH)•nH₂O</td>
<td>Mineral Dye</td>
</tr>
<tr>
<td>VHS2</td>
<td>Canary/chrome yellow (Koechlin, 1821)</td>
<td>PbCrO₄</td>
<td>C.I. Pigment Yellow 24, C.I. 77603, Mineral Dye</td>
</tr>
<tr>
<td>VHS3</td>
<td>Arsenical green (Sheele's green, 1778)</td>
<td>CuHAsO₃</td>
<td>Mineral Dye</td>
</tr>
<tr>
<td>VHS4</td>
<td>Aniline black (Lightfoot, 1863)</td>
<td>—</td>
<td>C.I. Pigment Black 1, C.I. 50440</td>
</tr>
<tr>
<td>VHS5</td>
<td>Chrome green(s) Chrome oxide</td>
<td>Cr₂O₃</td>
<td>C.I. Pigment Green 17, C.I. 77288</td>
</tr>
<tr>
<td></td>
<td>Chrome hydroxide Chromium arsenite</td>
<td>Cr₂O₃•2H₂O, Cr₆AsO₃</td>
<td>C.I. Pigment Green 18, C.I. 77289, Mineral Dye</td>
</tr>
<tr>
<td>VHS6</td>
<td>Dark blue Prussian blue, Royal blue (Prussian blue) (Diesbach, 1704; Macquer, 1749) Napoleon's Blue, Turnbull's Blue, royal blue</td>
<td>Potassium ferric ferrocyanide K[Fe₄[Fe(CN)₆]₃</td>
<td>C.I. Pigment Blue 27, Mineral Dye</td>
</tr>
<tr>
<td>VHS7</td>
<td>Light blue Prussian blue (Diesbach, 1704; Macquer, 1749) Napoleon's Blue, Turnbull's Blue, royal blue</td>
<td>Potassium ferric ferrocyanide K[Fe₄[Fe(CN)₆]₃</td>
<td>C.I. Pigment Blue 27, Mineral Dye</td>
</tr>
<tr>
<td>VHS8</td>
<td>Ponceau (type not specified)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>VHS9</td>
<td>Hofmann's Violet B (Hoffman and Geyger, 1863)</td>
<td>—</td>
<td>C.I. 42530</td>
</tr>
<tr>
<td>CQS Designation</td>
<td>Name(s) of Dye and Discoverer</td>
<td>Chemical Composition</td>
<td>Color Index and Color Constitution Number</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------------------------------</td>
<td>----------------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>VHS10</td>
<td>Nicholson's Blue 4B (Girard and deLaire, 1861; Nicholson, 1862)</td>
<td>—</td>
<td>C.I. Solvent Blue 3, formerly used as a basic dye, C.I. 42770 or Nicholson, 1862, C.I. Acid Blue 48/C.I. Pigment Blue 18, C.I. 427705</td>
</tr>
<tr>
<td>VHS11</td>
<td>Saffranine pink (Greville Williams, 1859)</td>
<td>—</td>
<td>C.I. Basic Red 2, C.I. 50240 Safranine T</td>
</tr>
<tr>
<td>VHS12</td>
<td>Coralline yellow (Persoz, 1859)</td>
<td>Sodium salt of Aurine</td>
<td>C.I. 43800</td>
</tr>
<tr>
<td>VHS13</td>
<td>Aurine orange (Runge, 1834)</td>
<td>Rosolic acid</td>
<td>C.I. 43800</td>
</tr>
<tr>
<td>VHS14</td>
<td>Madder red</td>
<td>—</td>
<td>C.I. Natural Red 8, C.I. 75330</td>
</tr>
<tr>
<td>VHS15</td>
<td>Artificial alizarin (Graebe and Liebermann, 1868/1869/1871)</td>
<td>—</td>
<td>C.I. Mordant Red 11, C.I. 58000</td>
</tr>
<tr>
<td>VHS16</td>
<td>Madder red (dark pink)</td>
<td>—</td>
<td>C.I. Natural Red 8, C.I. 75330, C.I. 75340, C.I. 75350, C.I. 75410, C.I. 45420</td>
</tr>
<tr>
<td>VHS17</td>
<td>Madder style as above</td>
<td>As in VHS16, a lighter shade</td>
<td>As above</td>
</tr>
<tr>
<td>VHS18</td>
<td>Madder style as above</td>
<td></td>
<td>As above</td>
</tr>
<tr>
<td>VHS19</td>
<td>Garacin (Robiquet and Colin, 1828)</td>
<td>Madder treated with sulfuric acid</td>
<td>C.I. Natural Red 10, C.I. 75330</td>
</tr>
<tr>
<td>VHS20</td>
<td>Madder and aniline black</td>
<td>See VHS14 Madder and VHS4 Aniline black</td>
<td>See VHS14 Madder and VHS4 Aniline black</td>
</tr>
<tr>
<td>VHS21</td>
<td>Dark indigo</td>
<td>—</td>
<td>C.I. Natural Blue 1, C.I. Vat Blue 1, C.I. 73000</td>
</tr>
<tr>
<td>VHS22</td>
<td>Light indigo</td>
<td>—</td>
<td>C.I. Natural Blue 1, C.I. Vat Blue 1, C.I. 73000</td>
</tr>
<tr>
<td>VHS23</td>
<td>Standard light brown Catechu or Cutch</td>
<td>—</td>
<td>C.I. Natural Brown 3</td>
</tr>
<tr>
<td>VHS24</td>
<td>Standard dark brown Catechu or Cutch</td>
<td>—</td>
<td>C.I. Natural Brown 3</td>
</tr>
<tr>
<td>VHS25</td>
<td>Cochineal</td>
<td>—</td>
<td>C.I. Natural Red 4, C.I. 75460</td>
</tr>
<tr>
<td>VHS26</td>
<td>Dark yellow with Persian berries Dyers buckthorn</td>
<td>—</td>
<td>C.I. Natural Yellow 13</td>
</tr>
<tr>
<td>CQS Designation</td>
<td>Name(s) of Dye and Discoverer</td>
<td>Chemical Composition</td>
<td>Color Index and Color Constitution Number</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------------</td>
<td>----------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>VHS27</td>
<td>Pale yellow with Persian berries Dyers buckthorn</td>
<td>—</td>
<td>C.I. Natural Yellow 13</td>
</tr>
<tr>
<td>VHS28</td>
<td>Ultramarine</td>
<td>Synthetic ultramarine 1828 Na₈₋₁₀Al₆Si₆O₂₄S₂₋₄</td>
<td>C.I. Pigment Blue 29, C.I .77007</td>
</tr>
<tr>
<td>VHS29</td>
<td>Carbonaceous gray</td>
<td>—</td>
<td>C.I. Pigment Black 6 or 7, C.I. 772666</td>
</tr>
<tr>
<td>VHS30</td>
<td>Padded green</td>
<td>Chrome green, see VHS5</td>
<td>—</td>
</tr>
<tr>
<td>VHS31</td>
<td>Light chrome orange</td>
<td>Chrome orange PbCrO₄•Pb(OH)₂</td>
<td>C.I. Pigment Orange 21, C.I. 76601 Mineral Dye</td>
</tr>
<tr>
<td>VHS32</td>
<td>Dark chrome orange</td>
<td>PbCrO₄•Pb(OH)₂</td>
<td>C.I. Pigment Orange 21, C.I. 76601 Mineral Dye</td>
</tr>
<tr>
<td>VHS1</td>
<td>Vermillion</td>
<td>Mercury sulfide (HgS)</td>
<td>C.I. Pigment Red 106 Pigment</td>
</tr>
<tr>
<td>VHS2</td>
<td>Spiller’s purple</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VHS3</td>
<td>Hofmann’s violet RRR (Hofmann and Geyger, 1863)</td>
<td>Mixture of rosaniline C.I. 42510 and C.I. 42500 para-rosaniline</td>
<td>C.I. 42530 Basic Dye</td>
</tr>
<tr>
<td>VHS4</td>
<td>Aniline gray (Castelhaz)</td>
<td>Precipitate of mauvine paste and concentrated H₂SO₄ treated with aldehyde</td>
<td>—</td>
</tr>
</tbody>
</table>

Reference chips consist of eight mid-tone values, along with six stronger colors—red, yellow, green, blue, “flesh,” and “forest” (fig. 2a). More recently, the National Institute of Standards and Technology (NIST) Color Quality Scale (CQS) system was developed. Although it also uses mid-tone values (neither too light nor too dark), the colors are much brighter, with significantly higher chroma (fig. 2b), and evenly represents the entire color wheel. Both systems use two textile color-measuring systems: spectrophotometry in the visible region provides a reflectance curve for a colorant from 400 to 700 or 750, and tristimulus colorimetry gives CIE L*a*b* values for the same physical color. The reference light source for these measurements is a calibrated D6500—a simulation of the SPD of white light of sunlight. Both systems collect the color differences for every reference chip between the spectrophotometric and colorimetric values reflected from the D6500 and those values from each test LED SPD to achieve final numerical valuation (Davis and Ohno 2010).

There are distinct advantages for textile conservators and museum scientists with the NIST CQS system. It incorporates root square differences rather than simple averages into its summary evaluation. The CQS final number is reduced when the chroma of a color is reduced or if the hue is shifted; it is not affected
so much by an enhancement of the chroma. The CRI system treats any shift of hue, chroma, or value as equally problematic (Optical Radiation Group 2015). Most importantly, the NIST CQS Excel program permits adjustments: it is possible to insert new reference reflectance curves as color chips. Thus, D6500 values of the fabric swatches illustrating Crookes’ *Practical Handbook* can be inserted and actually replace the CQS reference chips to create a “custom” CQS program. For each swatch, multiple spectrophotometric reflectance readings in three orientations—warp direction, weft direction, and bias—were taken, and the totals were averaged together. When the 8-mm-wide port in the Hunter Lab MiniScan EZ spectrophotometer was too large for the printed stripes on some swatches, photographic laboratory black paper with a paper hole punch 6 mm in diameter created an accurate filter; its readings were practically identical to the readings on a solid-colored swatch with or without such a filter (American Association of Textile Chemists and Colorists 2015).

### 3. RESULTS AND DISCUSSION

In figure 3, the new Crookes reference colors are shown inserted into the NIST program. The CQS program shows the CRI results at the top, and the custom CQS results are displayed in the lower half. Below each CQS reference color and its test color is the \( \Delta E_{ab} \)—there is very little difference, as this CIE Illuminant F8 standard is a special broadband fluorescent specifically designed to mimic daylight. On the CIE \( L^*a^*b^* \) chart, the blue “reference” color and its red “test” value overlap so well that it can be hard to see the blue and red spots apart.

Once their spectral data was entered into the NIST simulator, 124 SPDs of potential LEDs could be compared against the calico standards. Twenty-nine different lamps affected the color of the samples the least or made them appear very slightly brighter. Two of the “best” lamps had very similar correlated color temperatures (CCTs) and relative efficiency—the luminous efficacies of radiation (LERs) are very good (fig. 4).
TAYLOR MCCLEAN, COURTNEY A. BOLIN, AND MARY W. BALLARD

Fig. 3. The Color View page summarizes results in the customized NIST CQS Excel program. It shows the CRI and CQS results evaluating the effect of the CIE standard illuminant F8 (fluorescent) SPD on the Crookes colors. At the top, the $L^*a^*b^*$ map charts the sample results for the CRI results; at the bottom is the $L^*a^*b^*$ map for the Crookes swatches. Bar charts next to the CRI and CQS color swatches show the calculated averages that provide the final CRI and CQS scores seen in the top left-hand corner.

Fig. 4. Using the CQS program, these two LEDs produced the lowest $\Delta E_{ab}$ for the swatches from *A Practical Handbook of Dyeing and Calico-Printing*. 
THE EFFECT OF LIGHT-EMITTING DIODE LAMPS ON 19TH-CENTURY
DYED AND PRINTED COTTON FABRICS

The CRI numbers and the CQS summary numbers are not far off. At the same time, it is possible to read the
$\Delta E_{ab}$ results for the individual samples. This is quite valuable: VS9 and VS10 on the top row are Hofmann's
Violet and Nicolson's Blue, and both have relatively high differences. Clearly, had an exhibition with quilts had
a lot of purple, these LEDs would not have been suitable.

4. CONCLUSION

Rather than leave the color appearance of textiles to chance, it is possible to predict the effect of a particular
LED lamp before the lamps are purchased and before textiles are installed in a gallery. The important colors of
the palette of the dyed textiles can be evaluated directly against the SPD of the lamps proposed. To do this, the
NIST CQS Excel program is a wonderful tool. It can be downloaded free of charge. With a portable visible
spectrophotometer, the spectral reflectance curves of the predominant colors being exhibited can be inserted
into the program. If the SPD of the proposed LED has not yet been inserted into the NIST program, it too can
be incorporated (see NIST instructions), along with any other LED being considered for gallery use. Thus, a
spreadsheet of lamps and color palettes can be used to determine the best systems for different exhibition
needs. With all of the work and effort associated with organizing an exhibition, the CQS system ensures that
the exhibition lighting will make the colors of the textiles look their best.

ACKNOWLEDGMENTS

We are indebted to Dr. Yoshi Ohno of the NIST Sensor Division for his kind advice and 32-space blank ver-
sion of the NIST CQS program, and to the Smithsonian Institution Libraries for obtaining a copy of William

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24: 85–95.

Digital version: http://babel.hathitrust.org/cgi/pt?id=gri.ark:/13960/t5s76ht3d;view=1up;seq=775.


Doroszczyk, M., A. Gentry, N. Dalela, J. Giaccai, and M. W. Ballard. 2013. MCI# 6529: Report on XRF exami-
nation of the printed cotton samples. Unpublished manuscript. Museum Conservation Institute, Suitland, MD.


**FURTHER READING**


**SOURCES OF MATERIALS**

Hunterlab Visible Spectrometer: MiniScan XE Plus with Diffuse/8o Sphere Geometry and Small Viewing Area (8 mm)

Hunter Associates Laboratory Inc.
11491 Sunset Hills Rd.
Reston, VA 20190
800-471-6870
[http://www.hunterlab.com](http://www.hunterlab.com)
THE EFFECT OF LIGHT-EMITTING DIODE LAMPS ON 19TH-CENTURY DYED AND PRINTED COTTON FABRICS

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ABSTRACT—This article investigates the feasibility, effectiveness, and overall value of Reflectance Transformation Imaging (RTI) for documentation and analysis of archaeological textile impressions. The ability to manipulate the light source and enhance surface attributes with RTI facilitates identification of important textile features from documentation of textile impressions. This is especially important for ephemeral material, like archaeological soil impressions; the original material is often destroyed during ongoing excavation, and documentation becomes the sole record of the object. The interactive RTI files provide an alternative way to study textile impressions that minimizes object handling during examination. In this study, RTI images of impressions in ceramic, mudbrick, and soil were captured and then compared to digital photography based on standards for good documentation of archaeological textile impressions. The findings demonstrate that RTI can provide superior information to digital photography for documentation and analysis of textile impressions. Particularly promising is the ability of RTI to provide a lasting digital artifact of short-lived archaeological information for in situ archaeological textile impressions.

1. INTRODUCTION

The practice guidelines of both the AIC and The Institute of Conservation (ICON) articulate the importance of examination, documentation, and preventive conservation in the work of the conservation professional (AIC 1994; ICON 2002). These tasks can be particularly challenging for conservators working with archaeological textile impressions, because identification and study of textile features are complex and often require specific conditions.

The study of textile elements preserved by impression often requires significant object handling, which is undesirable (Frank 2014a). In cases where access to the material in conditions conducive to investigation is limited, documentation of the object, or a digital artifact, can be studied instead. Currently, textile impressions are primarily documented with digital photography. As technology evolves, it is important to readdress the standard practices for investigation and documentation of textile material.

RTI is a computational imaging technique that creates an interactive file in which an object can be relit from any direction. RTI allows mathematical enhancement of an object’s surface and color to reveal texture difficult to detect during empirical examination (Earl, Martinez, and Malzbender 2010; CHI 2013b). As such, it is an excellent way to document textured surfaces. Textile impressions preserve the negative space surrounding the material of paramount interest to textile specialists; consequently, the primary information is preserved in the surface topography, not by color or physical material. The ability to manipulate the light source and mathematically enhance surface attributes in RTI expedites identification of important features of archaeological textiles from images. This is especially important for ephemeral material, like in situ archaeological impressions, because the material will likely be destroyed by ongoing excavation. RTI offers more than just increased legibility; it can mathematically create the illusion of inverting an impression, producing a convex digital version of the concave impression, essentially a facsimile of the original organic textile.

1 The material in this article is largely based on Frank (2014b).
LIGHTS, CAMERA, ARCHAEOLOGY: DOCUMENTING ARCHAEOLOGICAL TEXTILE IMPRESSIONS WITH REFLECTANCE TRANSFORMATION IMAGING (RTI)

This study hypothesizes that RTI is superior to digital photography as a method of recording archaeological textile impressions for conservation. It proposes that RTI provides a more useful digital artifact than traditional digital photography. RTI is effective, noninvasive, temporally and financially feasible, and capable of documenting both previously excavated and in situ material.

2. REFLECTANCE TRANSFORMATION IMAGING

RTI technology compiles multiple digital “source” images of a static subject from a stationary camera with a changing light source (CHI 2013b). The resulting file not only holds the color and shape information of a traditional digital photograph but also allows active relighting of the subject from any direction (Hewlett-Packard 2009; Payne 2012; CHI 2013b). Additionally, the object can be rendered using mathematical enhancement functions that exhibit surface details often difficult to see or interpret during empirical examination (CHI 2013b). The origins of RTI are described in Frank (2014a, 2014b). For RTI file nomenclature, which can be confusing, and additional definitions, see glossary (Appendix 1).

To build an RTI, the compilation program must know or be able to determine the direction of illumination in the source images (Payne 2012; Frank 2014; Malesevic et al. 2014). This is accomplished in one of two ways. RTI images can be taken in an arc or dome, on which lights are mounted mechanically, and the locations of the lights are programmed into the fitting software. Alternatively, the source images can be collected with a moveable light, if a specular sphere is captured in each image. This technique is called highlight RTI (H-RTI). The primary differences between dome RTI and H-RTI are consistency of light distribution in the resulting RTIs, portability of the setup, and range of material sizes the setup can capture. An H-RTI setup can be compiled and moved anywhere, whereas at present, a lighting dome is far more involved to build and significantly less portable. Additionally, a dome can only image material that fits inside of it, which limits its use to smaller objects (Piquette 2011).

RTI’s value lies in the unique ability to accurately represent both color and form. In traditional photography, red-green-blue (RGB) color information is directly recorded per pixel. In contrast, RTI saves these color values as a best-fit polynomial model of the luminosity, or brightness. Surface “normals,” or the vectors perpendicular to a surface at any one point, can be determined from this information. In other words, the RTI documents the color in a way that can be mathematically translated into surface shape and reflection (Malzbender et al. 2001; Hewlett-Packard 2009; CHI 2013b; Frank 2014a).

Once an RTI has been created, the viewer can alter the surface appearance in the RTI viewer by manipulating the reflectance properties using various modes (Hewlett-Packard 2005). As shown in figure 1, these modes can exhibit surface details that are otherwise difficult to interpret.

Both .rti and .ptm files are buildable and viewable with a number of free, open-source software products available online. The interactive files can provide a far more comprehensive and detailed view of the object than any of the individual digital screenshots shown throughout this article. Please contact the author with requests to view the interactive RTI files discussed below.

3. RESEARCH QUESTIONS AND METHODS

3.1 RESEARCH QUESTIONS

This research asks the following questions: In terms of amount and quality of information preserved for conservation purposes, does RTI offer better documentation of archaeological impressions than digital photography? Is the digital artifact created by RTI better for identification of textile features than traditional
Fig. 1. Visual comparison of digital photography and RTI. A digital photograph (a) juxtaposed with a screenshot of an RTI in the specular enhancement rendering mode (b) of the flat base of a large ceramic vessel with a basketry impression from Periano Ghundai, Pakistan, in the UCL Institute of Archaeology Collections (Accession Number: 50/4348). The mathematically enhanced RTI image of the impression shows textural information that is not visible in the digital photograph. Courtesy of UCL Institute of Archaeology Collections.
digital photographs? Is RTI effective, feasible, and therefore valuable for recording ephemeral archaeological impressions in situ?

3.2 METHODS

3.2.1 RTI Testing

The findings in this article are based on experimental work. Digital photographs and RTIs of ten archaeological textile and basketry impression samples were captured, processed, and compared based on standards for good documentation of archaeological textile impressions.

From the synthesis of current practices for documentation of archaeological impressions, based on a literature review and the list of components of interest to specialists established by survey, a checklist of criteria for ideal conservation documentation of textile material was compiled. For convenience, these criteria for evaluating documentation are henceforth referred to as CED. Table 1 shows those elements required for successful documentation of archaeological textile impressions.

Table 1: Criteria for Evaluation of Documentation (CED) Checklist

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Images have been taken of all views</td>
<td>-</td>
</tr>
<tr>
<td>and components relevant to research.</td>
<td></td>
</tr>
<tr>
<td>Images include a scale.</td>
<td>For transparency regarding dimensions</td>
</tr>
<tr>
<td>Images include a color chart.</td>
<td>For transparency regarding object color, and where applicable, any remaining textile material</td>
</tr>
<tr>
<td>The following textile features are</td>
<td></td>
</tr>
<tr>
<td>legible and in focus (where applicable):</td>
<td></td>
</tr>
<tr>
<td>Materials and Fibers</td>
<td>Inclusive of all information regarding raw materials and fiber type</td>
</tr>
<tr>
<td>Overall Structure</td>
<td>Method for combining fibers</td>
</tr>
<tr>
<td>Weave Type</td>
<td>Pattern of fibers</td>
</tr>
<tr>
<td>Thread Count</td>
<td>Density of threads per unit (Seiler-Baldinger 1994, 87)</td>
</tr>
<tr>
<td>Binding</td>
<td>Active system fixing multiple passive systems (Seiler-Baldinger 1994, 29)</td>
</tr>
<tr>
<td>Selvage/Edge Structure</td>
<td>Inclusive of all information relating to termination of the structure</td>
</tr>
<tr>
<td>Sewing</td>
<td>Stitching used to combine elements</td>
</tr>
<tr>
<td>Fiber Structure</td>
<td>Inclusive of all information regarding fiber production method</td>
</tr>
<tr>
<td>Yarn/Fiber Thickness</td>
<td>Diameter</td>
</tr>
<tr>
<td>Spin Direction</td>
<td>S or Z spin for twisted, spun, or plied threads</td>
</tr>
<tr>
<td>Spin Angle</td>
<td>Acute angle formed by slant of twist with vertical orientation of thread for twisted, spun, or plied threads (Seiler-Baldinger 1994, 4)</td>
</tr>
<tr>
<td>Decorative Elements and/or Patterns</td>
<td>Areas with different materials or structure</td>
</tr>
</tbody>
</table>
After capture of the digital photographs and the RTI source image set, the RTI and all individual digital photographs were assessed using the CED. The quantified abilities of digital photography and RTI to record archaeological textile and basketry impressions were compared with unassisted examination and each other for each sample, using a form created for this purpose (table 2).

Standard capture and processing workflows for digital photography and RTI were followed to control variables introduced during image capture and processing. Creation of these workflows considered the current practices for documentation of archaeological textile material, the CED established for good

<table>
<thead>
<tr>
<th>CED</th>
<th>Present in or Discernable from Sample (No = 0, Yes = 1)</th>
<th>Present in or Discernable from Photograph (No = 0, Yes = 1)</th>
<th>Present in or Discernable from RTI (No = 0, Yes = 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials and/or Fibers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Structure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weave Type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thread Count</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Binding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selvage/Edge Structure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sewing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiber Structure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yarn/Fiber Thickness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spin Direction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spin Angle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decorative Elements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>and/or Patterns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evidence of Construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condition and/or</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evidence of Use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irregularities</td>
<td>Total:</td>
<td>Total:</td>
<td>Total:</td>
</tr>
</tbody>
</table>

Table 2: Form Used for Comparison of Digital Photography and RTI

2 Some of these features were best analyzed via microscopy; this in no way limited the use of RTI, because as with digital photography, RTI can be conducted on a microscopic level.
Lights, Camera, Archaeology: Documenting Archaeological Textile Impressions with Reflectance Transformation Imaging (RTI)

documentation of textile material, the Cultural Heritage Imaging (CHI) guides to RTI capture and image processing (CHI 2013d; CHI 2013e), and experimentation. Appendix 2 details these workflows.

H-RTI was used throughout this experiment so the results would have wider applicability, because most users will not have access to an RTI dome.

Throughout this article, black-and-white photographs of each object are provided to minimize distraction from color during comparison of textures. For the same reason, the RTI screenshots in this article are shown in black and white.

Though the RTI viewers available online collectively provide 10 rendering modes, the specular enhancement and diffuse gain modes were found to be especially useful for this analysis. The specular enhancement rendering mode maximizes pixel brightness (Hewlett-Packard 2005). This provides increased tonal contrast that can be quite valuable in identifying and clarifying barely visible surface features (Earl et al. 2010; CHI 2013b). Specular enhancement also reveals surface information where it might otherwise be lost due to specular reflection (Mudge et al. 2005, 7; Frank 2014). It was especially informative for dark-colored objects. Likewise, the diffuse gain rendering mode changes the surface shape of each pixel to magnify detail (Hewlett-Packard 2005). It is valuable as a way to maximize the change in surface appearance as a function of the illumination direction; this is somewhat analogous to increasing contrast in a photograph. It was especially informative for matte objects.

The normals visualization corresponding to each RTI accompanies the screenshots throughout this article. Normals visualization is a false color visualization that uses color to show different planes of the textile impression. Red, green, and blue are used to represent the x, y, and z components of the surface normal values per pixel, respectively. Pixels with a normal vector that falls between the three axes are shown as a relative blend of the false colors of the closest axes. This helps the viewer clearly understand convex and concave surfaces and is important for accurate understanding and documentation of the surface topography.

3.2.2 Sample Selection

Samples were selected for imaging with the following goals in mind: to establish patterns in the success or failure of RTI to legibly preserve textile impressions with a range of dimensions and structures, to assess the impact of the material with the impression on the legibility of textile information in RTI, and to assess the effects of surface shape on the legibility of textile information in RTI. Each sample was documented with both digital photography and RTI; each image set was recorded twice to control for routine variation.

Initial test RTIs suggested that RTI’s ability to document the textile impression effectively would rely heavily on the specifics of textile structure, strength of impression, and surface topography of the area of the object with the impression. The material makeup of the object that held the impression was postulated to be of secondary importance. As shown in table 3, which describes the samples, this experiment tested six ceramic samples, two sunbaked mud samples, and two soil samples.

4. Results

Table 4 provides the raw data from this experiment. Each slice of the pie graph (fig. 2) shows the percentage of the samples where the method, or methods, of examination or documentation yielded the most data in this experiment. The colored areas show the percentage of samples where RTI preserved at least the maximum
Table 3: Sample Details

<table>
<thead>
<tr>
<th>Sample</th>
<th>Museum Collection</th>
<th>Museum Number</th>
<th>Material</th>
<th>Surface Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Institute of Archaeology (IoA)</td>
<td>50/4348</td>
<td>Ceramic</td>
<td>Flat</td>
</tr>
<tr>
<td>B</td>
<td>IoA</td>
<td>56/2110</td>
<td>Ceramic</td>
<td>Flat</td>
</tr>
<tr>
<td>C</td>
<td>IoA</td>
<td>50/4349</td>
<td>Ceramic</td>
<td>~30° curve</td>
</tr>
<tr>
<td>D</td>
<td>IoA</td>
<td>56/2109</td>
<td>Ceramic</td>
<td>Flat</td>
</tr>
<tr>
<td>E</td>
<td>IoA</td>
<td>EXX.1/5</td>
<td>Ceramic</td>
<td>Flat</td>
</tr>
<tr>
<td>F</td>
<td>IoA</td>
<td>2011/130</td>
<td>Ceramic</td>
<td>~5° curve</td>
</tr>
<tr>
<td>G</td>
<td>Petrie Museum</td>
<td>UC36862</td>
<td>Sunbaked mud</td>
<td>Irregular surface shape</td>
</tr>
<tr>
<td>H</td>
<td>Petrie Museum</td>
<td>UC36854</td>
<td>Sunbaked mud, previously consolidated</td>
<td>Irregular surface shape</td>
</tr>
<tr>
<td>I</td>
<td>NA</td>
<td>NA</td>
<td>Soil</td>
<td>Flat</td>
</tr>
<tr>
<td>J</td>
<td>NA</td>
<td>NA</td>
<td>Soil</td>
<td>Flat</td>
</tr>
</tbody>
</table>

Table 4: Summary of Quantified Data in Tabular Form*

<table>
<thead>
<tr>
<th>Sample</th>
<th>Number of CEDs Present in or Discernable from Sample</th>
<th>Number of CEDs Present in or Discernable from Photograph</th>
<th>Number of CEDs Present in or Discernable from RTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>7</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>C</td>
<td>10</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>D</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>E</td>
<td>11</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>F</td>
<td>11</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>G</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>H</td>
<td>11</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>I</td>
<td>3</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>J</td>
<td>2</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Total:</td>
<td>84</td>
<td>85</td>
<td>96</td>
</tr>
</tbody>
</table>

* Shading is used to show the method(s) of examination that preserved the most data for each sample.

Information captured by any method. This accounts for 90% of the samples. In 40% of samples, RTI preserved data not preserved by digital photography or seen in unassisted examination. In no case did RTI provide less information than digital photography. The scope of this article only permits publication of representative images of selected samples.
LIGHTS, CAMERA, ARCHAEOLOGY: DOCUMENTING ARCHAEOLOGICAL TEXTILE IMPRESSIONS WITH REFLECTANCE TRANSFORMATION IMAGING (RTI)

Fig. 2. Summary of quantified data in graphic form. Each slice of the pie graph shows the percentage of the samples where the method(s) of examination indicated yielded the most data. The colored areas show that RTI preserved the maximum information in 90% of samples.

4.1 SAMPLE B

Sample B is a ceramic vessel with a basketry impression on the base from Teleilat Ghassul, Jordan, in the University College London (UCL) Institute of Archaeology Collections (figs. 3, 4) (Institute of Archaeology). For this sample, RTI provides superior information to digital photography and unassisted examination of the object under average lighting conditions. In this case, RTI rendering modes supply information regarding the fibers and edge structure that is not detectable through unassisted examination or in the digital photographs. In figures 4b and 4f, diffuse gain reveals thin lumpy strands surrounding the fibers that are not visible in the digital photographs in figure 3.

The impression in sample B, likely an example of coiled basketry, is deep enough that the structure is apparent in all modes of examination. However, figure 4 shows the tapered end of the coil with more clarity than figure 3. It is also notable how well the RTI in figure 4 provides information regarding irregularities in the coils. The missing wrapping strand is significantly more legible in the convex inversion provided by RTI than in the digital photographs (fig. 3).
Fig. 3. Digital photographs of Sample B: (a) color photograph, (b) black-and-white photograph. Courtesy of UCL Institute of Archaeology Collections; Accession Number: 56/2110.
LIGHTS, CAMERA, ARCHAEOLOGY: DOCUMENTING ARCHAEOLOGICAL TEXTILE IMPRESSIONS WITH REFLECTANCE TRANSFORMATION IMAGING (RTI)

fig. 4. a.

fig. 4. b.

fig. 4. c.

fig. 4. d.

fig. 4. e.

fig. 4. f.
Fig. 4. Screenshots from RTI of Sample B: (a) default, (b) diffuse gain, (c) specular enhancement, (d) normals visualization. (e)–(h), details: (e) default, (f) diffuse gain, (g) specular enhancement, (h) normals visualization. Courtesy of UCL Institute of Archaeology Collections. Accession Number: 56/2110.

<table>
<thead>
<tr>
<th>Image</th>
<th>Rendering Mode</th>
<th>Light (x,y)</th>
<th>Pan (x,y)</th>
<th>Zoom</th>
<th>Viewing Conditions*</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Default</td>
<td>(0.94,0.33)</td>
<td>(94,0)</td>
<td>40%</td>
<td>—</td>
</tr>
<tr>
<td>b</td>
<td>Diffuse Gain</td>
<td>(0.51,−0.42)</td>
<td>(94,0)</td>
<td>40%</td>
<td>G = 10</td>
</tr>
<tr>
<td>c</td>
<td>Specular Enhancement</td>
<td>(−0.31,−0.43)</td>
<td>(94,0)</td>
<td>40%</td>
<td>DC = 63, S = 13, HS = 9</td>
</tr>
<tr>
<td>d</td>
<td>Normals Visualization</td>
<td>(0.94,0.33)</td>
<td>(94,0)</td>
<td>40%</td>
<td>—</td>
</tr>
<tr>
<td>e</td>
<td>Default</td>
<td>(−0.63,−0.49)</td>
<td>(804,265)</td>
<td>74%</td>
<td>—</td>
</tr>
<tr>
<td>f</td>
<td>Diffuse Gain</td>
<td>(0.51,−0.42)</td>
<td>(804,265)</td>
<td>74%</td>
<td>G = 10</td>
</tr>
<tr>
<td>g</td>
<td>Specular Enhancement</td>
<td>(0.31,−0.62)</td>
<td>(804,265)</td>
<td>74%</td>
<td>DC = 83, S = 18, HS = 1</td>
</tr>
<tr>
<td>h</td>
<td>Normals Visualization</td>
<td>(−0.63,−0.49)</td>
<td>(804,265)</td>
<td>74%</td>
<td>—</td>
</tr>
</tbody>
</table>

* Column lists the viewing conditions used within the rendering mode in the RTIViewer. G refers to “Gain,” DC refers to “Diffuse Color,” S refers to “Specularity,” and HS refers to “Highlight Size.”

4.2 Sample D

Sample D is a large ceramic vessel with a textile impression on the base from Teleilat Ghassul, Jordan, in the UCL Institute of Archaeology Collections (figs. 5, 6) (Institute of Archaeology). In this sample, the impression is again strong enough that important information can be obtained from the digital photographs (fig. 5). However, the RTI is significantly more legible (fig. 6).

Sample D is most likely an impression of a right-angled plain weave. The passive system is a single-plied system with a 35° S twist. The increased clarity provided by diffuse gain in figures 6b and 6f provides a level of detail of the striations in the active system not visible elsewhere. Additionally, the digital photograph can play tricks on the eye. The twist angle of the passive system is such that the photograph can fool the viewer into thinking that the plain weave has oblique plaiting (fig. 5); the convex reconstruction created in the RTI (fig. 6) allows the viewer to quickly understand the system.
LIGHTS, CAMERA, ARCHAEOLOGY: DOCUMENTING ARCHAEOLOGICAL TEXTILE IMPRESSIONS WITH REFLECTANCE TRANSFORMATION IMAGING (RTI)

Fig. 5. Digital photographs of Sample D: (a) color photograph, (b) black-and-white photograph. Courtesy of UCL Institute of Archaeology Collections. Accession Number: 56/2109.
4.3 SAMPLE G

Sample G is a sunbaked mud fragment with textile impression on the interior from Abydos, Egypt, in the Petrie Collection (figs. 7, 8) (Petrie Museum). In this case, RTI allows identification of a number of features of sample G not otherwise visible. The impression in sample G is likely an example of a three-end twill. Twills are defined by a systematic uneven interlacing of warp and weft threads for decorative purposes (Seiler-Baldinger 1994).

Based on examination of the object, the textile appeared to be a right-angled plain weave. Only after examination of the RTI did it seem to be a decorative twill (fig. 8). There are not enough clear repetitions to be certain. If it is not a twill, the observed phenomena can be explained as an irregularity in a plain weave. In addition, in the specular enhancement rendering mode of the RTI, twisting can be identified on one of the fibers. With the zoom feature, the fibers have an S twist and about 35° twist angle (fig. 9).
Fig. 7. Digital Photographs of Sample G: (a) color photograph, (b) black-and-white photograph. Courtesy of the Petrie Museum of Egyptian Archaeology, UCL. Accession Number: UC36862.
LIGHTS, CAMERA, ARCHAEOLOGY: DOCUMENTING ARCHAEOLOGICAL TEXTILE IMPRESSIONS WITH REFLECTANCE TRANSFORMATION IMAGING (RTI)

fig. 8. a.

fig. 8. b.

fig. 8. c.

fig. 8. d.

fig. 8. e.

fig. 8. f.
Fig. 8. Screenshots from RTI of Sample G: (a) default, (b) diffuse gain, (c) specular enhancement, (d) normals visualization. (e)–(h), details: (e) default, (f) diffuse gain, (g) specular enhancement, (h) normals visualization. Courtesy of the Petrie Museum of Egyptian Archaeology, UCL. Accession Number: UC36862.

<table>
<thead>
<tr>
<th>Image</th>
<th>Rendering Mode</th>
<th>Light (x,y)</th>
<th>Pan (x,y)</th>
<th>Zoom</th>
<th>Viewing Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Default</td>
<td>(−0.8,−0.59)</td>
<td>(0,0)</td>
<td>33%</td>
<td>—</td>
</tr>
<tr>
<td>b</td>
<td>Diffuse Gain</td>
<td>(0.62,−0.76)</td>
<td>(0,0)</td>
<td>33%</td>
<td>G = 13</td>
</tr>
<tr>
<td>c</td>
<td>Specular Enhancement</td>
<td>(−0.7,0.0)</td>
<td>(0,0)</td>
<td>33%</td>
<td>DC = 61, S = 36, HS = 9</td>
</tr>
<tr>
<td>d</td>
<td>Normals Visualization</td>
<td>(−0.8,−0.59)</td>
<td>(0,0)</td>
<td>33%</td>
<td>—</td>
</tr>
<tr>
<td>e</td>
<td>Default</td>
<td>(−0.41,−0.91)</td>
<td>(1668,748)</td>
<td>120%</td>
<td>—</td>
</tr>
<tr>
<td>f</td>
<td>Diffuse Gain</td>
<td>(−0.36,−0.72)</td>
<td>(1668,748)</td>
<td>120%</td>
<td>G = 5</td>
</tr>
<tr>
<td>g</td>
<td>Specular Enhancement</td>
<td>(0.18,−0.98)</td>
<td>(1668,748)</td>
<td>120%</td>
<td>DC = 69, S = 43, HS = 2</td>
</tr>
<tr>
<td>h</td>
<td>Normals Visualization</td>
<td>(−0.41,−0.91)</td>
<td>(1668,748)</td>
<td>120%</td>
<td>—</td>
</tr>
</tbody>
</table>

In this sample, the irregularity of the surface causes some unavoidable self-shadowing that obscured sections of the textile in the digital photograph. The moveable light in the full RTI allows the viewer to examine these sections obscured in figure 7.

The RTI of sample G, which is a compelling illustration of the advantages of RTI, clearly provides information about weave type, fiber structure, spin direction and angle, and decorative elements that cannot be discerned by unassisted examination or from digital photographs.

4.4 SAMPLE I

Sample I is a textile impression in potting soil created in Gordon Square, London, in May 2014, for this research (figs. 10, 11). In this case, both the RTI and the photograph yield far more textile information than unassisted examination. Identification of textile features is complicated by both the lack of contrast surrounding the textile features in the dark soil and the visual confusion caused by the lighter specks inherent in the
soil chosen. Additionally, the impression could not be handled or moved and is far too fragile to touch, making any fruitful analysis by unassisted examination improbable. The digital views of the object allow identification of the overall structure and weave type, the selvage, and relatively precise measurement of the fibers. Sample I is an impression of a single crochet. The reconstruction possible in the RTI makes evident the regularity of the fibers and irregularities in the weave, which are not discernable in the digital photographs. Figure 11 shows a possible skipped stitch that is not evident elsewhere.

5. DISCUSSION

5.1 DOCUMENTATION AS A METHOD OF CONSERVATION

The data presented demonstrates that RTI is a valuable tool for conservation documentation. Purely in terms of information preserved, RTI provided documentation of impressions that was superior to digital photography.

The outstanding ability of RTI to provide information about soil impressions, as illustrated by the imaging of sample I, suggests that RTI can itself be a form of conservation for ephemeral impressions in situ. Figures 10 and 11 clearly show that RTI can provide a digital artifact of an object that would otherwise be destroyed.

For ephemeral soil impressions, the digital artifact created by the RTI can provide new information or insight that was previously overlooked or deemed insignificant. Archaeologists often re-examine finds long after they are unearthed. It is often only after strata are excavated that information starts to become clear.
Fig. 10. Digital photographs of Sample I: (a) color photograph, (b) black-and-white photograph.
LIGHTS, CAMERA, ARCHAEOLOGY: DOCUMENTING ARCHAEOLOGICAL TEXTILE IMPRESSIONS WITH REFLECTANCE TRANSFORMATION IMAGING (RTI)

fig. 11. a.

fig. 11. b.

fig. 11. c.

fig. 11. d.

fig. 11. e.

fig. 11. f.
The benefits of RTI are threefold: the RTI is a digital artifact that can be studied; the “digital handling” of the impressions made possible by RTI allows better interaction with the soil impression than might have been possible in situ; and a digital artifact allows for study from anywhere.

RTI can be quite valuable for documentation of this material, but in general RTI cannot replace good digital photography. However, if archival protocols are established, there is theoretically good digital photography inherent in the RTI capture process. If a scale is included in all the source images, a raking light source image could be white balanced, color corrected, and saved as a 16-bit TIF and DNG, minimizing the need for separate photography for documentation of this material.

5.2 TEXTILE ANALYSIS POTENTIAL

As discussed above, RTI has powerful documentary capabilities. It is an excellent way to document information for conservation purposes. But the benefits of RTI go further. The computational abilities of RTI make it an excellent analytical tool. The results presented above illustrate how information that is difficult to discern
LIGHTS, CAMERA, ARCHAEOLOGY: DOCUMENTING ARCHAEOLOGICAL TEXTILE IMPRESSIONS WITH REFLECTANCE TRANSFORMATION IMAGING (RTI)

Fig. 12. Cropped reproduction of Figure 11g. Figure 11g (specular enhancement rendering mode screenshot) shows a possible skipped stitch illegible elsewhere.

<table>
<thead>
<tr>
<th>Rendering Mode</th>
<th>Light (x,y)</th>
<th>Pan (x,y)</th>
<th>Zoom</th>
<th>Viewing Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specular Enhancement</td>
<td>($-0.2, -0.27$)</td>
<td>(1056,350)</td>
<td>50%</td>
<td>DC = 33, S = 59, HS = 5</td>
</tr>
</tbody>
</table>

from the original object is generally readable in the RTI. The image can be rendered in a variety of ways that help translate surface variation into more easily readable features. These computational tools can manipulate the surface to highlight detail. This is especially helpful for objects with shallower impressions, like sample F, or objects of varied or darker colors, as seen in sample A (fig. 1) and sample G (figs. 7, 8). In these samples, the shadows that fall from raised areas on impressed areas are either smaller (as a result of a relatively superficial impression) or less visible (as a result of a dark or varied object fabric), making interpretation of texture significantly more difficult. The specular enhancement feature of RTI, explained in Section 3.2.1, overcomes these issues by increasing the luster, thereby flattening the color of the object. The power of RTI to show surface detail in each case can be observed in figures 1b, 8g, and 13b, respectively.

Additionally, RTI has the ability to render concave surfaces convex, and vice versa. In each RTI it is possible to find a light direction that tricks the eye into seeing a convex reconstruction of the textile by inverting depth perception. This capability allows the viewer to understand detail that is not easily comprehensible from the original.
Fig. 13. Visual comparison of digital photography and RTI for shallow impressions. A digital photograph (a) juxtaposed with a screenshot of an RTI in the specular enhancement rendering mode (b) of the flat base and upright rim of a ceramic bowl with a textile impression from Periano Ghundai, Pakistan, in the UCL Institute of Archaeology Collections (Accession Number: 56/2110). The RTI image of the impression shows the benefit of RTI for shallow impressions. Courtesy of UCL Institute of Archaeology Collections.
Another benefit of RTI for examination and analysis is that the file allows the viewer to almost essentially reproduce the experience of handling the object under ideal light conditions to discern texture.

6. CONCLUSIONS

Previously published work on RTI has successfully focused on various analytical applications of the technique to a range of archaeological and museum materials. The work and findings in this study successfully apply these analytical capabilities to excavated archaeological textile impressions, and suggest that RTI has yet another promising application: the conservation of ephemeral textile impressions on site. The experimental work presented here suggests that RTI has the potential to be a superior way to document in situ textile impressions, a material class that until now has been documented with digital photography. Because the in situ textile impression samples tested used potting soil, the positive results imply, but do not demonstrate, the variable abilities of different naturally occurring soil types to preserve textile information.

The benefits of this work in conservation and textile studies are multifaceted. In these contexts, RTI provides a tool for effective documentation of textile impressions. This documentation is valuable as a record of the material’s condition in conservation as well as a platform for analysis in textile studies. For conservation and analysis of in situ impressions, RTI provides a permanent interactive record of an impermanent artifact.

Although the CHI, English Heritage, and AIC manuals provide guidelines for capture and processing, they gloss over many concerns a practitioner should consider before undertaking RTI (Warda et al. 2011; CHI 2013d; CHI 2013e; Duffy et al. 2013). At present a substantial limitation surrounding the use of RTI is the lack of established workflows and published methods papers. Current research at CHI is addressing this issue with the Digital Lab Notebook, but there is still a long way to go before a robust, sustainable, repeatable workflow and methodology emerges.

In addition, before RTI can be implemented effectively in conservation work, many considerations that fall outside of workflow must be examined. These include the implications of a shift towards RTI in conservation in terms of equipment, potential damage, image quality and size, image processing, archival protocols, repeatability, digital media conservation, image backup, and ethics. The extraordinary ability and potential of RTI to document archaeological textile impressions and to create permanent records of ephemeral artifacts, which can be used for research and conservation, more than justify further attention to these issues.

ACKNOWLEDGEMENTS

This project would not have been a reality without the guidance of my supervisor and many other faculty members from UCL and the Conservation Center at New York University (NYU), and help from my colleagues, family, and friends. I would like to express my heartfelt gratitude to James Hales and Dr. Margarita Gleba, whose guidance, input, and enduring patience made this work possible. Thank you to FAIC’s George Stout Grant for the support to attend this meeting. Thank you to Stuart Laidlaw, Dr. Renata Peters, Lindsay McDonald, Dr. Kathryn Piquette, Rachael Sparks, Ian Carroll, and Alice Stevenson from UCL’s Institute of Archaeology, UCL’s Geomatic Engineering Department, and the Petrie Museum of Egyptian Archaeology. Finally, thank you to Dr. Hannelore Roemich, Michele Marincola, Kevin Martin, and all the students, faculty, and staff at the Conservation Center at the Institute of Fine Arts at NYU for their enduring support of this project.
Appendix 1: GLOSSARY

CED: An abbreviation used to refer to “Criteria for Evaluation of Documentation” in this article.

Computational Imaging Technique: Imaging based on information extracted from a series of digital photographs that reveals information not visible in any individual source image (CHI 2013c). Also Computational Photography and Computational Photographic Imaging.

Copy Stand: A device used in photography to stabilize the camera to “copy” information. The object is placed on a flat surface, and the camera is mounted parallel to the surface above the object. The height of the camera can be adjusted.

Diffuse Gain: Diffuse gain is a rendering mode in the RTIViewer. It is a mathematical enhancement function that varies the slope of the second derivative of the reflectance function in order to increase the rate of change in the surface appearance as a result of luminosity (Hewlett-Packard 2005).

Digital Artifact: An object that is produced and stored digitally or electronically.

Digital Lab Notebook: The concept that a digital file should contain information detailing capture and each manipulation, much like a scientist’s lab notebook (CHI 2013a).

Digital Negative (DNG): A lossless, proprietary (Adobe) file format. Digital negatives are considered to be a stable, raw, open-format, archival file format (Duffy et al. 2013, 14).

Dome: A hemispherical lighting device with an equal distribution of lights on its interior. The positions of lights are static and known, negating the need for a specular sphere in RTI.

Hemispherical Harmonics (HSH) Fitter: The algorithm that compiles source images into a .rti file.

Highlight RTI (H-RTI): An RTI capture method that uses digital photography, a single, moveable light source, and a specular target.

JPEG (.jpeg): A common lossy file format. JPEG stands for Joint Photographic Experts Group (Duffy et al. 2013, 14).

Luminosity: The brightness of a color. One of two aspects of color as defined by Tom Malzbender in his 2001 paper introducing RTI. The other is chromaticity, the shade and intensity of color (Malzbender Gelb, and Wolters 2001, 7).

Negative Space: The area surrounding a subject of interest. This term is most often used in regard to artistic composition.


.ptm: The file format of an RTI compiled with the PTM Fitter.

PTM Fitter: The algorithm that compiles source images into a .ptm file.

RAW: Uncompressed or minimally compressed file format. This varies depending on the camera make and model (Duffy et al. 2013, 14).
LIGHTS, CAMERA, ARCHAEOLOGY: DOCUMENTING ARCHAEOLOGICAL TEXTILE IMPRESSIONS WITH REFLECTANCE TRANSFORMATION IMAGING (RTI)

Red-Green-Blue (RGB) Values: Color information for the three additive primary colors combined to produce a full range of colors for digital representation and display (Barnett ed. 2011).


There is an inconsistency in RTI nomenclature that should be addressed. The original RTI technique, Polynomial Texture Mapping (PTM), was invented at Hewlett Packard (HP); a PTM fitter creates files with a .ptm file extension. PTM is considered a form of RTI; thus, RTI is the umbrella term. At CHI, another method of constructing RTIs was created. This method is called RTI and uses an HSH fitter that creates .rti files. This tree of terms is summarized in the following table.

<table>
<thead>
<tr>
<th>Polynomial Texture Mapping (PTM)</th>
<th>Reflectance Transformation Imaging (RTI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Created by Hewlett Packard (HP) Labs</td>
<td>Created by Cultural Heritage Imaging (CHI)</td>
</tr>
<tr>
<td>Uses the Polynomial Texture Mapping (PTM) Fitter</td>
<td>Uses the Hemispherical Harmonic (HSH) Fitter</td>
</tr>
<tr>
<td>Builds .ptm files</td>
<td>Builds .rti files</td>
</tr>
</tbody>
</table>

.rti: The file format of an RTI compiled with the HSH Fitter.

RTI Builder: A free, open-source computer program that compiles source images into an RTI. This can be used with the HSH Fitter or PTM Fitter.

RTI Viewer: A free, open-source computer program for viewing and rendering .rti and .ptm files. CHI’s RTI viewer is called the RTIViewer.

Source Images: The images captured for eventual compilation into an RTI.

Specular Enhancement: Specular enhancement is a rendering mode in the RTIViewer. It is a mathematical enhancement function that maximizes pixel brightness by using estimated surface normal values from the illuminance direction to yield an artificially shiny surface through the addition of “synthetic specular highlights” (Hewlett-Packard 2005).

Surface Normals: Lines orthogonal to the plane of a surface.

TIF (.tif): A universally supported, proprietary (Adobe) file format that can be lossless. TIF stands for Tagged Image File Format (Barnett ed. 2011).

Slave Trigger: A remote device used to control the camera function from a distance.

Unassisted Examination: A term used in this article to refer to examination of an object with the naked eye under normal lighting conditions.

Virtual Dome: A simulated lighting dome created by lighting an object from a consistent distance at varying angles (Duffy et al. 2013, 14).
Appendix 2: CAPTURE AND PROCESSING WORKFLOWS

A. Indoor Digital Photography Capture Workflow

<table>
<thead>
<tr>
<th>Equipment, setup, and settings used for all indoor digital photography</th>
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<tbody>
<tr>
<td>Camera</td>
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<tr>
<td>Lens</td>
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<tr>
<td>Flash</td>
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<tr>
<td>Other Hardware</td>
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<tr>
<td>Settings</td>
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<td></td>
</tr>
<tr>
<td>Scales</td>
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<tr>
<td>Capture</td>
</tr>
</tbody>
</table>

B. Outdoor Digital Photography Capture Workflow

<table>
<thead>
<tr>
<th>Modifications to the indoor digital photography setup (A) above</th>
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</thead>
<tbody>
<tr>
<td>Other Hardware</td>
</tr>
</tbody>
</table>

C. Digital Image Processing Workflow

<table>
<thead>
<tr>
<th>Tools used to process images in Adobe Camera Raw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color Sampler Tool</td>
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<tr>
<td>White Balance Tool</td>
</tr>
<tr>
<td>Exposure</td>
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<tr>
<td>Contrast</td>
</tr>
<tr>
<td>Clarity</td>
</tr>
<tr>
<td>Measure Tool</td>
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<tr>
<td>Eraser Tool</td>
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<tr>
<td>Save</td>
</tr>
<tr>
<td>Crop Tool</td>
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<tr>
<td>Save</td>
</tr>
</tbody>
</table>
D. H-RTI Capture Workflow

<table>
<thead>
<tr>
<th>Equipment, H-RTI setup, and settings used for all indoor RTI source image capture</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Camera</strong></td>
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<tr>
<td><strong>Lens</strong></td>
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<td></td>
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<tr>
<td><strong>Flash</strong></td>
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<tr>
<td><strong>Triggers</strong></td>
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<tr>
<td><strong>Other Hardware</strong></td>
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<tr>
<td><strong>Settings</strong></td>
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<td></td>
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<tr>
<td><strong>Specular Balls</strong></td>
</tr>
<tr>
<td><strong>Scales</strong></td>
</tr>
<tr>
<td><strong>Capture</strong></td>
</tr>
</tbody>
</table>
EMILY B. FRANK

E. H-RTI Processing Workflow

The processing workflow outlined above for digital photography (C) through the Eraser Tool was followed before compilation of RTIs from the source images.

CHI’s RTI Builder Version 2.0.2 for Mac was used with HP’s PTM Fitter. Files were cropped in the final stage of the builder when prompted.

F. Outdoor H-RTI Capture Workflow

<table>
<thead>
<tr>
<th>Modifications made to the H-RTI setup (D) above</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote Control</td>
</tr>
<tr>
<td>Other Hardware</td>
</tr>
</tbody>
</table>
REFERENCES


Textile Specialty Group Postprints Volume 25, 2015 40


FURTHER READING


SOURCES OF MATERIALS

Cultural Heritage Imaging
2325 3rd Street, Suite 323
San Francisco, CA 94107
Tel: (415) 558-8672
 culturalheritageimaging.org
culturalheritageimaging.org/What_We_Offer/Downloads/index.html
AUTHOR BIOGRAPHY

EMILY B. FRANK graduated from McGill University in 2011 where she completed a major in art history with minors in chemistry and archaeology. She completed her master's in principles of conservation at University College London in 2014. At present, she is pursuing a joint masters of art in art history and masters of science in conservation of historic and artistic works at the Institute of Fine Arts, New York University. She first interned in conservation at the New York State Office of Historic Preservation at Peebles Island and has since worked at the Canadian Centre for Architecture, the Metropolitan Museum of Art, Poggio Civitate Archaeological Project, the American Museum of Natural History, the Natural History Museum, Agora Excavations, the Brooklyn Museum, and the Archaeological Exploration of Sardis. Within these institutions, she has had the opportunity to work with objects of diverse materials and contexts. Emily can be reached at: emilybeatricefrank@gmail.com.
ABSTRACT—The Shroud of Turin is a linen twill textile measuring 432 cm long and 110 cm wide, which bears the frontal-dorsal double image of a nude man, believed by some to be Jesus of Nazareth. It is believed that the shroud was used to wrap his body when he was removed from the cross and placed in a tomb. As a religious icon and sacred relic, it has been copied by artists since the Middle Ages. Between the 16th and 17th centuries, European monarchs commissioned copies and sent them to religious institutions in the new Spanish colonial settlements.

This article describes the conservation work performed on a copy of the shroud brought to South America by Jesuit missionaries. In the 19th century, it was donated to the Dominican convent in Santiago del Estero, the oldest city in Argentina, once part of the Spanish Viceroyalty of the Río de la Plata. The copy is a linen tabby cloth, the same size as the Shroud of Turin. Treatment included scientific documentation and improving the display method.

1. INTRODUCTION

Some textiles are iconic works of art and are also considered relics or devotional objects. Their preservation is challenging for conservators, who must contend not only with the textiles’ deterioration, but also with their symbolic value and the religious communities’ fears that the objects might be mishandled or disrespected during treatment.

This article will discuss the treatment of one of the many copies of the Shroud of Turin that exist around the world, carried out in Santiago del Estero, a city in northwest Argentina. The Shroud of Turin has been copied by multiple artists, and more than 90 reproductions are kept in churches, monasteries, and private collections in Europe, the United States, and South America.

The Shroud of Turin, or Sacra Sindone, is a centuries-old linen cloth that bears the image of a crucified man. It is believed by some that it represents Jesus of Nazareth and that the cloth was used by Joseph of Arimathea to wrap his body when he was taken down from the cross. Modern science has devoted many hours of detailed study and intense research to the shroud. It is one of the most studied artifacts in human history, yet controversy still rages as to whether it is a medieval forgery or a real relic. It is a matter of personal faith to believe, or not, about the origins of the shroud (fig. 1)

“The original shroud is a rectangular linen cloth, woven in a 3:1 herringbone twill, 432 cm long and 110 cm wide. Its faint brown image depicts both the front and back silhouette of a nude man whose hands cover his groin. The two views are arranged so that their heads point towards each other. Marks on the body appear to correspond with physical trauma consistent with crucifixion.” (Adler 2002, 103).

The shroud has been kept at the Turin Cathedral in Italy since 1578. It has been exhibited to the public periodically, most recently from April to June 2015. Since its conservation in 2002, it has been stored flat in an airtight, bulletproof glass case, and is protected from light while not on display.
Making copies of the shroud in different techniques was a tradition from the Middle Ages until the 19th century. The copies often included a Latin inscription related to their origin (Fossati 1984). Between the 16th and 17th centuries, the House of Savoy in Italy commissioned several copies. They were given as devotional and sacred textiles to European monarchs, who sent them as relics to religious orders, convents, or noble families in the new Spanish colonial settlements in South America. One of these is on display in a convent in Santiago del Estero, the oldest city in Argentina. Originally founded in 1554, the city was first ruled by the Real Audiencia of Charcas, today Bolivia, and from 1776 of the Spanish Viceroyalty of Rio de la Plata.
This article describes the conservation treatment performed on this copy of the shroud. It was likely brought to South America either by Jesuit missionaries or sent by King Philip II of Spain as a devotional object. The oldest document referring to this textile is a 1791 inventory of the Jesuits’ possessions. After the expulsion of the Jesuits from the Spanish territories in 1767, the shroud copy was kept in the hands of a local noble religious family. In the late 19th century, it was donated to the Dominican convent in Santiago del Estero, where it has been displayed for several decades, but not always properly. This copy of the shroud is considered a sacred textile and is visited by pilgrims from all over Argentina.

Treatment of this religious textile was undertaken to address its condition, and to improve its method of display. Treatment also presented an opportunity for extensive scientific documentation to identify the textile fibers and media used, and to determine whether these were consistent with the alleged European origin. Scientific studies had not been carried out previously, in part due to a lack of opportunity, knowledge, and the trepidation of the religious community to allow the devotional textile to be manipulated and analyzed.

This copy of the shroud is almost the same size as the original, 434 cm long and 104 cm wide, but has a tabby weave instead of a herringbone twill. Along one side, it bears an inscription in Latin, written in capital letters, “VERUM SACRAE SINDONE EXEMPLAR ASSERVATAE TA VRINI” (Authentic Example of the Sacred Shroud kept in Turin). It was damaged in several areas and; had previous mending, large brown stains, advanced moisture deterioration, water stains, rust marks, and wrinkles caused by inappropriate display methods. Parts of the letters in the Latin inscription were also missing, likely caused by degradation from iron gall ink.

There are photographs that document various display systems used previously for this textile: folded; pinned; framed horizontally on top of red velvet that stained the shroud; framed vertically, pressed between two pieces of glass, and folded in the center allowing the front and back to be viewed by rotating the frame, producing general deformations as the textile slid and wrinkled (fig. 2).

The conservation project was proposed in 2006, but was not begun until 2014. The criteria for treatment were based on the 1994 AIC Code of Ethics’ principles of minimal intervention, readability, reversibility, and respect for the original work of art. A strategy of gradual intervention was carried out in two stages over 3 months, from May to July 2014.

2. TREATMENT – FIRST STAGE

During the first stage of treatment, examination and documentation were undertaken to record the initial condition of the textile, the image, the folds, and the missing parts of the Latin inscription (fig. 3).

First, the frame was carefully opened and the back glass was removed. It was discovered that the textile was a single length of cloth, not cut, only folded across the middle and sewn together on the sides. A piece of cloth stitched at the bottom that kept both faces together was removed, and the textile was unfolded. Considerable amounts of dirt and dead insects were encountered, which were removed by surface cleaning with a soft brush and controlled vacuuming (figs. 4–5).

The textile was then photographed with a USB microscope, and small samples were taken of fibers, the image media, and the letters along the border to verify the presence of iron gall ink. Testing determined that the image media was not water-soluble.

The textile was moved and placed unfolded on a clean Mylar-covered surface in order to align the warp and weft. Introducing moisture with an ultrasonic humidifier and adjusting the tension with weights and pins produced good results, and also reduced the wrinkles. Attempts were made to remove localized
Fig. 2. The previous exhibition way: folded, vertical, pressed, and framed between two glasses. Front side.
Fig. 3. Graphic of damaged areas on the front side.
DOCUMENTATION, RESTORATION, AND DISPLAY OF A COPY OF THE SHROUD OF TURIN IN ARGENTINA

Fig. 4. Back side of the Holy Shroud copy, after the glass was removed.

Fig. 5. Shroud’s copy, unfolded and opened, before treatment.
brown water stains using cotton swabs and distilled water, with blotting paper beneath the treatment area with good results during the process. On the red stains, due to the ineffectiveness of the swab-cleaning method, it was decided to proceed with a wet-cleaning technique that would extend the time of action while allowing control of the work area. Carbopol was chosen as a gelling agent because of its inert chemical nature and its availability in the local market. However, there were no visible results of removal or discoloration (Gel: 2 g Carbopol 940, 100-mL distilled water, after Wolbers recipes during his course in Buenos Aires).

The textile was left protected and covered for 2 months, during which time the samples of fibers and the media were analyzed in Buenos Aires as explained in Laboratory Analysis.

3. LABORATORY ANALYSIS

A small sample of textile fibers was examined in order to identify the material. Fibers from the area of the Latin inscription were analyzed to determine the medium and to better understand the stains and degradation in this area. The image medium was also studied.

3.1. FIBERS

Textile fibers were examined at 100×–400× using a Nikkon Optilab optical microscope with transmitted light. The Gentian violet staining technique was used to define the fibers’ morphological structures better. When seen under a microscope, flax fiber appears cylindrical with cross nodes and a very thin lumen. The warp and weft fibers analyzed were consistent with flax, which would have been from Europe at the time of the textile's alleged manufacture. There was no flax production in South America.

3.2. INSCRIPTION MEDIUM

Fibers in the area of the deteriorating Latin inscription were analyzed. These fibers have a black material on top, which sometimes forms a thin, solid layer that stiffens the area with text. The fibers are very brittle or broken, likely as a result of inscription medium (fig. 6).

Through microscopic and microchemical techniques, described below, the presence of chemical compounds characteristic of iron gall ink were identified. The losses in the fabric and missing letters are typical damages caused by iron gall ink. This type of ink was widely used from the Middle Ages to the early 20th century in Europe and then in America.

Analytical methods were used for identification of the ink. Two microchemical drop tests were performed, for identification of Iron cation III with two different reagents potassium thiocyanate and ferric ferrocyanide. In both cases, the results were positive for Iron III. The pH of the fibers with dark material was also measured, and found to be pH 2, highly acidic. This is consistent with iron gall ink and the products of its decomposition, which occur not only due to acidic components inherent in the ink, but also due to excess iron (II) sulfate, which catalyzes the oxidative degradation of cellulose.

Complementary analyses were performed on a sample of a broken thread with the remains of material of presumed iron gall ink. The SEM technique was used and elemental spectra were taken of localized areas with the remains of writing ink. The results are compatible with the composition of the iron gall ink used in Europe until the 19th century: the presence of the elements iron and sulfur, which are related to iron sulfate; the element Chlorine (Cl) of the chlorhidric acid used for extraction of gallotanic acid; and the elements
Aluminum (Al) and Potassium (K), probably related to the alum used as a fungicide. It is possible to prove with the SEM microphotographs that fibers are broken, due to the action of the above-described materials (figs. 7–9).
Fig. 8. SEM microphotograph. (left) broken flax thread with 10,000×; (right) general view of a flax thread, 250×.

Fig. 9. Elemental spectra of the traces of iron gall ink.

The decomposition of the ink, and the subsequent acidification and degradation of the cellulose substrate, is accelerated when exposed to light (visible, UV, or infrared), and high heat and humidity. To improve the preservation of the textile, it is therefore recommended that moderate and stable environmental conditions be maintained and exposure to light be reduced.

3.3. IMAGE MEDIUM

The image on the textile was examined with photomicrographs taken in situ with a digital microscope. The brown brush strokes were applied directly to the face of the fabric. Pigment particles were found largely on the front surface, rather than on the back. Polysaccharides were detected with a microchemical-specific staining test (immunochemical test with fluorescent pigments) and the Fehling's test, suggesting a gouache or watercolor technique.
4. TREATMENT – SECOND STAGE

In July 2014, treatment resumed. The next steps were the consolidation of the fragile areas of the textile and the chromatic reintegration of the inscription. An appropriate method of conservation support and display was also devised.

Both ends of the textile were protected with polyester net and fixed with running stitches using regular fine silk thread. The missing parts in the inscription were consolidated onto a new support fabric with a similar weave and color. Losses in the inscription were compensated for by painting small strokes of Gamblin pigments in alcohol onto the new fabric, without touching the original (fig. 10).

Fig. 10. Latin Legend before and after conservation on a new backing support, loss compensation with Gamblin pigments.
The textile was then placed flat onto a new rigid support panel prepared for its display inside a new showcase, and stitched around the edges. The support panel was made of honeycomb polycarbonate, padded with polar fleece, and covered with an exhibition fabric. To reinforce the panel and prevent bending, three aluminum support bars were affixed to the back (figs. 11–13).

The new exhibition case was designed with metal supports and glass walls. The shroud was to be displayed in a horizontal position, fully open to expose the entire Latin inscription. A digital thermohygrometer was placed inside the case with two sensors, one inside and one outside the case, to monitor the environment. Although there was a plan to illuminate the display case with LED lights, they have not yet been installed (fig. 14).

Fig. 11. Working team fixing the textile to the new exhibition support.
DOCUMENTATION, RESTORATION, AND DISPLAY OF A COPY OF THE SHROUD OF TURIN IN ARGENTINA

Fig. 12. Textile extended after conservation.

Fig. 13. Detail of the central area with the legend, after conservation.
Fig. 14. New exhibition case—the textile is fully extended and watched from above.
5. CONCLUSION

All of this project’s objectives were accomplished: to solve the mystery of the shroud’s composition by identifying the materials and techniques of its manufacture by using laboratory tests; to open and extend the textile in order to avoid folds and wrinkles; to allow the Latin inscription to be read in full; to construct an appropriate display case using stable, conservation-grade materials; the presence of flax in the shroud to determine the European origin of the textile; and to identify the large damages as being caused by the iron gall ink degradation.

No specific radiometric dating methods were done of the textile, so the alleged 17th century date could not be justified.

Because of this treatment, an important religious relic and object of worship for Argentine Catholics will be preserved for future generations under controlled conditions. The copy of the Shroud of Turin in Santiago del Estero can continue to be an important highlight and landmark for pilgrims and tourists all over Argentina.

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REFERENCES


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ABSTRACT—A pair of embroidered bed curtains (53.32.1 and 53.32.2) was chosen to be included in the 2013 exhibition, *Interwoven Globe: The Worldwide Textile Trade, 1500-1800*, on view at the Metropolitan Museum of Art. It appeared that there was almost perfect color preservation on the face of the curtains, and because of this, it was assumed that the only preparation required for exhibition would be to attach Velcro to their top edges as a hanging device. When the curtains entered the conservation lab, it quickly became evident that treatment would not be as straightforward as originally thought. The most complicated issue was that the canvas the embroidery was executed on was breaking horizontally throughout both curtains.

Due to a desire to hang the curtains vertically, according to their original intended use, it was necessary to devise a way to consolidate the now-fragile canvas and support the heavy embroidery threads in such a way that further damage would be prevented. It was determined that undertaking a consolidation treatment by attaching support fabric in three vertical strips to the reverse would be the most effective method. The following essay details the history of the curtains and their conservation treatment.

1. INTRODUCTION

In fall 2013, a major textile exhibition, *Interwoven Globe: The Worldwide Textile Trade, 1500-1800*, opened at The Metropolitan Museum of Art. The exhibition spanned three centuries of the international trade of textiles and explored how it affected textile design for both export and domestic use. The exhibition featured approximately 70 textiles from the Museum’s collections, augmented by approximately 30 textile loans, in addition to costumes, books, paintings, furniture, and other related objects.

Many of the textiles in the exhibition were made as trade textiles to cater to a desire for the exotic, but were often altered in some way to suit the aesthetic of the destined market. Others were made by one culture to emulate another culture’s design aesthetic, resulting in textiles that often did not look truly authentic. Because of these qualities, most of the textiles do not fit into the narrative of the Museum’s permanent Decorative Arts galleries, which show objects made by a culture to reflect their own design aesthetic. As a result, many of the textiles had never before been exhibited and needed treatment ranging from minor to extensive. The conservation of these textiles required many conservators to work over the course of three years, with the author joining the team during the last year and a half of the project.

2. THE OBJECTS

During initial viewing of the collections by Museum curators and conservators, a pair of embroidered bed curtains (53.32.1a, 53.32.2a) dating from the early 18th century, was chosen to be included in the exhibition (figs. 1, 2). These curtains had been gifted to the Museum by Irwin Untermyer in 1953. Judge Untermyer donated almost 2,000 European decorative art objects to the Museum between 1940 and 1974, the bulk of which arrived in 1964.
Originally this particular acquisition would likely have been part of a matching set of embroideries for a European state bed, such as another set in the Museum’s collections, 53.2.1-.8 (fig. 3). The entire set would have included side curtains, upper valances for the tester, and lower valances for the bed frame. The upper and lower valences that would have coordinated with the curtains are missing, however, a set with very similar designs and a yellow background exists at Chateau de Fontainebleau (Peck and Bogansky 2013, 244). One curtain with the embroidery facing out would have hung at each side of the bed’s head. The original crimson silk damask lining would have faced inward toward the occupant of the bed and would have likely matched...
the bed coverings. After being acquired by the Museum, the curtains’ original crimson linings were removed. This likely took place in 1980. The linings are currently stored separately from the curtains on acid-free tubes in the Antonio Ratti Textile Center.

The chinoiserie design consists of oversized fanciful flora, figures dressed in vaguely Chinese costume, Asian-style dragons, and long-tailed birds. This design embodies the European fascination with the asymmetry and “beautiful disorder” prevalent in Chinese design, very different from the symmetry found in Western taste at that time (Peck and Bogansky 2013, 245). The yellow background suggests that the curtains may be French, since extant examples with lighter-colored backgrounds are associated with production or use in France (Peck and Bogansky 2013, 244). In Interwoven Globe, these curtains were included in a section concerning Europeans looking to the East for design inspiration. While these curtains have an air of being Asian, they are decidedly over-designed.

3. EXHIBITION HISTORY

Unlike many objects in the exhibition, the curtains had been on display at the Museum in the past. One notable time was as part of an exhibition titled The China Trade and its Influences (1941), during which the curtains were on loan to the Museum prior to their being gifted. Like Interwoven Globe, the show also explored
BREAKING CANVAS: A CASE STUDY ON A FRENCH EMBROIDERY

trade between China and the West, and how it influenced European and American design. Both curtains were also part of the Untermyer Collection exhibition in 1977. Finally, one of the pair, 53.32.2a, was displayed in the European Sculpture and Decorative Arts (ESDA) Galleries in 1993.

4. CONDITION

The object 53.32.1a is 338.46 cm long × 87.95 cm wide; 53.32.2a is 349.25 cm long × 87.96 cm wide. The embroidery is executed with heavy cross stitches (fig. 4) and finer tent stitches (fig. 5) in wool and silk. The linen canvas is a balanced plain weave with approximately 22 warps per inch and 22 wefts per inch. There are approximately 121 cross stitches per square inch and 484 tent stitches per square inch. Cross stitches are made over two binding points (each over two warps and wefts) and tent stitches are made over one binding
point. The warps and wefts supporting the tent stitches have remained in a balanced position, while the warps and wefts supporting the cross stitches have become compressed, creating tighter areas of two warps and wefts, with open spaces between them (fig. 4).

When the lining was removed during this treatment, it was possible to see the construction of the canvas. The top and bottom edges of the curtains are cut through the embroidery and folded toward the back. The diamond borders on the proper right of 53.32.1a and the proper left side of 53.32.2a were executed on separate lengths of canvas and then attached to the main canvas. The excess canvas on both sides of the diamond border is folded to the back and the canvas of the fold is unembroidered. Both edges of the main canvas are also folded to the back, and in some places these folds are embroidered and in other places not. Folds are secured with whip stitches. The long sides and bottom edges of both curtains are trimmed with decorative cording.

At their initial viewing, the curtains were thought to be in ready-to-display condition. They were lined with a modern grayish-green fabric that had most likely been attached in 1980. Even with the lining blocking access to the back, it appeared that there was excellent color preservation on the face of the curtains.
The embroidery was mostly intact and the colors bright. Because of this, it was assumed that the curtains would only require the addition of Velcro to each top edge in preparation for hanging.

Upon examination in the conservation lab however, it very quickly became evident that treatment of the curtains would not be as straightforward as originally thought. One problem was that the lining was too tight. Further scrutiny revealed a second and more complicated issue: throughout both curtains the canvas on which the embroidery was executed was splitting horizontally (fig. 6). Of less concern were the facts that the
decorative cord along the vertical edges was detached in several areas and that there was minor loss of embroidery thread, as well as a few minor losses of canvas on each curtain (fig. 7).

Notable in these curtains are the differences in the conditions of the various materials: the exposed embroidery is in better condition than the underlying support canvas. Additionally, the splitting of canvas tended to occur in areas of cross stitch, while losses of both embroidery and canvas tended to occur in areas of tent stitch. The theory is that compression of the warps and wefts in the cross-stitched areas created areas of

Fig. 7. Close-ups of loss of canvas.
pressure on the unembroidered warps between stitches, and that over time the stress coupled with the considerable weight of the cross-stitch threads caused the warps to split. Another theory is that perhaps the thicker cross stitches protected the canvas from external forces more so than the finer tent stitches, thus preventing losses in the canvas.

There is a fair amount of previous repair to the canvas and the embroidery. There is a channeling of repair threads scattered throughout the curtains to address the splitting canvas (fig. 8). Additionally, there is embroidery that has been reworked (fig. 9) throughout both curtains.

![Fig. 8. Close-ups of channeling repairs.](image)
5. CONSERVATION HISTORY

The considerable discrepancy between the curtains’ originally perceived condition and their actual condition was intriguing. Given the severity of degradation of the support canvas, it was thought unlikely that this situation developed recently. The author began to research previous records of condition, treatment, and display.

A 1954 MMA Bulletin states that with the exception of loss of sparsely used black, “...the curtains are in an unusually perfect state of preservation” (Standen 1954, 147). From that same year, however, there is a ‘request for treatment’ slip in the Textile Conservation Department's object folder, indicating that both curtain linings were lengthened, and the borders resewn. The slip had been sent by the Renaissance and Modern curatorial department (an early name of ESDA) to the Technical Laboratory (possibly a precursor of conservation departments). This information suggests that at the time, the original crimson linings were still attached and there was no apparent damage to the canvas. It is possible, as was the case during the viewing for Interwoven Globe, that either the state of the embroidery masked the canvas’ degraded condition, or perhaps all previous splitting had been repaired prior to the curtains’ being gifted to the Museum.

In September 1977, the curtains were installed in the galleries for a retrospective of the Untermyer Collection. In April of the following year, another ‘request for treatment’ slip asked for slits to be repaired in one of the curtains, 53.32.2a, as quickly as possible so that it could be returned to the exhibition. Records indicate that within three days, several slits had been couched to the lining as a temporary repair. There is no evidence of
couching on the current greyish-green lining, suggesting that these temporary repairs were made to the original crimson linings. According to the ESDA object card, after the curtains were removed from the galleries for the Untermyer exhibition, the curtains went to Textile Conservation in November 1979. Four months later, in March 1980, the EDSA object card noted that the objects were moved to storage, with the original crimson linings in a separate box. It is thought that the greyish-green linings were added during this time in Textile Conservation.

One curtain, 53.32.2a, was in the ESDA galleries again in 1993 for a short period. Both curtains have been in storage ever since. One reason for this may be that the 1980 lining was insufficient to mitigate the strain on the canvas, and a lengthy treatment could not be undertaken until the curtains were to be exhibited in Interwoven Globe.

6. PREVIOUS TREATMENT THEORY

The Department of Textile Conservation file does not have records of exactly when the greyish-green linings were added. A hypothesis has developed in light of the discovery of prior restoration. Perhaps most or all of the previous damage had been repaired and not immediately apparent in 1954, when the MMA Bulletin mentioned their pristine condition.

The curtains were most likely put on display in 1977 with their original crimson linings, without any perceived issues relating to the canvas. The stress of being in a vertical position caused the canvas to continue splitting, and after several months of exhibition, damage in the canvas of curtain 53.32.2a was noticed. Because the exhibition was scheduled to continue for another seven months, a temporary repair was undertaken and the curtain was returned to display. When the exhibition closed, it was noted that both curtains had splits in the canvas. The original crimson linings were removed and replaced with a new fabric that could, in theory, support the weight of the embroidery and relieve some stress on the canvas.

7. 2013 CONSERVATION TREATMENT

The function of these curtains was to hang from a canopy without additional support along their length. Although horizontal display would have put less stress on the curtains, it was preferred to develop a treatment that would allow them to be hung vertically, as they were originally intended. To do this, it was necessary to determine a treatment method that could both consolidate the now-fragile canvas and support the weight of the comparatively stable, yet heavy embroidery threads. A permanent mount was not considered appropriate in light of the curtains’ size and weight. An additional disadvantage of permanent mounting was that it would prevent researchers from studying the reverse, where color preservation is excellent and where the embroidery execution is clearly visible.

It was decided that the best method of treatment would be consolidating the curtains by attaching a support fabric in three vertical strips to the reverse (fig. 10). The support fabric would help bear the weight of the embroidery thread while hanging. Attaching the support in strips rather than as a single piece allows for the future study of the reverse without having to remove the support, as two swathes of embroidery are exposed. It also facilitates rolling for storage.

A Création Baumann fabric (Unisono III, 100% cotton) was selected as the support fabric for both its strength and color options. It was prepared first by washing and ironing. The fabric strips were then cut along one warp on each side to help prevent fraying when attached to the curtains. Lastly, the support fabric was attached in three vertical strips, with an approximately 5 cm (2 in.) gap between each strip.
As often is the case with embroidery, the curtains are not straight along any edge. To decide on a straight line to set the placement of the support fabric, vertical lines of bright thread were laid over the face of the curtains, and straight lines were determined based on the design. The open swathes were selected by determining the areas where there was the least amount of horizontal splitting of the canvas. The open areas were marked with bright thread over the face of the curtains and secured with pins at top and bottom. The lines were transferred to the back and the supporting fabric was laid out in place. In the support fabric, 3.8 cm (1 ½ in.) of ease was distributed throughout the length of the curtains. This ease was introduced to allow the curtains to relax slightly while hanging and to prevent the lining from being too tight, which could potentially cause more damage.

The support fabric was attached with herringbone stitch along both edges of each strip (fig. 11). Horizontal lines of stitching were introduced periodically to help support the weight of the embroidery threads and prevent their pulling on and continuing to weaken the canvas (fig. 11). Splits in the canvas were consolidated to the support with several colors of DMC cotton floss matching the colors in each embroidered area (fig. 11). Thread colors used along the edges of the support fabric were golden yellow and brown-grey (along the diamond border), except in areas of very dark embroidery, where another appropriate color was used. Weak areas of canvas not covered by the support fabric were consolidated to small patches of Philips Boyne pima cotton fabric (fig. 11). These patches were prepared and attached in the same manner as the full-length support fabric.
To allow for easier access to the middle sections of the curtains, and to allow straight needles to be used, the textile was rolled onto a 7.6 cm (3 in.) diameter acid-free tube supported by cradles attached to sawhorses (fig. 12). There was a 15.2 cm (6 in.) gap between the end of the table and the tube to allow access to both sides during sewing. The couching of the splits was completed first in each section; the herringbone stitch was then completed on the edges of the support fabric. After couching the splits in the canvas and securing the support fabric along each edge, the top and bottom edges of all support fabrics along with the outer edges of the side support fabrics were trimmed and folded back following the shape of the curtains. The edges were secured to the support fabric with a herringbone stitch (fig. 13). A header of the Création Baumann fabric was attached to the top with vertical lines of zigzag stitches. A 5 cm (2 in.)-wide loop-side Velcro was machine-stitched to 7.6 cm (3 in.)-wide polyester webbing and attached to the top of each curtain with a knotted stab stitch.

The curtains were displayed together in a single Plexiglas-covered mount (fig. 14). Typically, the mounts are manufactured in-house, but because so many were needed for Interwoven Globe, mounts were manufactured by an outside company. The installation mount used for the curtains had 15.2 cm (6 in.) of wood surrounding a panel of medium density overlay panel (MDO) covered in Philips Boyne pima cotton...
8. CONCLUSIONS

While these objects originally appeared to be in pristine condition, closer examination revealed inherent vice that took three months to conserve before display could be considered. While the best method to display these objects from a preservation standpoint is flat, they could not be studied, understood, and appreciated in that context. A safe method to exhibit the curtains in accordance with their original function and design was developed. There is more than one way to do what is right for an object.
Fig. 13. Completed treatment, curtain hanging from hoist in the department.
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FURTHER READING


SOURCES OF MATERIALS

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Création Baumann Unisono III, 100% cotton
Testfabrics
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www.testfabrics.com

Velcro
Levitt Industrial Textiles
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ABSTRACT—Historically, tribal kilims have been undervalued and underappreciated. Often the costs of conservation are higher than the perceived monetary value. A 19th century Central Anatolian kilim, incomplete and in poor condition, was made available to the Fashion Institute of Technology Graduate Studies program, creating an opportunity for a textile conservation student to examine the kilim, and propose and carry out the conservation treatment. The challenge was to determine what would be most beneficial to the stability of this textile while also realistic, given the finite amount of time and resources available for treatment and the need to reintegrate the kilim into the client’s home. Friable brown weft yarns most likely iron-tannate dyed, had suffered extensive loss throughout the kilim, leaving large sections of warp yarns exposed and broken. After researching the history and weaving techniques of kilims as well as doing basic dye and mordant identification, treatment included: surface and aqueous cleaning, construction of a tensioning frame to support the 1.8 × 2.4 m (6 × 8 ft.) rug during stabilization, repair of broken warps, and compensation for lost weft material. Treatment improved overall condition, restored visual continuity, and improved structural stability.

1. INTRODUCTION

“The term kilim, in its purest sense, means a tapestry-woven cover, hanging, or rug. The term is used throughout the Middle East” (Mallett 1998, 72).

There is a long history of weaving among the various nomadic tribes and village dwellers of Anatolia. Looms set up in, or near, the home or tent were an integral part of domestic life, and predominantly women’s work: weaving could be carried out while taking care of the home and children, and it was easily resumed after the interruptions and demands of childrearing and homemaking (Barber 1994). Marriage was of economic and political importance to nomadic tribal societies; therefore weaving was a woman’s social duty (Davies 2000), as production of kilims for use in the home and as part of a marriage dowry were an integral part of a young woman’s and her family’s wealth (Petsopoulos 1979). Dowry kilims were part of an exchange that also included grazing, water, and irrigation rights between two families (Hull and Luczyc-Wyhowska 1993).

Woven with great care to mark special occasions and to decorate the home, these textiles were for personal domestic use, not for commerce. This, combined with their nonstandard sizes, may be in part why kilims did not have more commercial importance for dealers and collectors of Oriental rugs. In addition, it did not occur to people to sell their dowry pieces, and as household goods the rugs were used until worn-out (Petsopoulos 1979).

Kilims were created and used for floor coverings, doorway and window curtains, prayer rugs, clothes, and storage bags. Long narrow lengths were made as covers to decorate loads camels would haul, and as coverings for banquettes, which served as seating as well as extra beds for visitors (Hull and Luczyc-Wyhowska 1993).

Many countries have weft-faced woven textiles, but geometrically patterned kilims are produced in areas of Islamic culture, predominately Anatolia [Ancient Asia Minor or Modern Turkey], the Caucasus [Georgia, Azerbaijan, North-West Iran, Eastern Turkey], and Persia [most of modern Iran] (Petsopoulos 1979, 12).
A TURKISH KILIM: ANALYSIS, STABILIZATION AND LOSS COMPENSATION

2. DESCRIPTION OF THE OBJECT AND METHOD OF MANUFACTURE

For the purpose of documentation, the kilim was divided into six sections (two columns and three rows), and numbered from left to right and top to bottom (fig. 1).

Fig. 1. The kilim divided into six sections for documentation.
This 1.8 m wide by 2.4 m long (6 × 8 ft.) section of an Anatolian kilim is handwoven in slit-tapestry weave. The warp is undyed wool, handspun S(2Z). Handspun, Z-twist, single-ply weft yarns form geometric patterns across the surface in shades of brown, red, indigo blue, turquoise-blue, orange, and green, with natural white S(2Z) cotton weft accents. The woolen weft yarns exhibit *ab rash*, the variation of color typical of small batch, naturally dyed yarns (fig. 2).

This type of rug would traditionally be woven on either a low ground loom or a high vertical loom, and the yarns most often spun on low whorl drop spindles (Balpinar 1983; Hull 1993). The rug has 14 warps per inch. The number of wefts per inch varies from 48 to 58. The pattern is formed with nonvertical weaving. Weaving on an angle avoids the formation of long slits; this is why diamonds and triangular shapes figure so prominently in kilim pattern designs (Hull and Luczyc-Wyhowska 1993). In addition the rug contains contour bands of eccentric-curved wefts, used to trace a majority of pattern motifs with a contrasting color, although much of this is now missing. Fine rows of brown and white complementary wefting, a technique in which two colors of weft yarn alternate weaving one-to-one to form stripes a single warp yarn wide, are found above and below border motifs (fig. 3). Two small (less than 2 cm wide) supplemental weft patterned *cicim* motifs, “interlaced into the regular system of warp and weft,” (Balpinar 1983, 55) are found in the lower left third of the rug, in section five.
Fig. 3. Top to bottom before treatment and after treatment details showing weft insertion, and complementary wefting located above and below the white stripe.
The rug is made from two, loom-width lengths joined down the center to form an inexact mirror image. One end is cut and finished with a 2.5 cm wide, double-folded, machine-stitched hem leaving the pattern incomplete; the other surviving original fringed end retains much of its warp-loop fringe, indicating attachment to the loom breast beam. “The opposite end would [likely] have been fringed in a different style” (Hull and Luczyc-Wyhowska 1993, 54).

There are weft floats found on the face of the white cotton motifs in sections two and five that lay horizontally across the surface. Sometimes, when multiple shuttles are used, a shuttle that has not been in use for a portion of the weaving trails its yarn across the back of a textile to the point where the yarn is once again incorporated into the weave. Floats can also occur as unintentional weaving errors. In the case of this kilim, the floats are not part of the pattern, and the presence of these floats likely indicates that the current face of the kilim was once the reverse. Also, the current face of the rug appears to be slightly more vibrant than the reverse, indicating that the reverse received more light exposure. This supports the hypothesis that the current reverse was once the face.

3. SELECTIVE DYE AND MORDANT IDENTIFICATION

As part of the effort to attribute a general date of manufacture to the kilim, yarn samples, of approximately 1 cm in length, of the red, orange, and turquoise-blue, weft yarn were retrieved from the raw edge found under the stitched and folded hem. Two dark brown samples were removed: one from the fringed edge in section five, the second from a degraded area in section one. The methods used for testing the dyed weft yarn samples were the preliminary tests developed by Helmut Schweppe (Schweppe 1988).

A small turquoise-blue yarn sample was placed in a white ceramic dish and manipulated in a few drops of concentrated sulfuric acid; the sample took on a yellow-green hue indicating indigo. A second blue sample was immersed in ammonia and sodium dithionite solution causing the sample to lose its color and form a yellow solution (soluble leuco indigo), with the addition of ethyl acetate a blue layer of oxidized indigo was formed. (See figure 4.)

The red yarn sample was placed in a white ceramic dish and manipulated in a few drops of concentrated sulfuric acid resulting in a brown-red color. Upon the addition of distilled water, the sample and surrounding fluid turned orange, and then yellow indicating the plant dye madder. A second sample immersed in glacial acidic acid resulted in a solution of a yellow color, while the fiber remained red, again indicating madder (fig. 4). These tests were performed on the orange sample with the same result of madder red as its red component.

The dark brown sample removed from the fringed edge proved to be natural brown wool when examined with polarized light microscopy. A variation of a spot test developed by Chamot and Mason (1940) was used to test for the presence of an iron mordant in the second dyed brown sample. The sample was wet with 5% citric acid solution over blotter paper, followed by a few drops of 2% potassium ferricyanide solution, 0.25% solution was initially used with less definitive results. The resulting blue markings on the blotter paper indicated the presence of iron, and therefore suggest the use of iron-tannate dyes to achieve a brown color (fig. 5).

The absence of synthetic dyes in the original materials of the kilim that were tested, along with color variations or abrash in the colored weft yarns, points to small noncommercial batch dyeing consistent with a rug produced in Anatolia in the 19th century. In addition the search for comperanda yielded an image of a similar kilim found in Davies (2000) plate 48, described as a 19th century kilim.
Fig. 4. The preliminary Sheweppe tests. Top row: the blue yarn sample with and without the addition of concentrated sulfuric acid. Top right: sample shown after the addition of ethyl acetate with the blue layer of oxidized indigo formed. Bottom row: the red yarn sample with concentrated sulfuric acid and at center the same sample with the further addition of distilled water the sample and solution are yellow. Lower right: the red sample in glacial acidic acid.

4. TREATMENT

The goal of treatment was stabilization for safe handling and reintegration into the client's home. Although no longer used as a floor covering, it would be draped as an interior accent and not displayed in a flat or static position. Any stabilization treatment would be visible from both sides. Improved aesthetics were also a consideration. Not interfering with the integrity of the rug and its history was of equal importance. A protocol was developed in harmony with the AIC Code of Ethics, addressing both the needs of the object and the desires of the owner. It was determined, given limited time and resources, that the greatest benefit would be derived from stabilizing areas of lost brown weft and the accompanying lost and broken warp yarns, after an initial surface and aqueous cleaning.

4.1. PRETREATMENT CONDITION

The pretreatment condition was poor. The kilim had a stiff hand. Overall particulate soiling and dog hair were deposited across the surface. Faint stains were noticeable, but not disfiguring, on the white cotton
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Fig. 5. A brown yarn sample, suspected to have been dyed with iron-tannate dyes, was moistened with a 5% citric acid solution over blotter paper, followed by wetting the same blotter paper with 2% potassium ferricyanide solution on the left, and 0.25% on the right. The resulting blue markings on the paper indicated the presence of iron.

weft fields. And as noted above, the current face of the rug appeared to be slightly more vibrant than the reverse.

Friable and oxidized brown weft yarns found throughout the rug had deteriorated and were actively shedding. Fiber loss had exposed warp yarns making tension uneven and leaving visually distracting voids, with
warps prone to wear, snagging, and eventual breakage. The left side of the rug had suffered considerably more loss than the right side. Many prior campaigns to relieve the loss of brown weft were visible throughout the rug, carried out in various shades of brown wool yarn. A few scattered repairs executed in brown and black cotton embroidery floss were coarse and nonstructural. The history of the prior repairs is unknown; a previous tribal owner may have made them, and removal of these repairs would erase the history of the rug. With the exception of a few scattered holes (less than 1–2 cm) that include warp loss, all other colors of weft and warp yarns were structurally sound.

Small voids surrounding the pattern motifs contained fragments of the contour bands of eccentric-curved wefts commonly found around the motifs of many Anatolian flat woven rugs, now largely missing from this kilim (fig. 6).

Fig. 6. Detail of the kilim, the white arrows point to existing contour-bands of eccentric-curved wefts. Most of the contour bands are missing from around the section of green motif on the right.
The hemmed edge was stable. The remaining fringed end of the rug was frayed. The selvage edges had been reinforced with whipstitch as part of an earlier repair campaign, and were no longer visible. The center seam had two raw, but stable, edges abutted and coarsely stitched together. Some of the stitching was loose or missing entirely. There were slight deformations along the center seam. The joining of two narrow kilim widths to make a larger whole is not unusual, but it is noteworthy that these abutted edges were cut and left unfinished.

4.2. SURFACE AND AQUEOUS CLEANING

In preparation for aqueous cleaning, particulate soil was removed from the surface of the rug by a variable-speed vacuum equipped with a high-efficiency particulate air (HEPA) filter, on a gentle setting. Vacuuming was carried out through nylon netting, and tweezers were used to remove more tenaciously embedded foreign materials from the rug’s surface.

For all preparatory stitching, 100% cotton sewing thread was used. The fringed bottom edge was secured from further raveling with loose whipstitches. Large slits were secured and aligned using a figure-eight stitch. Holes measuring 2.5 cm or less, found in otherwise robust sections of the rug, were secured with loose whipstitch. Weakened sections of friable brown weft and large areas of loss were encased in fine white nylon netting (fig. 7).

All dyed weft yarns were tested for wash fastness using deionized water and a 1% Orvus WA paste solution, on cotton blotter paper. The blotter showed movement only of grey soiling, with the exception of an orange-brown weft yarn used throughout the rug for repairs. Dye migration to the blotter was slight, and stopped on repeated wettings, an indication of a finite amount of fugitive dye present. Aqueous cleaning proceeded.

The rug was wet-out and acclimatized in a deionized water bath, slowly raising the temperature to approximately 32°C. After allowing the kilim to rest for 20 minutes, the tank was drained. Then, three cycles of sponge-delivered surfactant application to both the face and reverse surfaces of the kilim were carried out, each followed by a rinse: the first application was a 1% solution of Orvus WA paste; the second and third applications were solutions of 1% Orvus WA paste mixed with 1% citric acid. The second bath was a time of rapid soil release. The citric acid acted as a sequestering agent (chelator) by binding with the metal ions found in the soil and isolating, dispersing, and emulsifying these particles, reducing redeposition of released soils and improving soil removal during rinsing (Tímár-Balázs and Eastop 1998). During the final rinse, the kilim was rolled onto a tube and water was gently applied using a spray

Fig. 7. In preparation for wet cleaning fragile areas of brown weft, and areas of loss were encased (face and reverse) in undyed nylon net. From left to right: the face of the kilim, fragile areas of sections 1, 3, 5; center showing the reverse, horizontal bands across sections 1 and 2, and sections 3 and 4 were encased; at right a detail of a loss encased in net, and the large whipstitches used to secure the net and fringed edge of the kilim on the lower edge of section 5.
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nozzle, allowing both the back and front to be rinsed and rolled simultaneously on a 6-in.-diameter plastic-wrapped tube.

To speed the drying process, the rug was rolled twice on a tube between white toweling immediately after the last rinse to gently extract excess moisture, thus reducing the possibility of dye migration or the formation of tidelines that can occur during slow or uneven drying (Francis 1992). The kilim was dried flat, with cotton drying cloths placed in direct contact with the white cotton fields, to wick away any fugitive dye or yellow-brown degradation products. No dye migration or staining of any kind was visible on the drying cloths, and the kilim was completely dry in less than 24 hours. The net envelopes used to protect fragile areas, and their temporary stitches were removed. No additional fiber loss was noted. The drape, hand, and overall appearance of the kilim were improved.

5. TENSION FRAME CONSTRUCTION

A tension frame was constructed to support the rug during the reweaving process. A pair of sawhorses was adapted to hold two 2.5-m polyvinyl chloride (PVC) pipes parallel to each other, in order to support the kilim and hold it under tension. Washed muslin leaders were attached to the PVC pipes using duct tape; the muslin created a barrier between the tape and the kilim. Each end of the rug was attached with pins (pinned in the weft direction) to the muslin leaders and rolled onto the pipes. This allowed access to a 16-in. section of the rug while storing the balance neatly rolled.

To keep the rug under tension and advance the kilim as reweaving progressed, eight evenly spaced holes were drilled into the end of each pipe, allowing a 9-in. nail to be inserted through the holes and into the sawhorses, to act as a makeshift ratchet. The majority of the reweaving was carried out with the rug face up (fig. 8).

Fig. 8. Construction of the tension frame from top left clockwise: 2 × 4s secured across two commercial sawhorse frames with square cutouts to hold PVC pipe; detail of hole drilled in 2 × 4 to accept nail; PVC pipe locked into position in 2 × 4 with nail inserted through holes; the completed frame supporting the kilim.
6. COMPENSATION FOR LOSS

In order to ascertain which yarns might successfully be used for stabilization and compensation of lost brown weft, a miniature frame loom was created from cardboard and warped with fourteen warps per inch, matching the set of the kilim.

A fine, natural-colored, handspun, single-ply wool yarn was selected for use as a warp during weft trials, and for warp repair, purchased from HM Nababian and Sons, Inc., suppliers of yarns for Oriental rug repair. Samples of selected commercially available weft yarns were woven using a size 24 tapestry needle. Appleton Wool. Ltd. London two-ply crewel embroidery yarn, shade 588, a deep brown/black color was selected for use in areas of lost brown weft yarns. Once the appropriate brown yarn was selected, other shades of Appleton yarn were chosen for reweaving of other minor losses in the kilim (fig. 9).
6.1 WARP AND WEFT INSERTION

Warp yarns were repaired using the single-ply handspun wool referred to above, and a size 28 tapestry needle. The yarn was scoured in a 1% solution of Orvus WA paste before use, and manually given extra twist before insertion. Warp repair yarns are always anchored in a section of stable material. Inserted several centimeters below the section of warp yarn to be repaired or replaced, repair yarns bridge a section of lost or broken warp, and are reinserted into the sound woven material on the opposite side of the break or void for several centimeters. Insertions of repair warps were executed using the methods below.

The first is the traditional method of repair of multiple adjacent broken warps. A new warp yarn was inserted next to, and several centimeters below, a break in a warp; the repair yarn was woven in tandem with the warp, until it reached the section of missing or broken warp where it continued to be woven into and through any channels created between extant weft yarns. Close attention was paid to existing weft, recreating the under-over weave structure. The repair warp emerged from between the wefts, bridged any voids (or damage), and reentered the opposing side following the path of the warp yarn for several centimeters above the break and/or void. The yarn then made a “turnaround” and was reinserted into the adjacent weft channel, repeating the process to replace the next missing or broken warp. At the point where the new warp changed direction, a loop was visible on the surface (Stone 2010). Warp turns were staggered to reduce stress on weft yarns and decrease their visibility. (See figure 10 below.)

The second method of multiple warp insertion was less visible where the yarn changed direction. The new warp made a turnaround into its current channel by doubling back on itself. It traveled under several weft yarns and then was inserted into the adjacent channel, between weft yarns, to replace the next missing warp yarn. With this method, the weft yarns must be robust enough to handle the stress of two or three warp yarns in a void meant for one. Again the warp turns were staggered (fig. 10).

![Fig. 10. Left: warp yarn insertions into a commercially produced kilim illustrate the change of direction for adjacent lost warp yarns, moving from one channel into a second (no thread tails would be visible on a treated textile). On the right: a diagram of these techniques.](image-url)
When a single warp was replaced, the yarn was inserted into the existing path of the missing warp, as described above. The new yarn extended above and below a break or void for several centimeters into a stable section of weaving. The addition of weft secured the new warp into its position.

If a broken warp yarn was still present in an area of loss, the repair warp was woven in tandem with the broken warp as its support. To keep the broken warp under tension during repair, a lark’s head knot of sewing thread was temporarily attached to the warp, and anchored into position with a pin (fig. 11). While the insertion of repair warps when the kilim was off the tensioning frame was used in some areas (akin to traditional repair methods), the author’s preferred method was insertion of new warp yarns on the tension frame, with a slackened tension. This allowed for ease of handling, and the formation of equal tension between the new and existing warp yarns.

To stabilize and visually compensate for lost weft, new weft yarn was introduced using a tapestry (size 24) needle, individually weaving over and under the warp yarns (plain weave). In order to blend the appearance of new weft material with that of the original, weft compaction was varied during insertion. New weft yarns were anchored in place by inserting the weft into the body of the rug, next to a warp yarn and between existing weft yarns (Stone 2010). In weakened areas of partial loss, new weft material was interspersed with existing weft, extending into existing stable material, to serve as a future reinforcement. In large areas of weft loss, temples (devices for keeping cloth stretched on a loom) of thread temporarily held the width of the area of lost weft static, while reweaving was carried out. This kept the tension even and helped avoid a wavy, wrinkled appearance (fig. 12).
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Fig. 12. Example of a thread temple: top left before treatment, top right after treatment, bottom showing the thread temple used to control tension across an area of lost weft.

Additional stabilization to other areas of the kilim was also carried out. Whipstitch in like-colored cotton thread was used to stabilize the fringed edge. Holes smaller than 2.5 cm were stabilized with buttonhole stitch along their perimeters. Where needed, the center seam along the length of the kilim was stabilized with a figure-eight stitch. Figure 13 is an annotated photograph of the completed treatment (fig.13).
Fig. 13. Annotated image of the kilim treatment, section number and dimensions are green, areas of weft insertion are pink, warp insertions are noted in yellow, overcast and/or whipstitch is shown in blue.

7. CONCLUSION

Prior to embarking on the conservation of this kilim, it was determined which treatments were essential to the stability of the rug. Due to the before-treatment condition, and in consideration of time and resource limitations, not all issues could, or should, have been addressed. Losses were extensive in areas containing dark
brown weft yarns, most likely due to autocatalytic decay of an iron tannate dye. They continue to lightly shed, and although nothing can be done to reverse the process, stabilization, proper handling, low light levels, and climate control will retard future deterioration.

The overall condition of the kilim was significantly improved after treatment. Surface and aqueous cleaning removed soil and degradation products, enhancing the overall appearance, reducing deformation and stress to the fibers, and improving the flexibility and hand of the kilim. The replacement of broken warp yarns and the introduction of new weft material improved structural integrity and will inhibit future damage. Treatment has restored visual continuity, and improved aesthetics allow the kilim to be viewed as it was intended.

Tribal kilims historically have been undervalued and underappreciated. A kilim as deteriorated as this one, most likely would not have received conservation treatment, as often the cost of conservation is higher than the perceived monetary value of the textile. This rug received much-needed stabilization because it was generously made available to the Fashion Institute of Technology Graduate Studies program as a case study project for the textile conservation students. Not only did this rug present the prospect of researching the history and weaving techniques associated with kilims, but more importantly, it offered an opportunity to devise and apply an appropriate conservation treatment. The treatment proved revitalizing for the kilim: it has been returned to its owner in stable condition, and its bold pattern can again be appreciated for its use of color and design without major distractions. This treatment has added years to the decorative life of the textile, and it can now be displayed in the owner’s home, as its original creator once did, with pride.

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REFERENCES


CATHLEEN ZARET


FURTHER READING


SOURCES OF MATERIALS

Warp, hand spun
  HM Nababian and Sons, Inc.,
  36 E 31st Street
  New York, NY 10016
  Tel: (212) 213-2476
  [www.hmnabavian.com](http://www.hmnabavian.com)

Crewel embroidery yarn
  Appletons Wool Ltd
  13 Meadow View
  Crendon Industrial Park
  Long Crendon
  Bucks
  HP18 9EQ
  [www.appletons.org.uk](http://www.appletons.org.uk)
  Carried by various yarn suppliers
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Orvus WA paste
Gaylord Archival
PO Box 4901
Syracuse, NY 13221-4901
Tel: (800) 448-6160
Fax: (800) 272-3412
www.gaylord.com

Tensioner supplies
Home Depot
Tel: (800) 466-3337
www.homedepot.com

Muslin
Testfabrics
415 Delaware Ave
West Pittston, PA 18643
Tel: (570) 603-0432
Fax: (570) 603-0433
www.testfabrics.com

AUTHOR BIOGRAPHY

CATHLEEN ZARET recently completed an Andrew W. Mellon Fellowship in Textile Conservation at the Smithsonian Institution's National Museum of the American Indian and has joined the ranks of textile conservators in private practice. She graduated in May 2013 from the Fashion Institute of Technology with a degree in Fashion and Textile History: Museum Practices, with a concentration in Textile Conservation. She is currently working for museums and private clients in Washington DC, Maryland, and Virginia.
ABSTRACT—In the mid-1980s, Stephen Sprouse designed a leather motorcycle jacket, the back of which was subsequently painted by muralist Stefano Castronovo. The silver jacket depicts the unmistakable—albeit fluorescent green—face of the Mona Lisa. Designed as club-wear, the garment's full visual effect is only achieved under the blacklights found in nightclubs. Allowing the jacket to be exhibited under ultraviolet radiation with all of its concomitant degradation concerns presented an ethical conundrum: exhibited in this way, the jacket demonstrates to the museum visitor the effect desired by Castronovo, but the lifetime of the fluorescent colors would be significantly shortened. Castronovo's striking image already suffered from paint delamination and cracking due to the flexible nature of the leather garment. In painting these losses was complicated by the jacket's potential short-term display in both the visible and ultraviolet spectrum. Scientific analysis was conducted at the Indianapolis Museum of Art on both the original fluorescent paints and potential conservation materials, to investigate solutions for display and documentation under both lighting conditions. This essay explores how the potential display of a leather jacket painted with daylight fluorescent pigments under visible and/or ultraviolet radiation impacted the treatment, interpretation, and possible exhibition of the piece.

1. INTRODUCTION

In 2012, the Indianapolis Museum of Art (IMA) acquired a leather motorcycle jacket (IMA 2012.39) from Stephen Sprouse's 1984 collection. This piece is unique because the reverse was painted by controversial New York City muralist Stefano Castronovo in the mid-1980s. Castronovo painted a portrait of Mona Lisa using daylight fluorescent pigments on the back of the silver Sprouse jacket (figs. 1, 2). Both artists were drawn to the vivacity of daylight fluorescent paints, fabrics, and pigments, leading each to make a name for himself by employing fluorescent colors in his works (Padilha 2012; Castronovo 2015).

The jacket was removed from two previous exhibition checklists due to condition, display, and interpretation concerns, thus prompting research into possible solutions. The jacket exhibited cracking in the coated leather, and the portrait suffered paint losses due to the flexibility and previous use of the garment. After researching the fading and color shifts associated with daylight fluorescent paints (Connors-Rowe, Morris, and Whitmore 2005; Hinde et al. 2013), concerns were raised about the object's display. The jacket was intended to be seen in nightclubs under blacklight, so exhibiting this jacket under typical incandescent museum lighting would provide only a limited experience for the visitor. To further understand Castronovo's working methods and motivations, an artist interview was conducted by phone (Castronovo 2015).

In addition, the artist's working methods were investigated using near-infrared reflectography, the materials were characterized using a range of scientific analysis techniques, and the jacket was thoroughly documented using color-corrected ultraviolet-induced visible fluorescence photography.

1.1 STEPHEN SPROUSE

Stephen Sprouse (1953–2004) was raised in Indiana, and as one of four celebrated Hoosier fashion designers, the IMA took great pride in acquiring his work. Sprouse was considered by many to be a boy genius; when he
was only 14 years old the influential fashion writer of the 1960s, Eugenia Sheppard, wrote in The International Herald Tribune, “Music had its Mozart and fashion may have its Stephen Sprouse” (Sheppard 1966). That same year he traveled to New York to meet with two of the other three prominent Indiana fashion designers, Norman Norell and Bill Blass. By age 18, Sprouse began working with the third Indiana fashion designer, Halston, as his main assistant. In 1973, he moved to the Bowery where he became neighbors with Debbie Harry who had just formed a new band, Blondie. Sprouse created ensembles for her to wear on stage and designed her album covers, further launching his career. Around this time, Sprouse left Halston to focus on making clothes for his many famous friends and other performers, developing a reputation for his New York City street-wise fashion.

In 1982, Sprouse launched his first fashion collection, introducing several of his trademarks such as bright fluorescent colors, graffiti-inspired prints, and glow-in-the-dark outfits. In his Fall 1984 collection, Sprouse
focused on neon graffiti and metallic-coated lamb leather apparel, including the jacket described here. Sprouse wanted the show to have a rock concert atmosphere, employing strobe and black lights to make the colors pop. After this runway show, Sprouse became something of a celebrity, and even Andy Warhol sought out the designer. Many famous personalities, including Warhol, were photographed wearing Sprouse leather jackets at the time (Padilha 20012, 134; Ron Galella Ltd. 1985).

1.2 STEFANO CASTRONOVO

Castronovo was known in New York during the 1980s for his attention-grabbing murals, including a red-eyed Mona Lisa in the East Village. Castronovo was also well known for portraits of famous celebrities that he painted on the backs of jackets. His subjects included Marilyn Monroe, Darth Vader, Michael Jackson, and Marlon Brando, as well as portraits of friends and clients. He refers to these paintings as “Mobile Pop Art” (SomoS Art House 2015). Andy Warhol inspired Castronovo’s idea to have the faces of artists and personalities circulate freely around town and around the world. Indeed, Warhol was supportive of Castronovo’s artistic statement, so much so that he collaborated with the artist on several occasions (Francis and King 1997).

Castronovo has continued as a painter, currently operating a studio in Germany. During the interview, Castronovo (2015) confirmed that he always chose the subject matter and painted everything freehand. This was supported by near-infrared reflectography of the painting on the jacket, which did not reveal any signs of underdrawing. While Castronovo does not remember how many jackets he painted through the years, he suspects it might have been around 100. He listed Sprouse as the only designer with whom he worked directly, recollecting that he painted the Mona Lisa image on two to four individual jackets after having painted the same image as a mural. Castronovo remembered being drawn at the time to the strong color of daylight.
fluorescent paints, using them on both his murals and on some of the jackets. During the interview, he mentioned wanting to illuminate his outdoor mural of Mona Lisa with a huge blacklight, but that the cost and engineering necessary to accomplish this was prohibitive. He liked using daylight fluorescent paints on some of his jackets, because the colors were especially strong when worn to nightclubs in the 1980s and seen under the blacklights. Yet Castronovo was aware that these fluorescent paints changed quite rapidly, and he shared his acute observations regarding their shift in color over the years.

2. THE FLUORESCENT MONA LISA

The paints used on the IMA’s jacket are alkyds, based on their analysis by Fourier transform infrared (FTIR) microspectroscopy and pyrolysis-gas chromatography-mass spectrometry (PY-GC-MS). These commercial paints were often used on exterior walls and in sign painting, and Castronovo confirmed their convenient availability. The dark green and black paints on the Mona Lisa portrait are nonfluorescent colors, while the yellow and the red are daylight fluorescent pigments, commonly known as DayGlo based on their US trademark (Lindblom 2012). The glowing face is composed of a mixture of normal green and fluorescent yellow paints.

In figure 3, the jacket luminesces strongly under ultraviolet (UV) radiation and thus appears different than when viewed with purely visible light (fig. 4). This image highlights how the jacket would have been seen

Figure 3: Fluorescence of the painted area of the jacket under UV radiation along with the UV Innovations Standard for photography.
in clubs where blacklights were present. The image is strikingly more vivid, and the face shifts from a yellowish hue under visible light to an eerie green under blacklight. The intensity and color shift when viewed under UV versus visible light raises the question of viable display options and interpretation. People react strongly to seeing the jacket in both conditions. A successful conservation treatment should not diminish this reaction, limit potential display options, alter documentation of the visual effect, or hinder future interpretations of the fluorescent colors.

2.1 THE SCIENCE OF FLUORESCENCE

Fluorescence is the ability of a material to absorb radiation of one energy, and emit a photon of lower energy. Daylight fluorescent pigments require only daylight or an equivalent white light source to excite luminescence (Streitel 2009). These pigments produce colors that are visibly brighter than their nonfluorescent equivalents. Higher-energy visible light that is absorbed by the pigment is converted to lower-energy visible radiation, adding to that which is already reflected from the pigment’s surface. This fluorescence phenomenon can lead to reflectance values greater than 100% in specific areas of the visible spectrum. In figure 5, the reflectance spectrum shows the yellow fluorescent pigment in the jacket producing reflectance values of approximately 140% in the yellow-green region of the spectrum, indicating that the yellow paint is creating its own light of that frequency.

Although only visible light is necessary to experience daylight fluorescence, both short- and long-wave UV can also excite these pigments efficiently. Because the normal visible absorption-reflection phenomenon
is not seen when using blacklights, the observed color can be strikingly different under these conditions as well as the perceived intensity against a relatively dark background. It is exactly this effect that both Sprouse and Castronovo sought in their artworks.

2.2 DYE MIXTURE COMPLICATIONS

Commercial fluorescent pigments are created by first coloring a melamine-based polymer with fluorescent dyes (Streitel 2009). In DayGlo products, up to four dyes can be used to create a single pigment (Hinde et al. 2013). The dyed polymer is then pulverized into a fine powder that can be used as a fluorescent pigment. The transfer of energy from one fluorescent dye to another can be used to produce colors more brilliant for their particular spectral regions than one dye alone could produce.

This phenomenon of energy transfer from one molecule to another not only gives the fluorescent pigments their brilliance but also leads to problems in using conventional color-matching equipment to characterize fluorescent pigments (Streitel 2009). Complications also arise as dye mixtures age, resulting in differential fading of the fluorescent components and observable color shifts (Hinde et al. 2013). Microfadeometry performed on the red signature shows rapid fading and color shifts (fig. 6); the lightfastness of the red paint was determined to be equivalent to that of ISO Blue Wool 1. The abrupt color shift is seen in the data where rapid loss occurs in the red region of the spectrum while the blue reflectance values remain largely unchanged, resulting in a shift to a more maroon color.
3. CONDITION ISSUES

The Sprouse jacket was acquired by the museum in its current condition. The garment, confirmed by FTIR and X-ray fluorescence (XRF) to be chromium-tanned leather, had inexplicable damage over large sections of its surface. The metal foil was worn away in circular spots that varied in size, location, and groupings. The damage could be observed to varying degrees throughout the jacket and was inconsistent with damages associated with expected wear and tear. While the circles evoke images of mold, no evidence of branching hyphae was found, and the likely cause is thought to be physical or chemical alteration of the surface.

It is possible that these damages are intrinsic to the process of metalizing leather surfaces. Too little adhesive applied in bonding the metal to the substrate can result in a “powdering off” of the metallic foil (Leather International 2009). Additionally, heat and humidity can affect the adhesion between the leather/adhesive/metal foil boundaries. The metal surface has a topcoat confirmed by PY-GC-MS as an ethyl acrylate-methyl methacrylate co-polymer, which could be deteriorating, shrinking, or sloughing off and disrupting the reflective metal surface.

The paint in the signature and portrait exhibits a crack network related to the flexibility of the leather jacket; there are numerous scattered losses, some of the paint is lifting, and there are larger disfiguring losses in the face. These issues are compounded by the lack of adhesion between the paint and silver foil, and between the foil and the leather.
4. PAINT ANALYSIS, INITIAL TREATMENT

Microanalysis by FTIR confirmed that the paints applied to the jacket are alkyds, typical of commercial sign paints in use during the 1980s. The fluorescent series of alkyd paints differ from the regular variety of colors in that they are transparent and have poor covering power, necessitating a white priming layer to increase vividness. As anticipated, cross-sections revealed white priming underneath Mona Lisa’s fluorescent face, but surprisingly not under the vibrant red lettering, where instead the transparency allows the silver jacket foil to show through. Solubility testing was conducted on all colors, and indicated that the paints were insoluble in both mineral spirits and water, but soluble in almost all other common organic solvents. This limited options for cleaning and inpainting the damaged areas.

The first stage of treatment involved readhering lifting and flaking paint. A flexible, clear consolidation medium that would not interfere with the appearance of the painting under both UV and normal lighting was essential. After conducting several tests on products widely used in paintings conservation, Lascaux Medium for Consolidation was chosen, as it met all these requirements, as well as having a low surface tension and providing a barrier layer for filling and inpainting areas of exposed leather. Consolidation was done throughout the jacket to readhere lifting paint. Filling was also necessary, and following a series of tests, Flugger was chosen as the fill material as it remained removable and flexible and would provide an even white surface over which to apply the inpainting.

4.1 INPAINTING MEDIUM AND PIGMENTS

Choosing a suitable inpainting medium with the solubility limitations of the alkyd paints was challenging. Any mediums with UV-absorbers were excluded because they would interfere with the pigments’ fluorescence. After extensive testing, Golden MSA Gel in mineral spirits was selected as the inpainting medium. The gel remained flexible and resoluble in mineral spirits after aging, had no added light stabilizers, was transparent, and did not contribute its own fluorescence under ultraviolet radiation. With the inpainting medium chosen, appropriate pigments were needed to color match the paint under both UV and visible exhibition lighting.

Due to their luminescent properties and despite their inherent fading, fluorescent inpainting pigments must be used for convincing retouching of fluorescent paints used in artwork (Connors-Rowe, Morris, and Whitmore 2005; Hinde et al. 2013). For initial testing, daylight fluorescent pigments were acquired from Kremer Pigments (Flame Red 56350, Brick Red 56300, Orange 56250, Golden Yellow 56200, Lemon Yellow 56150, Green 56100, Blue 56050, Violet 56450, White 56000). Recent research indicates that these pigments are very similar to those offered by Day-Glo in the United States and Radiant in Europe, although the exact supplier of Kremer’s materials is unknown (Fremout and Saverwyns 2014). Of these colorants, the Lemon Yellow and Flame Red appeared closest to the yellow and red colors appearing in the Mona Lisa portrait.

4.2 OPTICAL BRIGHTENERS

In addition to the primary dye(s), optical brighteners have reportedly been added to fluorescent pigment mixtures to increase their brightness (Fremout and Saverwyns 2014). These brightening agents, however, are not usually listed in the composition and are only occasionally hinted at in the Material Safety Data Sheets. To determine whether optical brighteners were present in the Kremer fluorescent pigments and whether they could leach out and migrate to unwanted areas when used in mineral spirits or water-based binders, an
extraction test was conducted in both solvents. Vials with each of the nine fluorescent pigments were vortexed with mineral spirits and water in separate tests. The solutions were then filtered through 0.45-μm syringe filters and observed under long-wavelength UV. Except for the fluorescent green and violet pigments, all samples contained soluble optical brighteners based on the intense luminescence of the solutions (fig. 7). No attempt was made to identify the specific compound responsible, but its easy migration could present problems for the application or removal of fluorescent pigments in solvent-based systems.

Considering the jacket, it was determined that the risk posed by optical brighteners was minimal. Retouching with the fluorescent paints would be done sparingly using a thickened polymer gel through which the optical brighteners could not easily migrate to the surrounding paint, and the consolidation medium along with the flexible fill would serve as a barrier layer preventing the retouching from penetrating into the leather.

Figure 7: Vials containing Kremer Fluorescent pigments (top row) and corresponding vials indicating the presence of optical brighteners extracted from the pigments into mineral spirits (bottom row).
4.3 FADING RATES OF FLUORESCENT PIGMENTS

After testing the pigments and medium for inpainting, the challenge remained to match the unfaded fluorescent conservation pigments to the already faded paints on the jacket. Microfadeometry was conducted on the different jacket colors to establish their current lightfastness ISO blue wool equivalency rating (fig. 8). Unsurprisingly, all the paints proved extremely fugitive, fading at a rate of approximately Blue Wool 2 or faster. The fluorescent red of the artist’s signature faded alarmingly at a faster rate than Blue Wool 1, the fastest fading standard. This testing indicated that the jacket is almost impossible to display without expecting some degree of color change even within well-maintained museum conditions and a limited exhibition schedule.

Nevertheless, it was decided to treat one large area of loss to determine whether a suitable treatment protocol could be devised with the hope that one day an appropriate compromise to display the jacket could be reached. Since the fading rate of fluorescent pigments begins rapidly but slows as it progresses, the initial approach consisted of artificially aging the newly purchased fluorescent pigments in order to closely match the fading rates of the older pigments on the jacket. This way, the inpainting pigments would be in an aged state similar to the artwork itself and would more closely track the future fading that would inevitably occur before becoming noticeably different in color. It was also thought that preaging the inpainting material rather than simply diluting the fresh color might mimic the subtle darkening and color shifts that were observed between the Kremer pigments and the original artist’s pigments.

Figure 8: Accelerated fading curve indicating color changes of different paints (red, yellow, greenish-yellow) from the Sprouse jacket, compared to color changes of ISO Blue Wools 1 to 3.
4.4 ARTIFICIAL AGING OF FLUORESCENT PIGMENTS

Raman spectroscopy of the yellow paint in the Mona Lisa face reveals a single dye component with an identical spectrum to that of the Kremer Fluorescent Lemon Yellow 56150 (fig. 9), similar to what was found in the literature (Fremout and Saverwyns 2014). At present, insufficient data exists in the literature to identify the exact nature of the fluorescent dyes used in daylight fluorescent colors with the exceptions of phthalocyanine blue and green used, in their respective shades of fluorescent pigments (Fremout and Saverwyns 2014). The presence of a single dye in the yellow pigment allows a more accurate prediction of color change over time, compared to a pigment containing multiple dyes interacting with each other (Hinde et al. 2013).

A mockup of the yellow pigment dispersed in Golden MSA Gel thinned with mineral spirits (1g pigment: 5g medium: 5g mineral spirits) was applied to white ceramic tiles using the tape-trench method. Once dry, the painted tiles were artificially aged in a Q-Sun Xenon Test Chamber using ASTM D4303-06 Test Method D at

![Figure 9: Raman spectrum of fluorescent yellow paint from the Sprouse jacket compared to the spectrum of Kremer Fluorescent Lemon Yellow 56150, revealing the presence of a single dye. Asterisks mark the bands characteristic of the pigment resin.](image-url)
intervals until the yellow sample closely matched in appearance the faded yellow of the jacket. Mockups of Kremer Fluorescent Flame Red 56350 and Green 56100 were also artificially aged, and indeed additional color changes occurred in the red, most likely due to the preferential fading of one or more of the dyes. Analysis of the aged samples reflected what has been stated in the literature—that the paints first darken before lightening (Ellis, McGlinchey, and Chao 2002).

4.5 INPAINTING

In order to apply the aged yellow paint to the filled area of loss, the paint film was resolublized in mineral spirits using a small paintbrush. Resolubulizing the medium caused the inpainting mixture to become tacky and these working properties were undesirable for the delicate operation of retouching. Additionally, the pigment volume concentration was too low to generate enough color and opacity from the aged samples to match the area of loss. Possibly with continued testing, a better pre-aged fluorescent inpainting medium could be created.

In this instance, it was not possible to solve the inpainting problem analytically. As is often the case in conservation, hand skills and color matching by eye became the most logical way to proceed. In order to achieve the correct color, the fill had to first be toned with a non-fluorescent lemon yellow (BaCrO₄) to which unaged Kremer Fluorescent Lemon Yellow 56150 was also added. A combination of the resolubulized aged mockup paint with unaged pigment was then applied to the loss under the microscope, while alternating between UV and visible illumination to ensure visual integration under both spectral regions. The loss was successfully reintegrated into the composition. Upon close inspection, the inpainted area can be discerned based on its very slight color difference. Traditionally, the goal of inpainting is to be indiscernible from the original paint when viewed in visible light, but to remain detectable when irradiated with UV. In this instance, the inpainting deliberately mimics the artist's paints in both the visible and long-wave UV (365 nm) regions of the spectrum; however, under UVC radiation (254 nm), the inpainting remains clearly distinguishable (fig. 10).

Figure 10: Area of inpainting as seen under UVA (365nm, left) and UVC radiation (254nm, right) showing a difference of fluorescence with excitation wavelength.
5. DOCUMENTING FLUORESCENT COLORS AND DISPLAY CONSIDERATIONS

The instability of fluorescent colors requires precise documentation of artworks containing these pigments as possibly the best current method of preserving the artist's intent. However, accurately documenting daylight fluorescence colors is challenging, especially when the radiation source contains UV. In the past, UVA-induced visible fluorescence photography produced a subjective image—dependent upon the user, the camera, and the light source. As an example, figure 11 displays two images that show two digital photographs of the same pigment.

Recently, conservators Paul Messier and Jennifer McGlinchey Sexton developed standards to achieve repeatable and consistent photographic documentation of UVA-induced fluorescence. The standard proved effective in accurately documenting the jacket's fluorescent portrait and has increased the options for display of the artwork, which includes exhibiting the jacket under typical museum lighting conditions alongside an image of the jacket glowing on a monitor.

6. CONCLUSION

While the conservation was initially approached with an objective and analytical methodology, the materials of the painting ultimately demanded a more nuanced approach to achieve a harmonious color match, even when dealing with paints comprising a single fluorescent dye. Undoubtedly, pigments containing multiple interacting dyes will prove even more problematic and difficult to restore. The IMA is exploring options for future display and interpretation of the jacket. These include showing an image of the jacket under UVA on an interactive monitor next to the jacket under visible light. Additional possibilities being considered are visitor-activated lighting, push-button UVA illumination, and other creative solutions. If a viable exhibition condition can be met, further interventive conservation of the Sprouse jacket may be warranted, necessitating further development of the current inpainting protocol.
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SOURCES OF MATERIALS

UV Innovations™ Standards Target UV and UV Gray Card
Image Science Associates
6898 Townline Road
Williamson, NY 14589
Tel: (888) 801-6626
www.imagescienceassociates.com

Daylight Fluorescent Pigments
Lascaux Medium for Consolidation
Kremer Pigments, Inc.
247 West 29th Street
New York, NY 10001
Tel: (212) 219-2394
shop.kremerpigments.com

Golden MSA Gel
Golden Artist Colors, Inc.
188 Bell Road
New Berlin, NY 13411
Tel: (800) 959-6543
www.goldenpaints.com

Flugger
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MAKING CONSERVATION WORK DOWN UNDER: DEALING WITH THE UNEXPECTED

HANNAH ROSE BARRETT

ABSTRACT—This article will cover four case studies the textile conservation team at the National Gallery of Australia have dealt with in recent years: an Annette Messager (1943–) textile art installation loan to the Museum of Contemporary Art, Sydney; traveling the exhibition Stars of the Tokyo Stage: Natori Shunsen's kabuki actor prints; installing the Arthur Boyd (1920-1999) tapestries; and installing costumes from Fiona Foley’s (1964–) work HHH, both at the National Gallery of Australia. Changing circumstances such as gallery environmental conditions, artists’ intervention, and miscommunication have all made seemingly simple installations a challenge. Adaptations to plans and schedules, resourcefulness with available materials, and compromising with other stakeholders are useful tools a textile conservator can utilize to reach the best outcome for all involved.

1. INTRODUCTION

The National Gallery of Australia (NGA) was established as a concept in 1967, and opened to the public in 1982, on completion of the commissioned Colin Madigan designed building. It is the largest art museum in Australia and is based in Australia’s capital, Canberra. Since then, the NGA has expanded to include a new larger Aboriginal and Torres Strait Islander (ATSI) wing, and opened the off-site NGA Contemporary (NGAC) dedicated to displaying contemporary Australian art. The NGA has four main collection areas: Aboriginal and Torres Strait Islander art, Australian art, International art, and South East Asian art. The NGA hosts numerous travelling and special exhibitions as well as producing its own travelling exhibitions and loaning its own works to other domestic and international galleries and art museums. The NGA Conservation Department is made up of a conservation staff specializing in artworks from four main sections: objects, paintings, paper, and textiles. The Conservation Department also has a conservator dedicated to preventive conservation and a loans and exhibitions conservator. The conservation projects at the NGA are primarily exhibition and loan driven.

For the purpose of this article four case studies have been selected to demonstrate both typical and challenging conservation and installation issues, with practical solutions resulting in positive outcomes related to textile works of art for exhibitions held at the NGA and for loans to other Australian institutions.

2. STARS OF THE TOKYO STAGE – INSTALLING THE COSTUME FOR BENKEI

Stars of the Tokyo Stage: Natori Shunsen’s kabuki actor prints was a traveling exhibition comprised of the NGA’s exquisite collection of Natori Shunsen’s (1886–1960) kabuki actor woodblock prints dating from the early 20th century, with a number of modern silk kabuki robes and a composite kabuki costume. Stars of the Tokyo Stage travelled in parts to four venues along the east coast of Australia beginning in June 2012, before ending with a full exhibition at the NGA in July 2014. The costume for Benkei (fig. 1), a well-known character in Japanese folklore, was the signature costume of the exhibition. This costume is a complicated piece comprised
of numerous parts involving very specific dressing requirements in a particular order, and using a particular method.

In March 2012, two professional costume dressers from the Shochiku Costume Company in Japan, Takako Fukushima and Mikako Masuda, accompanied by interpreter Masao Nakano, visited the NGA to instruct the textile conservation team on the correct dressing procedure. The tutorial took a full day with six NGA staff, including textile conservators, art handlers, and curatorial staff, present to learn the procedure.

A photographic documentation of the process was produced by the NGA, comprising 32 pages of contact sheets of detailed imagery, supported by video footage of the entire process. Recording the process of dressing Benkei was of paramount importance, as the complexity of the dressing of the costume cannot be logically interpreted working from the constituent pieces. On completion, the Japanese dressers explained the desired alignment of Benkei: this is based on perfect symmetry and geometry between the various parts
of the costume such as the pleats in the pants, the corners of the robe, and the panel that hangs from the belt (fig. 3).

In the following two months, working without assistance from the Japanese dressers, the NGA conservators struggled to produce the desired alignment when dressing Benkei for photographic sessions, taking nearly six hours to dress the costume. In four weeks, the costume was to tour as part of the travelling exhibition *Stars of the Tokyo Stage: Natori Shunsen’s kabuki actor prints*, and the conservation staff still had not perfected the complex dressing method required.

In June 2012, the traveling exhibition was installed at its first venue in Melbourne. Just two and a half days were allocated to install 6 kabuki robes (including Benkei), plus over 60 kabuki actor prints, with only the curator of the exhibition and two textile conservators on hand to complete the installation. The costume for Benkei was prioritized as the first task, due to its complexity and the tight time frame that the staff was working under. The dressing of the costume went very smoothly, and staff managed to dress Benkei in a record two hours. For the first time, staff also managed to recreate the desired alignment – this was a huge achievement. The printed works were then removed from the crates and arranged around the gallery ready for hanging, and four of the five other kabuki costumes were dressed and installed. At this stage, the installation was progressing ahead of schedule with only the works on paper waiting to be hung, and the installation of the last costume.
Fig. 3. A diagram showing the desired alignment of Benkei costume parts.
In the afternoon of the first day of the installation the venue suffered HVAC failure, with all gallery environmental controls lost. Readings were taken every 30 minutes to ensure accurate measurements of fluctuation in the main gallery (Gallery 2) where Benkei and the block prints were located, and the secondary gallery (Gallery 3) where the five Kabuki robes were to be displayed. The readings indicated a steady rise in temperature and decline in RH (relative humidity) in Gallery 2, with a rise in temperature and plateau of RH in Gallery 3. During this time, intensive discussions were being held between the various stakeholders of the exhibition, the NGA Conservation Department, and the travelling exhibitions coordinators, as well as between the two respective institution directors. The NGA staff installing the exhibition could not be certain whether this HVAC failure was a temporary problem or how long it would take to reinstate the controls in the building, so therefore awaited confirmation on how to proceed. However, as further readings were taken of the galleries’ environmental conditions, installation staff decided to return the works on paper to their storage crates to protect the very vulnerable block prints from damage.

The National Gallery of Australia Loan Agreement requires a borrowing venue to maintain a controlled environment with temperature between 20°C and 22°C ± 2°C and relative humidity of 53% ± 5% with no more than a 3% change in relative humidity in one hour, unless otherwise agreed in writing by the NGA. As this could not be maintained at this venue, it was decided by both directors the following day that the exhibition would be withdrawn and postponed for future dates. Though there was significant disappointment on the part of a number of stakeholders, it was neither safe nor appropriate to display or hold the works of art in these adverse conditions, which were in contravention of the NGA Loan Agreement. The HVAC system at the venue was not able to be repaired for some months following its initial failure in June; therefore, it was justified to remove the works and return them to storage in preparation for the travelling exhibition’s next installation in Rockhampton, Queensland, Australia.

Due to its complexity and difficulty, the costume for Benkei was only ever scheduled to appear at the Melbourne venue in June 2012, and at the NGA on the final leg of the show in July 2014. Upon being returned to the NGA, the costume for Benkei took pride of place in the exhibition having been dressed in only a few hours and with perfect alignment (fig. 4).

3. INSTALLING THE ARTHUR BOYD TAPESTRIES

The NGA has 20 tapestries designed by famous Australian artist Arthur Boyd, based on his drawings of the Bible stories of Saint Francis. The tapestries were made in Portugal at the Tapeçarias de Portalegre studios in the early 1970s, and each measures approximately 2.5 × 3.5 m. The tapestries are constructed in wrapped weft technique with cotton warps and wool wefts, and are unlined. The majority have a stitched Velcro hanging mechanism, which replaced the previous original hanging mechanism of steel hoops sewn at intervals along the top edge. Some of the previously undisplayed tapestries still retained this original hanging mechanism, which had corroded in places, leaving marks and stains on the tapestries’ top edge backing.

The curators of the planned exhibition Arthur Boyd: Agony and Ecstasy wanted to view 9 of the 20 tapestries “in the flesh” to assess which tapestries would eventually be included in the exhibition. As a number of the tapestries had never been displayed, including some of the nine selected for the curators’ viewing, the viewing provided a valuable opportunity for conservation staff to assess the condition of the tapestries together.
Each tapestry weighs close to 45 kg and requires a minimum of four people to carry, unroll and reroll once viewed, making the viewing of these tapestries a large undertaking in terms of staff and time required. Due to their size the only feasible location for viewing the tapestries together as requested by the exhibition curators was the NGAs function room, the Gandel Hall. The decision to use the Gandel Hall required careful assessment, as this part of the NGA is not environmentally controlled. It was determined that the space should still be used for the purpose of viewing the tapestries by implementing appropriate manual environmental controls. Figure 5 shows the nine tapestries displayed for the curators. The blinds were opened only for the period in which the tapestries were being viewed. Each tapestry was laid out on polyethylene sheeting and the polyester rolling sheets (used for interleaving during rolling) were used to cover the tapestries when not
being viewed. Five tapestries from this viewing and four unviewed tapestries were selected and prepared for display in the exhibition. In some cases this required the removal of the old metal hoops and the stitching of Velcro to the top edge.

For the exhibition, the tapestries were to be displayed in the final room of the exhibition space. The display required three of the nine tapestries to be hung on a curved wall; something which had not previously been attempted by the NGA, and which therefore required a new approach to safely and effectively hang the works. The textile conservation team worked in consultation with the exhibitions/installations team to devise a solution whereby flexible aluminum battens were used for the installation of the tapestries. Coincidentally, these battens worked well for both the curved and flat display walls, eliminating any need for unnecessary switching of display mechanisms. Flexible, yet lightweight and strong, the aluminum battens were cut to the length of each corresponding tapestry. The battens were predrilled with countersunk screw holes to ensure a flush finish. Each batten was then covered on one side with industrial-strength Velcro (“scratchy,” or hook side). Beneath each batten, Mylar film was affixed to the wall with double-sided 3M tape, to provide a protective barrier between the textile and the wall (fig. 6).
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To install the tapestries, the method for both the flat and curved walls was the same. The rolled tapestry was suspended between two scissor lifts (held by two installation team members) by a long steel pole inserted through the tapestry’s rolling tube (fig. 7). The scissor lifts were then raised in synchronization to the point where the Velcro at the top of the tapestry was in line with the Velcro on the aluminum batten. This had to be done carefully to prevent jolting of the tapestry. The ties holding the rolled tapestry were then released, and the tapestry securely attached to the Velcro batten by an art handler on a ladder placed centrally in front of the tapestry. The ladders were then cleared, before a team of four people carefully unrolled the tapestry downward on top of the protective Mylar film, at the same time removing the polyester rolling sheet (fig. 8).

The only adjustment needed for the curved wall was the angle of the scissor lifts to the wall. This did create some difficulty in lining up the tapestry to the aluminum batten, with a larger central gap created by the angle of the curved wall. Despite this relatively minor difficulty, the solution devised by NGA staff to enable the display of large-scale textile artwork was found to be appropriate for works in a space with differing requirements.

Fig. 6. Art Installers at the National Gallery of Australia prepare the hanging aluminum baton for the tapestry on the curved gallery wall.
Fig. 7. The tapestry is suspended between the two scissor lifts by a steel pole. The Velcro is aligned to the aluminum baton.

Fig. 8. Once secured, four people are required to support and unroll the tapestry.
The NGA received a loan request from the Museum of Contemporary Art (MCA), Sydney, for two Annette Messager works for a retrospective *Motion/Emotion* exhibition to be held in July 2014. The installation of the two works: *My Vows*, a paper/photography installation piece; and *Pénétration*, a textile installation piece, were scheduled for a three-day install with two NGA conservators. The artist would be present for this install and was personally installing a number of the works in the show. Annette Messager’s 1995 work *Pénétration*, consists of 101 ‘body parts’ made from cotton fabric and stuffed with polyester wadding. The pieces are strung with intertwined nylon fishing line and colored mohair yarn. From this they are suspended from the ceiling via cable struts (which do not form part of the work). Two suspended light bulbs are interspersed throughout the work to produce eerie shadows cast upon the gallery walls. At the MCA, cabling was suspended across the ceiling in the same way as previous NGA hangs, and was already in position on arrival. Light fittings were suspended at points corresponding to a map previously used for installation at the NGA. The MCA decided to use three (as opposed to two) light fittings for their exhibition due to their larger gallery space. Whilst the bulbs used were not heat emitting, they still produced unavoidably high light levels.

Each numbered piece of the work *Pénétration* was retrieved according to the placement map and passed to the installation team in the scissor lift. The piece was then hung in place using a slip knot to secure the yarn/nylon string to the cable strut. The scissor lift was then gently lowered, ensuring the piece was safely holding its weight before maneuvering to the next position and repeating the process for each numbered piece (fig. 9).

Installation was on schedule and near completion late on the second day, with only a few more rows to complete; it was at this point Messager decided to change her vision for the space. The MCA-held work *Anatomie* was originally to be installed on a wall within the *Pénétration* gallery; however, Messager decided to extend *Anatomie* into the corridor leading out from the gallery in which *Pénétration* was now nearly installed.

Unfortunately, the corridor wall on which Messager wanted to place *Anatomie* was painted a lighter shade of grey, and the artist wanted the background color of the display to be consistent with that of the *Pénétration* gallery (fig. 10).

The NGA *Caring for the Collection Policy* requires four days of “off-gassing” for freshly painted galleries before exposure to NGA works. The repainting of the corridor wall would have been possible in accordance with this policy, as the opening of the exhibition was not scheduled for another eight days. However, Messager’s assistant was due to depart Australia in only three days, and his assistance was required to install *Anatomie*. The NGA loans team was notified and negotiations began between NGA and MCA exhibition stakeholders on how to manage the situation. These negotiations continued through the evening and into the third and final day of installation. A key consideration of the negotiations was that the room in which *Pénétration* was installed had its own air handling system that fed in fresh air and removed stale air using an isolated system. This meant the room received numerous air exchanges throughout the day and did not feed fumes into the other gallery spaces. A compromise was negotiated between the MCA and the NGA, whereby the doorway to the gallery was sealed with plastic and off-gassing allowed for two days. The reduced off-gassing period was based on the size of the wall (approximately 30 m²) being much smaller than the gallery space for which the NGA’s four-day recommendation is based. Messager had
concerns about the timeframe, but it meant that her vision could be met while still adhering to the intent of the NGA policy. This outcome allowed for a visually consistent space displaying both works as envisioned by the artist, whilst not compromising on the intent of the NGA policy to ensure appropriate care for the loaned works (fig. 11).

Fig. 9. The 101 pieces for Pénétration were laid out and retrieved one-by-one for installation by the team of four art installers.
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Fig. 10. The wall in question can be seen leading out into the corridor on the right, painted a lighter shade of grey than that of the walls in the gallery space.

Fig. 11. The final installation of *Pénétration* and *Anatomie* at the Museum of Contemporary Art in Sydney. The painted corridor wall (far left) looks seamless against the rest of the gallery wall. Annette Messager, *Penetration (Pénétration)*, 1993–94, cotton stuffed with polyester, angora wool, nylon, electric lights, National Gallery of Australia, Canberra, purchased 1996. NGA 96.681. Courtesy of the artist and MCA, Australia © Annette Messager/ADAGP. Licensed by Viscopy, 2015. Photograph: Alex Davies.
5. GIVING FORM TO ARTIST FIONA FOLEY’S WORK \textit{HHH}

In 2010, the new Aboriginal and Torres Strait Islander (or ATSI) wing of the NGA was completed, significantly expanding the space available for displaying Indigenous Australian art. For the grand opening of this new wing, a series of works were selected by the ATSI curators, which reflected the NGAs varied and fine collection of traditional and contemporary Aboriginal and Torres Strait Islander art. Fiona Foley is a well-known and established Indigenous Australian female artist whose work revolves strongly around the themes of politics, race, and gender. Foley often uses confrontational and challenging imagery and concepts in her work to express the treatment of Indigenous Australians, both in the past and in contemporary Australian culture. This can be seen explicitly in her works such as \textit{Land Deal} (1995) and \textit{Stud Gins} (2003).

The 2004 work \textit{Hedonistic Honky Haters or HHH}, is one of Foley's most well-known pieces, with the NGA holding in its collection the photographs and costumes which make up the artwork. The photographs consist of one collective portrait showing all seven figures in the costumes, plus seven individual portraits. One of the individual portrait photographs from \textit{HHH} was featured in the \textit{Global Feminisms} exhibition at the Brooklyn Museum in 2007. The costumes form part of \textit{HHH} with the photography pieces, and were made specifically for each of the seven figures and reflect their individual sizes and shapes. Figure 12 shows the original display.
of the HHH costumes flat and pinned to the gallery wall before the work was purchased by the NGA in 2010. The NGA ATSI curators wanted to replicate the artist’s original hang for the costume display from 2005, but in 3D to replicate the positioning of the figures in the photographic portrait.

The NGA has a number of forms for displaying costume works of art, including malleable padded forms created and supplied by Museum Mannequins Proprietary Limited. The “mannequin” forms arrive as a wire frame that is an adjustable polyethylene-coated wire mesh torso form. The forms require the attachment of an internal adjustable pole system, followed by Dacron (polyester wadding) and cotton stockinet to produce a soft body-like support (fig. 13).

The resulting “mannequin forms” remain fully malleable and can be resized and reshaped, with the height remaining adjustable. They can carry significantly weighty costumes, yet are themselves lightweight, portable, and easy to store. The forms are designed to stand on the floor; the pole simply slots into a bracket/tube-peg fixture that is in turn either screwed onto a temporary MDF (medium-density fiberboard) base for portability, or screwed onto a plinth for fixed display. In this case, however, the curators wanted the costumes to protrude from the wall and “float,” reflecting the artist’s original hang (fig. 12) and group portrait photograph. The conservation staff worked with the curators to devise a prototype display mechanism whereby the forms could sit at varying depths away from the wall to re-create the HHH image. The display required newly devised “L”-shaped poles that needed

![Fig. 13. Left, the torso form as it arrives from Museum Mannequins. This is then secured to an adjustable central pole (right) and finally covered with Dacron and cotton stockinet.](image)
to be manufactured along with two depths of brackets, which were screwed into the wall. The new display concept simply incorporated a $90^\circ$ bend in the pole and wall-mounted brackets as opposed to floor-mounted brackets.

Each head support was custom padded to ensure the correct positioning and shape of the hood. Some of the hoods were much bigger than others, and in the photographs the differing head sizes and hair shapes can be seen. The heads were made from carved Ethafoam covered in cotton stockinet and slotted onto the pole, which protruded from the neck of the torso. To install the works the costumes had to be dressed on tables immediately prior to installation, since the modified forms could not stand on floor bases due to their L-shaped poles. One at a time, each costume was dressed and secured onto the pre-fixed brackets with grub screws (fig. 14).

Fig. 14. The costumes are one-by-one secured in place by an art installer and supported by textile conservators. An example of the bracket used can be seen protruding between the first and second figures.
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Cotton stockinet tubes were used to cover the metal poles under the costumes. Though powder-coated, the stockinet served as an extra protective layer and covered the top of the grub screw preventing snagging on the costumes. The heights of the costumes could be altered at this point to ensure all the hems of the costumes aligned to mimic the varying heights of the original wearers, and to provide visual consistency with the original hang and photograph. The opening of the new ATSI galleries was well received by the media and public, and HHH proved very popular with the NGAs visitors (fig. 15).

6. SUMMARY

In retrospect, I would like to change the title of this article to Conservation in Australia: Practical Solutions to Everyday Problems. This article initially started as a look at how the Australian climate, landscape, indigenous culture, and collecting areas made it unique and challenging in its own ways when compared to Northern Hemisphere conservation issues. However, putting the talk and subsequent paper together has shown that although Australia does have some issues unique to its climate and collections, Best Practice and Collections Care is always at the forefront and is the same the world over.
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OFF THE WALL AND INTO THE ROUND: INSTALLING JOSEP GRAU-GARRIGA’S TAPIS POBRE

JULIE BENNER AND ALLISON MCCLOSKEY

ABSTRACT—Josep Grau-Garriga (1929–2011), a Catalan weaver, revolutionized contemporary tapestry by using nontraditional materials and creating works with highly sculptural qualities. His work Tapis Pobre from 1972 is one of the earliest examples of his three-dimensional weaving technique. Measuring approximately 3 meters high and nearly 4 meters wide, it has a variety of weaving structures and yarns in assorted natural colors. Tapis Pobre was selected for the 2015 exhibition Creative Crossroads: The Art of Tapestry at the Denver Art Museum.

This large and weighty tapestry has a very uneven surface, many slits, and partially attached components inherent in its construction. These factors combine to create significant challenges for safe handling, assessment, documentation, and storage. These challenges were exponentially increased for installation, as a hanging system would need to provide support for several months of open display. As well, the curator decided to showcase this work in the round to emphasize its sculptural qualities, requiring a hanging system to safely suspend the artwork from the gallery ceiling in an aesthetically pleasing manner.

This essay describes techniques developed to handle the tapestry during examination and documentation, test hanging with a new support system, and final installation.

1. OVERVIEW

For the exhibit Creative Crossroads: The Art of Tapestry (May 31, 2015–April 19, 2016) in the Textile Art Gallery at the Denver Art Museum (DAM), former curator Alice Zrebiec decided to explore the varied use of tapestry weave in a wide range of cultures and time periods. This included historic European tapestries, Qing dynasty Chinese court textiles, an 18th century Peruvian tunic, as well as several contemporary works. One of the objects selected was Josep Grau-Garriga’s Tapis Pobre. Grau-Garriga was a Catalan weaver who came to the field through painting and sculpture, studied tapestery weaving in France, and was active from the 1950s until his death in 2011. This tapestry has been in the DAM collection since 1991, and had not been previously shown at the museum. It was made in 1972, and measures approximately 3 meters tall, nearly 4 meters wide, and up to 20 cm thick in some areas. This essay will discuss the examination of this object, the process of developing the exhibit plan, the potential issues uncovered, and the solutions chosen for its display.

2. EXAMINATION

Associate textile conservator Allison McCloskey and Andrew W. Mellon Fellow in Textile Conservation Julie Benner looked at the tapestry for the first time in collections storage in the fall of 2014. It was an irregular form, loosely rolled on itself and wrapped in cotton sheets (fig. 1); a thick plywood support board, custom-made by the collections team, provided needed support for handling and storage. Peeling back the cover revealed a very irregular shape created by a wide range of weaving elements and techniques (fig. 2). Closer examination showed warp pairs of 8-ply cotton twine along with wefts of fine wool yarn, coarse jute rope, fine cotton yarn, nylon cord, full skeins of wool yarn, and entire hanks of unspun flax. Grau-Garriga used several
Fig. 1. Julie Benner, Mellon Fellow in Textile Conservation, and John Lupe, manager of installations, prepare to remove *Tapis Pobre* from its storage support during initial examination.

Fig. 2. Unrolling the artwork revealed its sculptural quality and the wide variety of techniques used to create the tapestry.

different weaving techniques and a wide variety of materials in *Tapis Pobre* to create its remarkable texture and sculptural qualities (figs. 3, 4): traditional tapestry weave (weft-faced plain weave with discontinuous wefts) combines with balanced plain weave, open web-like weaving, semi-attached panels, and pockets. Large
Fig. 3. Detail of variation in the tapestry weave, featuring areas of open weave and weaving off the straight grain, left.

Fig. 4. The variety of fibers used include wool, jute, and hanks of unspun flax, as well as cotton and nylon.
vertical slits woven into the panel add to the sculptural nature of the textile. Coiled jute twine appendages protrude from the top edge of the ground, with one large appendage on one face and four smaller appendages on the opposite face. These consist of a cluster of cut lengths of jute twine, folded over on itself forming a loop at the top, with tightly coiled twine around the outside holding the bundle together. Stitches made with cotton twine, similar to the warp yarns, secure the considerable weight of the appendages to the main panel. A mass of pile yarns creates extra fullness near the top center as well, adding to the textural complexity. The warp yarns create an irregular fringe at the bottom edge, while along the top edge they are gathered into 41 clusters, each cluster consisting of approximately 8 warp pairs secured together with an overhand knot. Examination revealed significant surface soiling. Cleaning with a variable-speed, high-efficiency particle air (HEPA) filter effectively removed loose debris and soiling, but testing with dry-cleaning methods such as urethane cosmetic sponges proved unsuccessful, so no further cleaning was proposed. Efforts then focused on developing a strategy for display and support.

3. DESIGNING THE HANGING SYSTEM

3.1. STYLE OF DISPLAY

The artwork has many clues about Grau-Garriga’s intentions for its display. Treatment of the warp ends, along with several hanging elements, clearly designate a top and bottom edge of the textile. Appendages protruding from both sides, along with other details of textural interest, indicate that he meant for this work to be seen from both sides or in the round. The side edges undulate significantly, but other straight lines in the body of the textile offer an indication of true vertical orientation, which can assist with installation.

Curator Alice Zrebiec located an exhibition catalog that includes an installation photo of *Tapis Pobre* from 1976 to 1977. The catalog confirms that Grau-Garriga’s studio oversaw an installation of *Tapis Pobre* in the round, suspended by its groups of warp yarns; the warps supported all of the weight, knotted at different heights and secured to a pipe with intermediate connecters (fig. 5). The team felt confident pursuing this type of installation once they had proof it had been completed successfully in the past, and decided to explore a possible free-hanging installation in the DAM gallery using the existing Arakawa track system. This would entail using an individual attachment point for each warp bundle, distributing the hanging stress over the width of the tapestry.

3.2. INSTALLING FREE-HANGING TEXTILES AT THE DAM

The installations team at the Denver Art Museum frequently uses the Arakawa rail system to suspend artworks of various types. The rails come in 10-foot lengths, and they connect to the lighting track with clips on the top face. In typical installations, pivoting tensioners connected to the underside of the rail provide attachment points for airline cable. The cable feeds through the bottom of each tensioner, and a ball bearing locks it in place; a user releases the cable by pushing up on the bottom tip of the tensioner. This cable system generally supports a hanging slat of some type, and the installations team can modify the hanging height of the slat by using the tensioners to adjust cable length (fig. 6). This usually involves adjusting only two points; however, for *Tapis Pobre* there would be over 40. Raising all of the cables at the same time under even tension seemed problematic, as the tapestry would likely be under diagonal stress during this process and vulnerable to potential damage.
3.3. ADAPTING APPROACH FOR TAPIS POBRE

Bias stress can cause significant damage to a tapestry (Zahara 2009). Though Grau-Garriga intentionally incorporated elements that depart from the traditional form, the basic structure of Tapis Pobre, like conventional tapestry, relies on the interaction of warp and weft elements for integrity and strength. The woven structure is much stronger in the horizontal and vertical directions than on the diagonal, and passages such as the open weave areas and partially attached panels are particularly vulnerable to the stresses of diagonal tension. In order to prevent damaging stress during handling and hanging, our team aimed to execute the installation in a way that would support most of the tapestry’s weight as it was being raised to its hanging height, allow it to be quickly fixed into place, and gently lowered into its vertical orientation. This would minimize stress and strain, and confine any minimal stress to the vertical and horizontal directions. In order to accomplish this, we used our in-house test-hanging system for flat textiles to prepare Tapis Pobre for safe installation.

Conservators usually treat and prepare textiles for exhibit in PreVIEW, a multidisciplinary workspace that is on view to museum visitors through large windows in the back of the textile gallery (McCloskey 2015).
PreVIEW has a test-hanging system for flat textiles consisting of a series of eight individually tensioned padded clamps, spanning the length of a 16-ft. aluminum beam, which is slowly raised and lowered via a motorized winch. In preparation for hanging, the textile to be hung is unrolled on a table surface positioned below the beam. The beam is then lowered to an appropriate working height to secure the upper edge into the padded clamps. The beam is then slowly raised as conservation staff members on either side help guide the object until it is fully vertical. This system has been used for the successful hanging of a variety of textiles, and adapted to both hook and loop (Velcro) and magnet systems (fig. 7). Until this exhibition, however, it had not been used to test textiles hung from the Arakawa suspension system.

Head conservation mountmaker Steve Osborne and assistant mountmaker Nick Donaldson made the modifications to attach the Arakawa rail to the beam. For each of the eight clamps, they fashioned a steel adaptor that could slide into the upper track of the Arakawa rail on one end, and be secured into the corresponding padded clamp on the other (fig. 8). Once the rail was clamped in place, it could then be safely lowered to an appropriate height and the tapestry could be secured (fig. 9); following the example of the 1976 installation, the hanging system would support each of the warp groups. To minimize stress on each attachment point, a loop of scoured cotton twill tape was inserted through the center of the warp bundle, in order to support the knot from the underside. The twill tape was prepared with stay stitching to minimize stretch, and box stitching to close the loops. A steel U-shaped thimble was then hooked through both ends of the loop. The thimble acted as a positioning channel guide for the airline cable, which
Fig. 7. Test hanging two barkcloths before treatment to assess the impact of improper rolled storage. To hang them, a slat with a steel receiving strip was fitted into the clamps, and the barkcloth secured with rare earth magnets through a Mylar® barrier.

Fig. 8. Detail of steel adaptors to allow Arakawa rail to be clamped onto the PreVIEW test hanging system.
ultimately connected the hanging system to the rail above. Crimped ferrules secured the ends of the airline cables (fig. 10).

Achieving the correct tension for each of the warp bundles proved to be a significant challenge. With *Tapis Pobre* on a group of tables, the team suspended the rail just above the tapestry’s top edge in order to attach the cables and fine-tune the tension for each group. Due to the variable height of the warp knots and the available display height in the gallery, there would not be enough height clearance at some of these groups for the tensioners, which measure approximately 10 cm long (fig. 11). Thus, Osborne devised a lower-profile system that uses custom-made rectangular aluminum washers that slide into the lower track of the Arakawa rail and have a central hole for the top end of the airline cable. The cable loops through the hole of the washer and a ferrule locks it in place at the desired height. The disadvantage of this adaptation is that once the ferrule is crimped, the length cannot be adjusted further without starting over with new cable and ferrule. This development in the plan made it all the more critical to get the tension adjusted correctly prior to installation. Without the possibility of a quick on-the-spot adjustment, it would be both risky and time-prohibitive to perform any final tweaks to the cable length after initial installation. Using the hoist to raise the tapestry in small increments allowed the team to test and adjust the length of each cable to achieve the proper height and maintain a supportive and relatively level hanging plane.
Concurrent to the development of the hanging system for Tapis Pobre, plans for the gallery were being finalized. The design team originally considered a low stanchion to provide security, but in the end they chose a 15-cm-high platform to surround and extend beyond the narrow footprint of the free-hanging tapestry for this purpose. As a result of this decision, there was less hanging height from the ceiling than originally anticipated and the low-profile system described above proved very helpful).

3.4. PROVIDING ADDITIONAL SUPPORT

From the start, it was clear that the large appendages that hang from the tapestry would need to be individually supported, to prevent significant strain on the object from their substantial weight over the time of exhibition. Formed from looped bundles of jute rope tightly coiled in more rope, the appendages are loosely attached to the woven structure – an attachment that could fail under prolonged strain. The team addressed this concern by supporting each appendage with its own cable. The appendages are tightly looped, and there is limited access to the interior of each. However, with great care it was possible to access each loop interior and insert a very narrow gauge support cable. To protect the artwork from damage the cable was first threaded through a barrier layer of silicone tubing, to cover the area of contact with the artwork. The silicone-tube-covered cable was then gently
Fig. 11. Associate textile conservator Allison McCloskey assesses tension on the slightly raised warp groups. Both Arakawa tensioners and the revised washer and cable hardware are shown attached to the rail. The team removed each tensioner and replaced it with the revised hardware to ensure proper hanging clearance (Courtesy of Christina Jackson).

Fig. 12. Individual support cables were added to support each of the five appendages on the tapestry: one face features a large single appendage and the other face, four smaller appendages. Cable was threaded through silicon tubing and inserted through the loops using a blunt needle formed from brass rod (Courtesy of Christina Jackson (left)).
guided through the loop’s interior using a large blunt bodkin formed from brass rod (fig. 12). The cable was then secured to the rail using the low-profile washer and crimped ferrule system mentioned above.

3.5. MAKING ADJUSTMENTS

Once the warp bundles and appendages were attached and secure, the team raised the beam and gently guided *Tapis Pobre* to a hanging position (fig. 13). After a brief moment of awe, finally seeing the artwork in a vertical orientation and marveling at its scale, they began to closely scrutinize its alignment. It was clear that some adjustment would be necessary. Like so many textile artworks, *Tapis Pobre* is not square; keeping the major vertical elements as straight as possible will help maintain visual balance. To accomplish this, the conservators needed to lower the right side to correct a visible draw in the lower right-hand corner, by undoing and reattaching seven of the attachment cables on the right-hand side. To facilitate these adjustments, the tapestry was lowered onto a support skid. Constructed of steel and plywood on rolling casters, the skid was built to house the tapestry in the interim between preparation of the hanging system and installation, and to serve as a support platform during installation by forklift.

To make these adjustments, the team partially lowered the tapestry onto the skid (constructed to fit the tapestry’s entire width). A single horizontal fold accommodated the height, with cotton sheeting interleaved between the layers. Still attached to the hoist beam, the cables on the right hand side were cut and replaced to provide a slightly lower hanging position. The team then raised the beam a last time to assess the result of
the change. Satisfied with the alignment, *Tapis Pobre* was lowered to its skid where it would stay until installation. Wooden braces were added to the sides of the skid, to support the Arakawa rail and keep it lifted off of the surface of the object. This also served to keep the cables aligned and in proper tension.

4. INSTALLATION

To install *Tapis Pobre* in the gallery, the team loaded the skid onto a forklift and slowly raised it to the height of the support track in the ceiling. The team then attached the Arakawa rail to the support track, lowered the forklift, and *Tapis Pobre* gradually unfurled (fig. 14). Everything went according to plan and the tapestry was safely hung in a very short amount of time, following the extensive preparations. No additional adjustments to

Fig. 14. With the Arakawa rail secured to the lighting track above, *Tapis Pobre* is slowly lowered on its custom-built skid via forklift operated by Steve Osborne, flanked on either side by conservators (Courtesy of Christina Jackson).
alignment were necessary after installation. Securely hung in its vertical position, Tapis Pobre was finally able to be displayed for the first time since coming into the collection over 20 years before (fig. 15).

5. CONCLUSIONS

Through creative collaboration, successful hanging of Tapis Pobre was achieved. This project presented one of the most significant challenges in the Creative Crossroads exhibition, requiring resourceful problem solving and providing the opportunity to utilize existing resources in new ways. Understanding the artist’s intent and having access to previous installation information were essential to defining a strategy for installing the artwork. The practical challenges involved in hanging Tapis Pobre helped refine the approach to hanging large textiles at the DAM and contributed to a critical re-examination of institutional habits. The legacy of Tapis Pobre will continue to inform future installations of complex and oversize artworks.

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TO AVOID ADDITIONAL PIERCINGS: THE MOUNTING OF A 1795 SAMPLER WITH ORIGINAL PAPER BACKING VIA A PAPER CONSERVATION HINGING METHOD

JOY GARDINER

ABSTRACT—Certain historic needlework pieces have been stitched to a paper backing as part of their original fabrication. For these objects the approaches to mounting for exhibition in a vertical orientation are limited, as there is high potential for causing damage to the paper with a traditional textile conservation stitched mount. In this case study, the 1795 silk embroidery on linen ground with a pleated silk ribbon at the edges by Mary Elizabeth Heister of Reading, Pennsylvania in the collection of the Winterthur Museum, Garden & Library had such a paper backing and was successfully mounted for framed vertical display. In collaboration with colleagues in paper conservation, a method used for the mounting of heavy paper artifacts by bringing the paper hinges through the mounting board and securing it to the verso of said board—pass-through hinging—was used for the piece and is described.

1. INTRODUCTION

In August 2014, an exhibition of needlework titled The Diligent Needle: Instrument of Profit, Pleasure, and Ornament, opened at the Winterthur Museum, Garden & Library. Included in the object checklist for the exhibition was a needlework by Mary Elizabeth Hiester of Reading, Pennsylvania, dated 1795 (fig. 1).

Fig. 1. Needlework by Mary Elizabeth Hiester, Reading, PA; 1795. Courtesy of Winterthur Museum, photograph by James Schneck, #2009.0006. Museum purchase with funds provided by the Henry Francis du Pont Collectors Circle.
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The needlework is polychrome silk embroidered on a linen ground, with the rare survival of its original pleated silk ribbon stitched to the edges. Also requested for the exhibition was a portrait of Mary Elizabeth (fig. 2), which had been painted by Jacob Witman around the same date as the creation of the needlework. It was hoped that the needlework could be reframed and hung next to the portrait. Examination and consideration of all of the components of the needlework revealed that a standard stitched mount would not be appropriate, and an alternative mounting system was sought.

Fig. 2. Portrait of Mary Elizabeth Hiester, painted by Jacob Witman, Reading, PA; about 1795. Oil on canvas. Courtesy of Winterthur Museum, photograph by James Schneck, #2012.0006. Museum purchase with funds drawn from the Centenary Fund and partial gift of Kurt and Valerie Malmberg in memory of Dr. Peter Muhlenberg.
2. THE COMPONENTS OF THE OBJECT

By examining the face of the object, it was determined that the needlework is comprised of a linen ground with polychrome silk embroidery, both in good condition, plus a fragile pleated silk ribbon that is stitched along the edges (fig. 3). The needlework had come into the Winterthur collection in a later, nonperiod frame; it was removed from this frame to allow for a closer examination of the reverse. After removal from the frame, the textile mounting method was visible: a few spots of adhesive were used to adhere the top corners of the object to a paper board (fig. 4).

Fig. 3. Detail of silk ribbon on upper proper left corner of needlework, #2009.0006A.

Fig. 4. View of the verso showing the paper board. Courtesy of Winterthur Museum, photograph by James Schneck, #2009.0006A.
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Careful lifting of the free edges along the bottom revealed that the textile had been lined with a paper backing. This backing is comprised of two separate pieces of paper that are stitched together and are also stitched to the edges of the needlework with a linen thread. The paper backing is thought to be original to the piece, and as such, is an integral part of the object (fig. 5).

Fig. 5. View of the paper backing stitched to the needlework. Courtesy of Winterthur Museum, photograph by James Schneck, #2009.0006A.
Other examples of needlework with paper backings are known, such as an 1843 piece of wool embroidery on linen ground in Winterthur’s collection made by Mary Elizabeth England of Maryland (fig. 6). This has a blue-faced stiff paper backing, as seen in figure 7, and also has a silk ribbon edging. According to Linda Eaton, John L. and Marjorie P. McGraw Director of Collections & Senior Curator of Textiles at Winterthur, curators and collectors are aware of this backing method, but no in-depth study has been done to date (Eaton 2015).

Fig. 6. Needlework by Mary Elizabeth England, Cecil County, MD; 1843. Courtesy of Winterthur Museum, photograph by James Schneck, #1991.0020A. Gift of Florence L. Bell in memory of Helen E. Lynch.
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3. MOUNTING CONSIDERATIONS AND OPTIONS

Although paper boards would have been available at the time of the needlework’s creation, it was thought that this board was not part of the piece’s original mounting system. At Winterthur, a concerted effort is made to keep all original components associated with a needlework piece intact, if possible. To confirm that the board was not original, Joan Irving, Winterthur’s paper conservator, tested a small sample. Using polarized light microscopy and Graff’s C-Stain, she identified the fibers as mainly softwood with bordered pits, with a very few hardwood vessel segments and cotton fibers scattered throughout. This would date the board to the last quarter of the 19th century at the earliest (Irving 2014). Thus, it was decided to remove the paper board and as the adhesive appeared to be a hide glue, the needlework was released using controlled moisture.

The presence of an original paper backing complicated the available exhibition mounting options. It had been requested that the needlework be reframed and hung vertically next to the portrait of the maker. While an argument could have been made to show the needlework flat in a case with slanted deck, it was
decided to explore ways to safely achieve the vertical format. Although the linen ground fabric was in stable condition, there were two main issues that precluded using the standard mounting method of stitching the object to a fabric-covered board. One was the fragility of the silk ribbon, although it might have been possible to utilize the previous stitching holes to minimize further damage. The second was the paper backing, and how to attach the object without putting additional holes into the paper.

Consideration was given to all of the components of the object: the linen ground fabric, the silk embroidery, the silk ribbon, the paper backing, and how they interact. Since the paper is stitched to the fabric along the perimeter, the fabric cannot be put under any more tension and is fixed in position. The paper therefore supports the textile, and the following was posited: could the piece be hinged like a work of art on paper? In consultation with Joan Irving and Aleksandra (Aleks) Berger, the conservation assistant in preservation housing, it was decided that this was a viable option and that Berger would mount the piece. There was some damage to the paper, but overall it appeared strong enough to support both itself and the needlework.

4. HINGE MOUNTING

Various types of hinges, often created from Japanese papers, are used in paper conservation and preservation housing for mounting paper objects to backing boards. Two common types include the hanging hinge and the
V- or floating hinge. With the hanging hinge, a portion of the hinge is adhered to the verso of the top edge of the object, and the remaining projecting portion is adhered to the face of the backing board. With the V- or floating hinge, the hinge is also adhered to the object’s verso, but the hinge is then folded back to form a “V” and adhered to the board so that the entirety of the hinge remains hidden behind the object. These methods work for many pieces, but the combination of needlework, ribbon and paper made for a rather heavy object that might not be supported by either of these hinges. Irving suggested the use of pass-through hinges, in which the paper hinge literally passes through a slit in the support mount board and is adhered to the verso of said board. This method, described by Hugh Phibbs (2005), is designed to support more weight. This method is illustrated in figure 8 and proceeds in the following manner:

1. The hinges are adhered to the verso of the piece slightly below the upper edge (fig. 9).
2. The object is positioned on the backing board and the location of the hinges is marked.
3. The piece is removed and the slits are cut at an angle and slightly wider than the hinges to allow for exact positioning before the hinges are adhered in place (fig. 10).
4. The object is placed on the board and the hinges are fed through the slits to the reverse. Covering the leading end of the hinges with a folded piece of thin paper or Mylar allows the hinge to be easily slipped through the slit.
5. The object is adjusted into its final position, the board flipped over, and the hinges adhered to the verso of the board, usually in the “up” position (fig. 11).

Fig. 9. Japanese paper hinges adhered to the verso of the Hiester needlework.
Fig. 10. Detail of the slit cut into 4-ply acid-free backing board.

Fig. 11. Hinges brought to the back of the backing board. In a variation on the procedure, these hinges were adhered down for extra security and in the final version, there were three hinges.
5. MOUNTING THE NEEDLEWORK

For the needlework piece, Berger adhered two Sekishu Japanese paper hinges with Atex-P starch paste to the verso of the object. However, due to the slickness of the hot-pressed glazed surface of the original backing paper, it was found with gentle testing that there was not sufficient peel strength with this often-used adhesive. The initial hinges and adhesive were removed. Moving on to adhesives that had more secure bonds with similar slick surfaces, the acrylic resin emulsion Lascaux 498 HV was tested and also found to be insufficient. Beva Gel (ethylenevinylacetate/acrylic dispersion) did have the peel strength required, and was used with three hinges for extra security. In addition, the hinges were pasted in the “down” position. Although this creates a fold in the hinge, it was felt to be an advisable measure to help support the weight of the needlework.

The object was placed in a new frame that had been designed with a wide rabbet, allowing the spacers to be positioned beyond the trimmed edges to prevent any crushing of the fragile, dimensional ribbon. It was installed in the exhibition and hung safely next to the portrait of its maker (fig. 12).

Fig. 12. The needlework installed in the exhibition *The Diligent Needle: Instrument of Profit, Pleasure, and Ornament*. Courtesy of Winterthur Museum, photograph by James Schneck.
6. CONCLUSIONS

The successful mounting of this needlework piece would indicate that, in similar instances where a textile is attached to a paper backing, hinging the paper may be a viable option for mounting. But perhaps more importantly, when fiber-based objects under our care contain components of other media, being aware of how conservation professionals dealing with that particular media would approach treatment, and having a dialogue with those professionals, can lead to a wider range of choices for object care.

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PADDED INSERT FOR PRE-COLUMBIAN TUNIC

ROBIN HANSON

ABSTRACT—The construction of custom-sized padded inserts for pre-Columbian tunics described in this essay was presented at a tips session of the Textile Specialty Group of AIC during the annual meeting in Miami in 2015. Each insert consists of two layers of cut-to-shape high-loft polyester batting with fitted cotton broadcloth cover and is modeled on a padded insert developed by Christine Giuntini, textile conservator at the Metropolitan Museum of Art. The padded insert is designed to work with a hanging rod; shoulder straps of silk crepeline ribbon attached to the batting are also secured to the cover to prevent slumping and/or movement of the batting. Each padded insert is custom-sized to fit a specific tunic and constructed of cotton in a sympathetic color.

1. INTRODUCTION

Wari: Lords of the Ancient Andes, an exhibition organized by the Cleveland Museum of Art (CMA), opened in Cleveland in October 2013 and then traveled to two additional venues in the United States. Before the Inca—between 600 and 1000 AD—the Wari forged a complex society widely regarded today as ancient Peru’s first empire. The first exhibition of this culture in North America, Wari included more than 100 artworks from more than 45 lenders in all major Wari media, including ceramics, ornaments made with inlays of gold and silver, and sculpture, in addition to tunics and other garments from one of the world’s most distinguished textile traditions.

Because the exhibition included so many similar textiles, many of them tunics, a flexible, easy-to-install mounting system that also satisfied the requirements of the museum’s design department had to be created, since the CMA was responsible for mounting the majority of the textiles. Both the exhibition curator and designer wanted the neck slit in the tunics to be visible. Lender requirements determined the angle at which each tunic could be displayed. The padded inserts are versatile and can be used for free-hanging tunics, and tunics displayed on slant boards. An added challenge was that not all of the tunics were displayed at all venues; CMA’s textile conservator traveled with the exhibition to install the tunics at the additional venues.

One component of the mount was a custom-fitted, padded insert fabricated by the textile conservator. These inserts had a dual function: they provided some three-dimensionality for the tunics while on display, and once inside the tunic they remained in the object for the duration of the exhibition tour, thereby providing padding during transport. The padded insert was designed to work with a hanging rod; each insert had a gusset at the neck to facilitate viewing the neck slit. If the color of the neck edge differed from the rest of the tunic, an overlay of cotton that matched the neck edge color was added (fig. 1). The following section details the design and construction of a padded insert.

2. CONSTRUCTION PROCEDURE

The padded insert is constructed of Philips-Boyne 1/50’s Superba cotton broadcloth and Museum Services Musetex 2.5 cm (1 in.) high-loft batting. The single piece of cotton broadcloth for the cover should be washed
twice, dried, and ironed prior to use; the first wash is done in hot water using Orvus WA paste, the second wash is done in hot water with no detergent.

1. Measure the tunic while it is lying unfolded on a table. The narrowest width and shortest length of the artifact provide the dimensions for the padded insert. Also determine and record the length of the tunic’s neck slit.

2. With these measurements in hand, lay the cotton broadcloth flat on a worktable and mark the center with tailor’s chalk across the width of the fabric and down the length of the fabric. The horizontal line establishes the shoulder line and the vertical line establishes the center front and back. The broadcloth will be trimmed to the appropriate dimensions for the tunic in step 11.

3. Mark the length of the neck slit centered on the vertical chalk line. Mark points 2.5 cm (1 in.) above and below the length of the neck slit.

4. Draw the neck edge with chalk as follows: mark the shoulder line 1.9 cm (¾ in.) to each side of the neck slit line. Draw lines connecting these points and the points above and below the neck slit, tapering the lines to form a “V.” Rather than being pointed, the bottom of each “V” should be slightly rounded.

5. Machine-stitch the neck-edge chalk lines with thread the color of the cotton broadcloth using very short stitches to act as stay stitching, particularly at the bottom of the “V.”
6. Cut the neck slit along the chalk line from the bottom of the “V” in front to the bottom of the “V” in back (fig. 2).

7. Cut a gusset of the same cotton broadcloth, 6.4 cm (2½ in.) in width and the length of the neck slit. Fold the gusset in half and iron the fold to facilitate the gusset’s placement.

8. Place the gusset fold at the bottom of one “V” (either front or back) and pin it to the tunic; pinning proceeds upwards from this point. Machine stitch the gusset to the tunic with a 1.3 cm (½ in.) seam allowance; the seam pivots at the bottom of the “V” and should stop on each side 4.5 cm (1¾ in.) below the shoulder line to allow clearance for the hanging tube to slip through.

9. After one side of the gusset is stitched, press the seam allowance towards the tunic. Pin and stitch the second side to the tunic in the same manner as the first side. The excess gets folded under and finger pressed.

10. Fold the 1.3 cm (½ in.) seam allowance around the tube opening to the interior and hand stitch through both layers to keep it flat (fig. 3).

11. Fold the broadcloth in half, right sides together, at the shoulder line. Align and pin the sides and bottom edges (fig. 4). Mark the sides and bottom at the appropriate width and length for the specific tunic. Machine-sew them together and trim as necessary to create a 1.3-cm (½-in.) seam allowance. The side seams should stop 5.1 cm (2½ in.) below the shoulder line, leaving an opening to permit the tube to slip through. Sew the bottom edge only about 25.4 cm (10 in.) in from each side seam, to create an opening that will allow the batting to be inserted. The remainder of the bottom seam will be closed with hand sewing later in step 18.
PADDED INSERT FOR PRE-COLUMBIAN TUNIC

Fig. 3. Neck slit with completed gusset.

Fig. 4. Padded insert turned inside out to sew side and bottom seams.
12. Once the side and partial bottom seams are sewn, open the two seam allowances at the lower corners and align them. Stitch a 3.8-cm (1½-in.) line across each corner to give the insert depth (fig. 5). Trim the corners and turn the broadcloth right-side out. Iron seams open and remove wrinkles as necessary (fig. 6).

13. Cut two pieces of high-loft batting to the shape of the insert. The two pieces of batting can be stitched together with long basting stitches if necessary, so that they function as one.

14. Cut four pieces of crepeline ribbon to 22.9-cm (9-in.) lengths. Attach each piece of ribbon to the batting at the shoulders, one at each neck and armhole edge. The ribbon should form a loop that is of sufficient diameter to go around the hanging tube (in this case 3.2 cm (1¼ in.) diameter archival tube was used). One large cross stitch extending through both batting layers and the ribbon in front and back, and well tied off, should be sufficient to secure the ribbon loop to the batting (figs. 7, 8).

15. Insert the batting into the cover through the opening in the bottom seam.

16. Fit-test the padded insert by sliding a tube of the appropriate diameter through the shoulder openings, making sure to catch the ribbon loops. Slide a smaller diameter metal tube through the tube, and suspend it from two telescoping tripod stands. In this way the tunic insert can hang and the batting can be shifted around, properly positioned, and trimmed as necessary (fig. 9).
PADDED INSERT FOR PRE-COLUMBIAN TUNIC

Fig. 6. Padded insert turned right-side out.

Fig. 7. High-loft batting with crepeline ribbon straps.
Fig. 8. Detail of crepeline ribbon strap stitching.

Fig. 9. Completed padded insert; center bottom seam not yet stitched closed.
17. At the shoulder line, hand stitch through the cover into each crepeline ribbon loop. This will ensure that when the final is inserted (and interior access to the padded insert is no longer available because the bottom seam is sewn closed), that all loops are “caught” as the tube is inserted.

18. By hand, sew up the bottom seam.

19. Carefully slide the padded insert into the tunic. Insert the rod/display mount through the shoulder openings.

3. TOOLS FOR CONSTRUCTING PADDED INSERT

sewing machine, spray bottle for water, iron, scissors, straight edge, tape measure, pencil, tailor’s chalk, rotary cutter or scalpel, sewing needle.

4. MATERIALS FOR CONSTRUCTING PADDED INSERT

2.5 cm (1 in.) thick high-loft polyester batting, cotton broadcloth, 3.1 cm (1¼ in.) diameter blueboard, 2.5 cm (1 in.) wide silk crepeline ribbon (or other ribbon if crepeline is not available), cotton sewing thread, Orvus WA paste.

ACKNOWLEDGMENTS

The author would like to thank her conservation and mount making colleagues at the Cleveland Museum of Art for their support, and contract mount maker Carlo Maggiora for his simple but elegant mount system for the pre-Columbian tunics included in *Wari: Lords of the Ancient Andes*. She would also like to thank Metropolitan Museum of Art conservator Christine Giuntini for her design of this padded insert. All the author did was codify her design by writing it down.

SOURCES OF MATERIALS

Musetex polyester batting, 2.5 cm (1 in.) thick
Museum Services Corporation
385 Bridgepoint Way
South Saint Paul, MN 55075
Tel: (651) 450-8954
Fax: (651) 554-9217
www.museumservicescorporation.com

Archival blueboard tube, 3.2 cm (1¼ in.) diameter
Neilson Bainbridge (Archivart)
40 Eisenhower Drive
Paramus, NJ 07653
Tel: (800) 342-0124
Fax: (215) 625-4946
www.neilson-bainbridge.com
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Superba 1/50’s cotton broadcloth, 114.3 cm (45 in.) wide
Philips-Boyne Corporation
135 Rome Street
Farmingdale, NY 11735
Tel: (631) 755-1230
Fax: (631) 755-1259
www.philipsboyne.com

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ABSTRACT—Over the past few years, conservators and exhibition specialists at the National Museum of the American Indian developed a slant board for displaying both tanned hides and textiles with rare earth magnets. Designed to be rigid and relatively lightweight, the aluminum panel, covered with a thin sheet of galvanized steel, allows placement of mounting magnets anywhere on the surface making the slant board both versatile and reusable. Boards are fabric-wrapped with a nappy surface under the footprint of the object to help support the hide or textile while on display. The mounting cleat and standoff system on the back of the slant board allow the angle of the board to be adjusted from vertical to about 30° off the vertical. Textiles are mounted with rare earth magnets positioned between the slant board and a fabric sleeve, stitched to the back of the textile, which receives a steel slat. Hides are mounted with rare earth magnets placed beneath the hide on the slant board and a corresponding round steel disk covered with a toned, adhesive-backed sueded material to camouflage its placement on the face of the hide.

1. INTRODUCTION

Magnetic mounting solutions are becoming increasingly popular in the display of collections for three-dimensional objects, textiles, and paper. Rare earth magnets in particular enable additional mounting possibilities because of their high strength. However, they must be handled and used carefully because they can damage objects and injure people. The National Museum of the American Indian (NMAI) has been using magnets in various mounting methods for at least 12 years, and their mounting techniques continue to evolve. This paper describes the construction of an adjustable angle, reusable slant board that works for mounting both hides and textiles. The reusable design was based on slant boards in the Infinity of Nations exhibition, however these boards were cut to the specific shape of a textile or hide, and the display angle was fixed (fig. 1). The mounts make the objects appear to float because they have no handling margins, but they do not allow for easy rotation of objects during the run of the exhibition, and boards cannot be used for future exhibitions. A simplified general construction method, allowing for handling margins and some angle adjustment, was used for slant boards in the exhibitions Song for Horse Nation (fig. 2) and Nation to Nation: Treaties between the United States and American Indian Nations.

2. BOARD CONSTRUCTION

The boards are constructed using ½ in. thick aluminum honeycomb panel as the primary support. A 24-gauge sheet of galvanized steel cut 2 to 3 in. smaller than the panel on all sides serves as the ferromagnetic material that will attract the magnets; the smaller size of the steel makes the panel slightly lighter, and it is unlikely that the ferromagnetic material will be needed out to the edges of the panel. The steel is secured to the support panel with contact adhesive such as 3M Fastbond 30NF, or it can be mechanically secured. The panel edges are taped with 3-in. aluminum duct tape to cover raw panel edges; the tape can also be used to cover the edge of the steel sheet to soften its edges on the panel.
ADJUSTABLE ANGLE, REUSABLE SLANT BOARDS FOR MOUNTING HIDES AND TEXTILES WITH RARE EARTH MAGNETS

**Infinity of Nations slant boards**

- Floating design
- No handling margins
- Cotton fabric wrapped with cotton flannel silhouette

**Fig. 1.** Infinity of Nations slant boards for hides and textiles with non-adjustable standoffs at bottom.

**Song for Horse Nation slant boards**

- Horizontal positioning
- Lifting aid at bottom corners
- Adjusting magnets
- Painted muslin with glazing

**Fig. 2.** Song for Horse Nation slant boards for hides and textiles showing horizontal positioning and magnet placement (upper left), and magnet adjustment after hanging slant board.
The mounting cleat at the top consists of two parts, both made of 90° aluminum angle: one part attached to the wall, and the other to the back of the slant board. The wall angle has two holes cut into the horizontal portion, which receive screws/posts that are secured to the horizontal edge of the angle mechanically attached to the back of the slant board (fig. 3, right). Near the back lower edge of the slant board, two galvanized standoffs are attached, which receive threaded aluminum posts to hold the lower edge of the slant board off the wall (fig. 3, left). The length of the posts can be slightly adjusted by about 2 in. by screwing or unscrewing them into the standoffs. The holes in the wall cleat are large enough to allow the upper screws/posts to move within the holes as the board is adjusted closer to, or away from, the wall allowing the board angle to be adjusted. The height of the standoffs at the bottom of the panel are the same height as the angle attached to the top of the panel, so that when the slant board is laid on a surface for object placement, the entire panel can rest flat.

3. FABRIC COVERING

Textiles or hides are better supported if a nappy fabric such as 200-wt. Polartec is used. It is preferable to use a polyester fleece fabric not made from recycled materials because of the potential for unknown impurities. However, nonrecycled, or “virgin” polyester fleece is getting harder to find, and the color palette of the non-recycled fleece is more limited than the recycled product. The wrapping fabric is loosely placed on the board with Spray 77, wrapped to the back of the panel, secured with double stick tape, followed by aluminum tape over the raw fabric edges. If designers choose a slick (non-nappy) display fabric, a layer of polyester fleece or a cotton flannel can be stitched or adhered to the fabric-wrapped board directly under the footprint of the object.
ADJUSTABLE ANGLE, REUSABLE SLANT BOARDS FOR MOUNTING HIDES AND TEXTILES WITH RARE EARTH MAGNETS

4. MOUNTING HIDES

With the slant board laid flat, the hide is positioned for display, and rare earth magnets are placed in strategic locations beneath the hide around the edge, and in central areas if extra support is needed (fig. 2, upper left). Preferred magnets are neodymium rare earth magnets, grade N42, axially magnetized, ½ in. or ¾ in. diameter and ⅛ in. or ⅛ in. thick, depending on the size, weight, and thickness of hide. A round ferrous disk matching the diameter of the magnet beneath the hide is covered with acrylic adhesive-backed polysuede on both sides. On the top side, the polysuede is toned with acrylic paints to match the color of the hide and camouflage its placement; the face of the magnet in contact with the hide also receives a polysuede cover to prevent slippage. The covered disk is placed on top of the hide matching the position of the magnet below the hide. Recently hand-fabricated tin plate ferrous disks were used, but commercially available alternatives also exist, such as galvanized punch-outs from electrical junction boxes, or cold-rolled steel disks (fig. 4). However, because the cold-rolled steel has no protective coating, like the galvanized steel or tin plate, this option may present rust issues. “Magnetic” 22 gauge stainless steel disks such as those available through StampingBlanks.com may offer the best option.

Having the magnet behind the hide—and not on top of it—prevents some compression on the hide and eliminates the “upholstered button” look. A thinner profile ferrous disk, such as the tin plate, makes the covered disk less visible on the surface (fig. 4, lower left). After the disk/magnet pairs are placed, the panel is lifted from the horizontal position and fitted into the wall cleat, and the threaded posts are screwed into the standoffs to the desired mounting angle from the wall.

Fig. 4. Magnets on hide surface (1-2); ferrous disks on hide surface with magnets beneath hide (3-5). Lower left: magnet and ferrous disk profiles. Lower right: colors of sueded polyethylene.
5. MOUNTING TEXTILES

Instead of using magnet/disk pairs as described for the hides, a fabric or twill tape sleeve is hand-stitched to the back of the textile to receive a 1 in. to 1.5 in. wide strip of flat steel – this can be the same 24 gauge steel used in the board fabrication, or another type of coated steel. Tyvek tape tabs adhered to the ferrous strip ends facilitate removal from the sleeve, as they provide a flexible end to grasp. The textile, with ferrous strip inside the sleeve, is oriented on the slant board in the horizontal position. After positioning, Neodymium rare earth magnets (N42 strength, axially magnetized, ½ in. or ¾ in. diameter and ¼ in. or ⅛ in. thick, depending on the size and weight of the textile) are placed between the back side of the sleeve and the slant board, spacing the magnets 8-10 in. apart along the length of the sleeve (fig. 5). The panel is mounted to the wall as described above for the hide.

6. CONCLUSION

The design of this slant board offers flexibility in the types of materials that can be mounted, as well as the capacity to adjust the angle from vertical to about 30° off the vertical. Because the ferrous material on the panel covers all but a 2-3 in. margin around the edges, the hide or textile can be mounted anywhere on the panel, and the magnet placement need not be specific, making the mount reusable for rotations or other exhibitions. The use of a polyester fleece as a display fabric provides nap and some padding to support a displayed textile or

Fig. 5. Twill tape sleeve stitched to textile with galvanized steel strip inserted and magnets placed on the sleeve. A Tyvek tape tab is attached to both ends of the steel strip to facilitate removal from sleeve.
ADJUSTABLE ANGLE, REUSABLE SLANT BOARDS FOR MOUNTING HIDES AND TEXTILES WITH RARE EARTH MAGNETS

hide. The thickness of the fleece also allows the depth the magnet to sink into the fabric, creating a lower profile. Using the thin ferrous disks on top of the hide, instead of magnets, also presents a lower profile on the hide surface. Likewise, using a steel strip in a sleeve attached to a textile gives a lower profile than a bulky Velcro band. While textiles could also be mounted like the hides without a sleeve, the sleeve distributes the mounting stress over a larger area, and the yarns are not locally compressed by magnetic force. Sleeves are not generally considered as an option for hides because stitching into them makes small holes that can be damaging. Placing the magnets on the fabric-covered panel as opposed to placing them on top of the actual object produces less risk of compression damage to the hide or textile. The strength of the neodymium magnets can be lessened by using thicker fabric or additional fabric layers, or by adding layers of the adhesive-backed polysuede on the magnet surface. The added layers increases the “gap” between the magnet and the attractive ferrous material, thus reducing the magnet’s pull force. Care must be taken to use a magnetic system that has enough strength to hold the object in position without causing compression on the object.

ACKNOWLEDGMENTS

Thanks to Stacey Jones, NMAI-NY exhibits specialist, who worked with conservation to design our first round of “magnetic” slant boards for hides and textiles in the Infinity of Nations exhibition.

REFERENCES


SOURCES OF MATERIALS

½ in. aluminum general purpose panel, potential source (original supplier no longer available)
Pacific Panels Inc.
74 98th Ave.
Oakland, CA 94603
Tel: (510) 568-7288
www.pacificpanels.com

½ in. aluminum composite panel, potential source (original supplier no longer available)
Alucobond
3A Composites USA Inc.
208 West 5th Street
P.O. Box 507
Benton, KY 42025
Tel: (270) 527-4200
Fax: (270) 527-1552
www.alucobond.com
22 gauge “magnetic” stainless steel stamping blanks
   StampingBlanks.com
   PO Box 1093
   Conifer, Co 80433
   Tel: (877) 207-4473

24-gauge galvanized steel
   OnlineMetals.com
   1848 Westlake Ave N
   Suite A
   Seattle, WA 98109
   Tel: (800) 704-2157
   Fax: (206) 285-7836
   www.onlinemetals.com

3M Fastbond 30NF
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Junction boxes
   McMaster-Carr
   200 New Canton Way
   Robbinsville, NJ 08691-2343
   Tel: (609) 689-3000
   Fax: (609) 259-3575
   www.mcmaster.com

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   K and J Magnetics Inc.
   18 Appletree Ln.
   Pipersville, PA 18947
   Tel: (888) 746-7556
   Fax: (215) 766-8054
   www.kjmagnetics.com

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ROBERT PATTERSON is an exhibit specialist at the National Museum of the American Indian, Smithsonian Institution (SI). With a background in ornamental blacksmithing and studio art, Robert joined the Smithsonian Institution Office of Exhibits Central as a mount maker in the late 1990s. Robert has worked on over 60 SI exhibits, traveling and permanent, in the capacity of mountmaker, interactive fabricator, and preparator. He has worked closely over the years with SI conservators to safely store and display 2D textiles, paintings, and hanging sculptures. He has extensive experience in the design, development, and installation of museum exhibits and gallery installations. Most recently he was part of a traveling consortium to mitigate damage and ensure the safety of artifacts in at risk environments. He lives in Washington, DC. National Museum of the American Indian, 4th & Independence Ave SW, Washington, DC 20013-7012, pattersonr@si.edu.
ABSTRACT—Rare earth magnets can be creatively incorporated into simple and supportive mounts. This article offers tips on using and concealing magnets while working with a basic ferromagnetic receiver and weight-distributed or point fastener magnetic mounting system.

1. INTRODUCTION

Rare earth magnets may not be such a new tool in the conservator’s box, but they are incredibly helpful and can be adapted and used in numerous ways; they are strong, easy to conceal, and can readily be incorporated into simple supportive mounts. Methods of building supports may differ, but the basic components of mounts do not. There are two materials working in tandem: a magnet and a ferromagnetic material. The variables that need to be considered in terms of strength of bond (and thus compatibility with object and mounting method) are the orientation of magnetic poles, strength of the magnet, quality of the ferromagnetic material (the receiver), and the space or gap between the magnet and the receiver (generally the combined thickness of show fabric and object) (Spicer 2010). Adjusting any of these components alters the strength of the mount system and can be used to fine-tune the support.

2. FERROMAGNETIC RECEIVER

The basic magnet mount at the Asian Art Museum, San Francisco, begins with a ferromagnetic receiver solid support board consisting of: aluminum-sided signboard (D-Lite), 26-gauge galvanized steel, cotton flannel, and show fabric (Migdail Forthcoming). Aluminum tape is placed along the edges of the bottom two layers, securing the steel to the D-Lite board as well as softening the edges beneath the show fabric (fig. 1). Whether

![Fig. 1. Construction of a magnetic mount. Asian Art Museum of San Francisco, ©Asian Art Museum of San Francisco](Image)
vertical, horizontal, or slanted, this board forms the receiver component of the mount; the magnet portion securing the artwork to it, is either a strip (weight-distributed) fastener or a variation on a point fastener (a single positioned magnet). The backing boards can be specifically cut to the size of an artwork (creating a virtually invisible mount), or generally sized to be interchangeable and reused for gallery rotations.

3. WEIGHT-DISTRIBUTED FASTENERS

At the Asian Art Museum, weight-distributed fasteners consist of magnets embedded in strips of acid free board. These are strips of rag board cut to specific sizes (based upon the artwork being mounted) with magnets dispersed within them (fig. 2) (Magnet Mounts 2011). Weight-distributed fasteners are extremely versatile. They can be used within sleeves instead of traditional rods (fig. 3), or placed externally on the top of a work of art (fig. 4). They can be covered in fabrics themselves, toned to a specific color with paints, wrapped in Japanese tissue, or hidden by a photographic overlay. The possibilities are endless and the format allows for numerous
Fig. 3. Use in an internal sleeve. Asian Art Museum of San Francisco, ©Asian Art Museum of San Francisco
modifications. For instance, a strip can be composed of multiple parts, as in figure 5, where an interlocking two-part mount supported the neck (triangular portion) and sleeves (rectangular portion) of a ceremonial robe. In addition, it is possible to alter the strength of the mount by changing the number or size of magnets utilized.
4. POINT FASTENERS

Point fasteners are another magnetic variation. As with the weight-distributed fasteners, these magnets can be camouflaged with paint, fabric, Japanese tissue, beads, or sequins. The concept of a point fastener can be applied to hook supports (fig. 6) whereby a magnet secures a bracket/hook to the receiver board, thereby supporting some component of the artwork (a lower rod of a scroll, for example). Magnets can also be secured to pillow inserts, as in the example shown in figure 7, of a vest with a lightly padded insert. With magnets stitched to the reverse of the pillow, when in position, the insert not only supports the vest, but secures it to the receiver mount as well. Point fasteners can also be used in a manner similar to snaps: if a fabric-covered magnet is secured to the front flap of a garment with a second magnet positioned inside the garment, an additional closure mechanism is created. Such a system can be used to remove weight from fragile button closures. If concerned about the strength of the bond between magnets, this localized pressure can be reduced by substituting flashing or metal washers in lieu of a magnet as the receiver. Another solution would be to increase the gap, introducing a polyester felt or ultra-suede disc into the magnetic sandwich.
5. MAKING THE SYSTEM WORK

Rare earth magnets are brittle and subject to shatter upon impact. They should be stored in stacks separated by spacers. This can be as simple as interleaving them with twill tape ties, or using cut plastic spacers. Magnets should be stored wrapped in protective padding and kept away from computers or other electronic equipment; websites, such as K&J Magnets (www.kjmagnetics.com) offer tips and insights into the safe storage and use of rare earth magnets.

Magnets are drawn to each other. This can be dangerous if one is not paying attention. Always be aware of magnet placement. If magnets are left on a nonferrous surface in close proximity to each other, they may interact and move unexpectedly. Similarly, if trying to stack magnets without spacers, one may find fingers painfully pinched between two magnets. Conversely, however, it is possible to use the strength of magnetic attraction to one’s advantage. A strong magnet will attract a weaker one; thus, by positioning a stronger magnet over a weaker mounting magnet and lifting, the smaller mounting magnet can easily be removed from the surface of the artifact.
6. CONCLUSIONS

Rare earth magnets are difficult to produce and are hard on the environment (Gocha 2015). Therefore, it is critical to store them properly and to recycle and reuse them to the greatest extent possible. When stored properly, these magnets maintain their strength indefinitely and can be used and reused in numerous supports.

REFERENCES


SOURCES OF MATERIALS

Aluminum Foil Tape
  Uline
  2950 Jurupa Street
  Ontario, CA 91761
  Tel: (800) 295-5510
  [www.uline.com](http://www.uline.com)

D-Lite Board
  Product Signs Supplies
  625 Emory Street
  San Jose, CA  95110
  Tel: (408) 294-5823
  [www.productsignsupplies.com](http://www.productsignsupplies.com)

Rare Earth Magnets
  K&J Magnets
  18 Appletree Lane
  Pipersville, PA 18947
  Tel: (888) 746-7556
  [www.kjmagnetics.com](http://www.kjmagnetics.com)
A NEW 3M: MINIMAL MAGNET MOUNTS

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www.amazingmagnets.com

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For the past nine years, Denise Migdail has held the title of Conservator, Textiles, at the Asian Art Museum in San Francisco. She received a BA in biology and studio art from Occidental College in 1984 and an MA from the Williams College Graduate Program in the History of Art in 1987 while pursuing her interest in conservation. Denise worked at the Textile Conservation Workshop, South Salem, New York, for many years before returning to the Bay Area. She currently serves on boards for both the Western Association for Art Conservation (WAAC) and the North American Textile Conservation Conference (NATCC).

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HAT MOUNTS FOR EGG HEADS

LAURA MINA AND CASSANDRA GERO

ABSTRACT—This article presents two types of mounts that secure hats to bald head forms or “egg heads.” The mounts were developed for 19th and 20th century American and European hats included in two exhibits organized by the Costume Institute at the Metropolitan Museum of Art. One type of mount is designed for hats with crowns that are too large for the head form. The other mount addresses the needs of hats with small crowns that are not intended to fit over the head. This article includes variations for each basic mount type that are suitable for a range of hats. The mounts use Volara Type A polyethylene closed-cell foam and other common conservation materials to provide appropriate support. Both types of mount achieve three goals: provide the desired aesthetic placement of the hat on the head form, secure the hat to the head form without pins or other fasteners, and avoid the use of drill holes or other permanent modifications to the head form.

1. INTRODUCTION

This article presents mounts for hats exhibited on head forms or mannequins without wigs. The mounts were developed for 19th and 20th century American and European hats included in two exhibits organized by the Costume Institute at the Metropolitan Museum of Art. For both Death Becomes Her: A Century of Mourning Attire and High Style: The Brooklyn Museum Costume Collection, curators chose to exhibit hats on abstracted head forms, or “egg heads.” Since hats are typically designed to fit over styled hair, bald mannequins or head forms pose a challenge. These head forms require specialized mounts to ensure that the hats can be appropriately placed and secured without the use of wigs.

Two types of mounts are presented, each with variations. One basic mount is suitable for hats that are intended to be worn around the full circumference of the head, but are too large for the head form. These are referred to as mounts for hats with large crowns. The second type of mount is for hats with small crowns that are not intended to fit around the full circumference of the head. Instead, the small crowns of these hats are designed to fit over, and be supported by, gathered hairstyles such as buns or chignons. These are referred to as mounts for hats with small crowns. Both types of mount detailed in this article were designed to achieve three goals: (1) provide the desired aesthetic placement of the hat on the head form, (2) secure the hat to the head form without pins or other fasteners, and (3) avoid the use of drill holes or other permanent modifications to the head form. All of the mounts presented in this article are intended for lightweight hats, and only for temporary display. These mounts do not provide the type of support required for long-term object display or storage.

2. HATS

2.1. HAT CONSTRUCTION

Hats are made in many different styles and shapes. While it is beyond the scope of this article to describe all hat variations, the parts of a typical hat are shown in figure 1. There are three parts of a hat that have the greatest impact on the type of mount needed to provide support: the crown, brim, and sweatband. The crown covers the top of the head, while the brim extends outward at the base of the hat. The sweatband is in the interior of the hat where the brim and crown meet and is usually the part in contact with the wearer’s head.
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The mount should support the hat’s weight from the sweatband when possible, not the crown. Many hats are made with the crown as a separate piece that could begin to detach if stressed for too long.

Before beginning to make a mount, conduct research to determine how the hat was worn at the time of its creation, since existing object photography may not display the hat correctly. If the sweatband has a seam, this typically indicates center back. Fashion plates or photographs of similar hats from the same time period can help determine the placement and angle of the hat on the head. Always consult with the curator to ensure that the hat’s placement will be appropriate for the exhibition.

While moving the hat on or off the mount, hold it by the sweatband as much as possible. When not on the exhibition mount some hats can sit safely on the flat surface of a table; others require a storage mount or a ball of archival tissue for support if the brim cannot safely support the hat.

2.2. HAT CONDITION

Most hats are composite objects with many different materials contributing to both structure and decoration. The (potentially different) condition issues of each component should be considered to ensure that the exhibition mount will provide appropriate support. If a hat will be positioned off-center on the head form, it is particularly important to confirm that the hat and all decorative elements are stable and secure. Assuming the hat is structurally stable for exhibition, the interior of the crown is the most critical area to consider when devising a proper mount.

If the hat has a lining, its condition will greatly influence mount choice; a common condition problem is a shattering silk lining. If the lining or exposed hat interior is fragile, the mount should be constructed with smooth surfaces that limit potential damage from abrasion. For example, it may be best to use Volara for these mounts, and/or to cover them with silk habutai.

As mentioned above, the sweatband is the area intended to distribute and support the weight of the hat. This area of the hat will be in the most direct contact with the mount. If the sweatband is fragile or damaged, it will need stabilizing treatment before the mount system can be developed.

While the tip of the crown is not typically intended to support much weight, this is not true for all hat designs. Some hats may benefit from gentle support throughout the crown interior to ensure that the sides and tip of the crown maintain the appropriate shape. Such support may be able to address unwanted creases with minimal or no humidification treatment.
3. MATERIALS AND SUPPLIES

All materials used in these mounts should undergo accelerated corrosion testing, such as Oddy testing, or other materials tests to ensure that they do not emit volatile compounds or pose other risks to the objects. Textiles that are used near objects should be tested as mentioned above, as well as for potential risks such as dye transfer and crocking.

Head forms, such as those used in *High Style*, can be purchased ready-made from different vendors. They are typically made of either wood or fiberglass, and are usually painted with water-based enamel paint (fig. 2).
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If there are concerns about the surface of the head mount, a barrier such as washed fabric, Mylar polyester film, or Teflon PTFE film should be used between the object and the head form. Many of the mounts in this article make use of Volara Type A polyethylene foam to support the hats. While this material is available in many thicknesses in both white and black, all example mounts were made using 1/8 in. thick white Volara. Other mounts are made with virgin 100% polyester felt and batting. It is important to ensure these materials are needle-punched rather than held together by resins or binders, which could be harmful to the object.

While this mount system relies heavily on the use of archival double-sided tape, the adhesive is never in contact with the object. The purpose of the tape is to secure the mount materials to the head form without the use of drill holes or other permanent modifications. Keep in mind that the mount should have enough surface area to support the hat and be lightweight enough to stay adhered to the head with only double-sided tape.

A successful mount will not only safely support the hat at the desired angle, it will also be virtually invisible. A good way to make a mount less visible to the viewer is to cover it in a fabric the same color as the hat. Fabrics should be washed in Orvus W A Paste in water (3% w/v solution), rinsed with deionized water, and dried completely before being used.

The instructions provided here are suitable for many hats. However, since each object has its own unique needs, it may be necessary to experiment a bit, and use the following instructions as a jumping-off point rather than exact directions.

4. MOUNTS FOR HATS WITH LARGE CROWNS

Since head forms and mannequin heads are often small in size, a common problem is that the hat is too big for the head mount. The goal of this mount is to secure the hat through gentle pressure on the sweatband, as the hat was meant to be worn. The mount should provide enough stability that the hat will not slide down the mount over the course of the exhibition, but the pressure created by the mount should not be so much that it stretches or distorts the hat.

After assessing the hat’s condition to make sure it is sturdy enough to be mounted, determine the correct placement and angle on the head form through research and/or consulting with the curator of the exhibition. While holding the hat in place, mark its placement lightly and strategically on the head form with a pencil; an extra set of hands may helpful for this step. Lightly draw a line to mark where the sweatband should sit on the head. If the hat has a bow or other notable embellishments, mark a line on the form corresponding to its position. These elements can then be lined up to ensure the correct placement. If the surface of the head form does not allow for pencil marks, use small pieces of blue painter’s tape.

Next, look carefully at the shape of the hat’s opening. The shape of the mount will need to match that of the hat (i.e., if the hat opening is oval, the mount should be oval, too). Hold the hat in place on the bare head form and note where the gaps are; the padding on the mount will be placed to fill these areas.

4.1. BASIC MOUNT FOR HAT THAT IS SLIGHTLY LARGER THAN HEAD FORM

If a hat is only a little too big, and its interior, sweatband, and lining are sturdy, then it is a good candidate for the simplest mount, which uses only felt or Volara and double-sided tape. For sturdy hats with a sweatband in good condition, polyester felt works very well, providing cushion and tooth to keep the hat in place.
However, polyester felt is too abrasive for hats with fragile interiors or linings. For hats with more fragile interiors, this same technique can be used, but with Volara instead of felt, or the felt can be covered with a smooth fabric such as silk habutai using the methods described in section 4.2. The following instructions describe a mount made with felt.

Cut pieces of felt approximately the same width as the sweatband or a little wider. The pieces will be placed in correspondence with the gaps noted between the hat and the head form. It may not be necessary to pad the entire circumference of the head; it is often possible to achieve the proper fit with only one piece of felt on either side of the head. Smaller pieces can be added around the head or taken away to achieve the desired fit. Curved pieces will lie flatter against the mount than straight strips of felt. (fig. 3). Adhere the pieces of felt to the head with double-sided tape. Place the felt on the head form to line up with the hat’s sweatband.

With this type of mount, the crown of the hat often hovers above the top of the head form. If the crown of the hat needs to be supported, and the lining (or hat interior) is stable, soft archival tissue can be gently inserted into the hat crown before the hat is mounted on the head. It is important to make sure that the texture of the tissue is soft enough so as to not damage the hat interior. Never overstuff a hat, as this can cause permanent damage.

The padding for this mount system is thin enough that it is often hidden by the hat. Look at the hat at the height it will be displayed; consider the variety of points of view the visitors will have, and adjust the padding so it is hidden by the hat. Shadows from the hat may hide the padding enough that there is no need for a cover.
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fabric. Consider the placement of the hat in the exhibition design and keep in mind that gallery lighting will be different than work lighting.

4.2 MOUNT VARIATION FOR HAT THAT IS SIGNIFICANTLY LARGER THAN HEAD FORM

Some hats are much too large for the head mount, and one layer of padding is not enough to provide support. In these cases, Volara can be used in multiple layers to pad out the head form to the proper size and shape. Volara is a better choice for this mount variation because it is more rigid than felt, has a smooth surface, and can easily adhere to itself with double-sided tape.

Follow the steps listed in section 4.1 to determine hat placement, mark the head form, and examine the hat’s shape. Measure the hat’s interior sweatband circumference. Start adhering one long band or a few shorter bands of Volara around the head with double-sided tape until the shape and dimensions match the hat interior. The bands should be approximately the width of the sweatband. As mentioned above, the hat should be held on the mount through gentle pressure on the sweatband. Soft archival tissue can be used to support the crown, if appropriate.

Once the Volara mount has been built up enough to properly support the hat, it will likely be visible between the hat and the head form. A fabric cover can help the mount blend in with the hat.

When selecting a cover fabric, choose one that will match the color of the hat as closely as possible. The fabric should be lightweight so as to not add extra bulk to the mount, and it should also be smooth so that the hat can be placed on and taken off the mount easily. In the example in figure 4, a black cotton/polyester broadcloth was used. Very smooth fabrics such as silk habutai should be used for hats with fragile or damaged interiors.

Fig. 4. Mount with fabric cover for a hat that is larger than the head form. Crocker, Mourning hat, ca. 1916, silk, feathers, MMA 2009.300.1843. Brooklyn Museum Costume Collection at The Metropolitan Museum of Art, Gift of the Brooklyn Museum, 2009; Gift of Helen Ray in memory of Mr. and Mrs. William Ray and Miss M. Ray, 1951.
Once the fabric has been chosen and washed as described in section 3, cut a strip of fabric a couple inches wider than the sweatband and long enough to encircle the padded head mount. Create a casing on one of the long edges and insert a drawstring. Wrap the fabric around the head, positioning the drawstring just under the Volara, tie the drawstring near the center back, and tuck the strings behind the fabric. The fabric should cover all of the Volara. Carefully place the hat on the fabric covered mount to check that the material blends with the hat, and does not distract from the display of the object.

5. MOUNTS FOR HATS WITH SMALL CROWNS

Some hats, including many from the late 19th century, have small crowns that are not intended to fit over the head (fig. 5). These hats are challenging to mount on head forms that lack wigs or other stylized versions of
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hairstyles. For hats with small crowns, the mount acts as surrogate hair to support the hat from the crown interior (fig. 6). These mounts provide gentle positive pressure to the crown interior and can be attached to the head form at any angle.

5.1. BASIC MOUNT FOR HAT WITH SMALL CROWN

The basic version of a mount for a hat with a small crown is a ring of Volara made to match the height and circumference of the sweatband (fig. 7). The short ends of the Volara are cut with beveled edges and joined
with adhesive tape on the interior of the ring. Two pieces of twill tape are stitched to the bottom of the mount to form a cross, and double-sided tape is used to secure the twill tape to the head form. The Volara ring will conform to the oval shape of the hat and the twill tape will curve over the head form. If the hat has a relatively tall crown, the ring can be cut with a greater height than the sweatband. If the mount may become visible, the ring can be covered with fabric to match the color of the hat or head form.

5.2. VARIATION 1 WITH FULL CROWN SUPPORT

If the crown requires additional shape or support, the Volara ring can be filled with polyester batting (fig. 8). In this case, the mount should have a fabric cover that extends over the batting, in order to maintain
the shape of the batting and to keep it from coming in contact with the hat. For most mounts of this type, the fabric can be cut in an elongated rectangle the same length as the Volara and the height of the ring plus 4 in. to accommodate the batting.

First, the two short ends of the fabric are sewn together to form a ring. Next, one long side is folded over the bottom of the Volara ring and sewn in place. This creates a neat edge along the bottom of the mount. The top edge of the fabric can be folded over the batting and secured with tacking stitches; alternatively, a gathering stitch can be used to draw the fabric over the batting.

5.3. VARIATION 2 FOR HATS WITH SHALLOW OR IRREGULAR CROWNS

For hats with shallow or irregular crowns, it may not be possible to create a ring to match the sweatband (fig. 9). In these cases a modified system can be used. An oval of Volara is made to match the dimensions of
where the base of the crown meets the brim of the hat. If appropriate for the hat, a strip of Volara that matches a sloped side of the crown is stitched to the oval. Polyester batting is placed on the oval to create a mount that matches the contours of the crown interior; stitches may be needed to shape and secure the batting. The mount is covered with fabric to match the hat, with the edges turned under between the batting and the Volara; the bottom of the oval should be bare (fig. 10). For some hats, it is helpful to allow extra fullness in the fabric cover so that small folds of fabric can be arranged along the edge of the hat to help conceal the mount.
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Double-sided tape is used to attach the oval to the head form (fig. 11). The shape and gentle pressure of the mount are sufficient to secure the hat without pins.

6. DISCUSSION

Although these mounts can support a wide variety of hats, a few limiting factors are worth noting. These mounts were developed for relatively lightweight hats with short-term (three to six months) display. Different materials or mounts might be more suitable for hats of a greater weight or for long-term display. Also, the opaque materials for these mounts might prove distracting for hats made of translucent or transparent materials.

The mounts described in this article successfully provided stable placement for hats on bald head forms, or “egg heads,” without requiring pinning into the hats or drilling into the head forms. This article describes mounts that can be used for hats with crowns that are larger than the head form as well as mounts for hats with small crowns. These hat mounts are simple to construct, use materials that are readily available and relatively inexpensive, and allow the head form to be reused in future exhibitions.

SOURCES OF MATERIALS

Death Becomes Her hat mounts: custom-made by Bonaveri
   DK Display Corp
   147 West 25th Street
   New York, NY 10001
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Tel: (212) 807-0499
Fax: (212) 807-0860
www.dkdisplaycorp.com

*High Style* hat mounts: teardrop head forms
Bernstein Display
151 West 25th Street
New York, NY 10001
Tel: (212) 337-9578
Fax: (212) 337-9579
www.bernsteindisplay.com

3M 415 double-sided polyester film tape
ULINE
12575 Uline Drive
Pleasant Prairie, WI 53158
Tel: (800) 295-5510
Fax: (800) 295-5571
www.uline.com

Cotton twill tape
Twilltape.com
4847 Lake Forrest Drive
Atlanta GA 30342
Tel: (800) 876-4783
www.twilltape.com

Musetex polyester batting
Museum Services Corporation
385 Bridge point Way
South St. Paul, MN 55075
Tel: (651) 450-8954
Fax: (651) 554-9217
www.museumservicescorporation.com/index.html

Polyfelt liner, Volara polyethylene foam, and interleaving tissue
University Products
517 Main Street
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Tel: (800) 532-9281
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