

# **Objects Specialty Group Postprints**

## **Volume Thirteen**

**2006**



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**2006**

**Compiled by Virginia Greene, Patricia Griffin  
and Christine DeRe**

**Proceedings of the Objects Specialty Group Session  
June 19, 2006  
34th Annual Meeting  
Providence, Rhode Island**



**The American Institute for Conservation  
of Historic & Artistic Works**

This publication entitled *Objects Specialty Group Postprints, Volume Thirteen, 2006* is produced by the Objects Specialty Group of the American Institute for Conservation of Historic & Artistic Works.

Cover photograph by Joe Rogers, The Nelson-Atkins Museum of Art.

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This publication is primarily intended for the members of the Objects Specialty Group of the American Institute for Conservation of Historic & Artistic Works. Additional copies of this publication are available for purchase by contacting AIC.

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## FOREWORD

This is the 13<sup>th</sup> volume of *Postprints* published by the Objects Specialty Group (OSG). Collected here in print form are ten lectures and a poster presented at the OSG Session of the American Institute for Conservation Annual Meeting in Providence, Rhode Island, on June 19<sup>th</sup>, 2006. The theme for the session - *Mounts, Armatures, and Structural Repairs* - provided a forum for objects conservators to address the difficulties of repairing and safely supporting broken and fragile artifacts in any number of materials, sizes, and situations.

The range of subjects and problems presented at the meeting was remarkable. At one end of the spectrum, Scott Fulton presented mounting strategies for housing the tremendously fragile glass filaments composing Harvard University's collection of glass flowers. At the other, Tina March and Lisa Bruno discussed mounts and repairs on a series of massive gypsum Assyrian relief sculptures weighing several tons apiece.

Solutions for armatures, like mounts, were equally varied and innovative. Joe Rogers and Dale Benson described the complex engineering and construction hidden within a fragmented marble lion from ancient Greece, while Julia Lawson, Ellen Carrlee, and Howard Wellman addressed difficult and unconventional problems raised by reconstructing and stabilizing large, but compromised, archaeological objects.

Conservation treatments also ran the spectrum from the monumental to the microscopic: Michael Belman used innovative industrial materials to repair a giant Alexander Calder mobile, while in a poster by Anya McDavis-Conway *et alia*, consolidation of hair fibers was approached at the molecular level.

Functioning objects raise other ethical and practical problems. Steve Dykstra's solution to repairing the mechanisms in an 18<sup>th</sup>-century clock could only be documented using audio recordings and short films, while Gerri Strickler's stabilization of an experimental, site-specific figural sculpture required a multi-phased, multi-pronged approach. In the final presentation, Clara Deck's report on conservation of large industrial equipment drew together many of the issues raised throughout the day.

On behalf of the OSG, I extend my thanks to all participants in the 2006 session. The hard work of speakers, authors, and session organizers made this contribution to the profession an outstanding success, as did the support and feedback by conference attendees and OSG members. In particular, however, my deepest thanks are offered to Virginia Greene, Pat Griffin and Chris DelRe, *Postprints* editors, who together shepherded the text into press. They captured this sharing of knowledge for posterity - without that final effort all record of the achievement would be lost. Thank you.

Katie Holbrow, OSG Program Chair 2006

## **SEND THEM OUT OR KEEP THEM HERE? - THE DILEMMA OF LOANING HARVARD'S GLASS FLOWERS**

Scott E. Fulton and Susan M. Rossi-Wilcox

### **Abstract**

The year 2000 marked a milestone in the history of the Ware Collection of Blaschka Glass Models of Plants at Harvard University. This was the year that a selection of these intricate constructions, popularly known as *The Glass Flowers*, made a historic return trip to France, the first since their celebrated showing at the Paris Exposition of 1900.

This paper will present an overview of the history of the Glass Flowers and their creators; the materials, techniques and methods of fabrication; and a brief discussion of the conservation of the collection, before broaching the topic of traveling these objects. Aside from the inherent conservation challenges and unique packing problems presented by the fragile models, there were unavoidable issues of compromise and decision-making between collections manager, curator and conservator. This paper touches on one international venue, the 2000 French National Millennium exhibition *La Beauté* in Avignon, the problems faced in packing and transporting a select group of the Glass Flowers, the lessons learned, and the subsequent successful outcome.

### **The Creators and the Collection**

Around 1886 George Goodale, the director of the Botanic Garden of Harvard College, realized a need for an alternative to exhibiting perishable plants in the natural history museums being planned for Harvard University (Fig. 1). It was at this time that Goodale became familiar with the well known glasswork of Leopold and Rudolf Blaschka, a father and son lampworking team of Dresden, and their precise reproductions of invertebrates. Inspired by what glass could bring to a collection of botanic models for his department, he invited the Blaschkas to take on a small commission. The first group of models arrived in Boston later that year. Ultimately, the commission continued for 50 years, with the last models received at Harvard University in 1936. Currently about three-quarters of over 4300 individual models are on permanent exhibition in the Harvard Museum of Natural History, and the remaining portion is in storage awaiting various degrees of conservation treatment.

Initially, when Harvard's museum collections were used for teaching, the models served to supplement plant dissection in the botany labs. Today the Botanical Museum collections are no longer used for teaching, especially as the emphasis in teaching botany has changed from the classification of organisms to one weighted in favor of genetics and molecular analysis. The function of the Glass Flowers as a collection also necessarily changed from being thought of as a set of teaching tools that were potentially

replaceable, to becoming a world renowned tourist attraction possessing intrinsic value as irreplaceable art objects. In effect, they became emblematic treasures of the Botanical Museum and, in the context of an international exhibition such as *La Beauté*, they served as ambassadors for Harvard University (Piechota 2006).



Figure 1. *Centaurea cyanus*, Bachelor Button with moth #761 (1913).

### Materials and Techniques of Fabrication

With little information on the Blaschkas' working methods available in the archival record, the major portion of our understanding of their techniques comes from consulting with present day flame-workers and glass specialists. Not surprisingly, the models were created from a combination of organic and inorganic materials. Leopold and Rudolf Blaschka used their knowledge of jewelry making to produce a copper wire understructure. Like a necklace, sections of glass tubing were fashioned into the likeness of stems and branches that were strung like beads on a central armature. The leaves and flower parts typically have a wire that is fused to the base with frit or glue and fed into the hollow of the stem piece (glass tubing) where the part was held in place with animal glue or flame-worked with glass frit (Fig. 2 a, b).

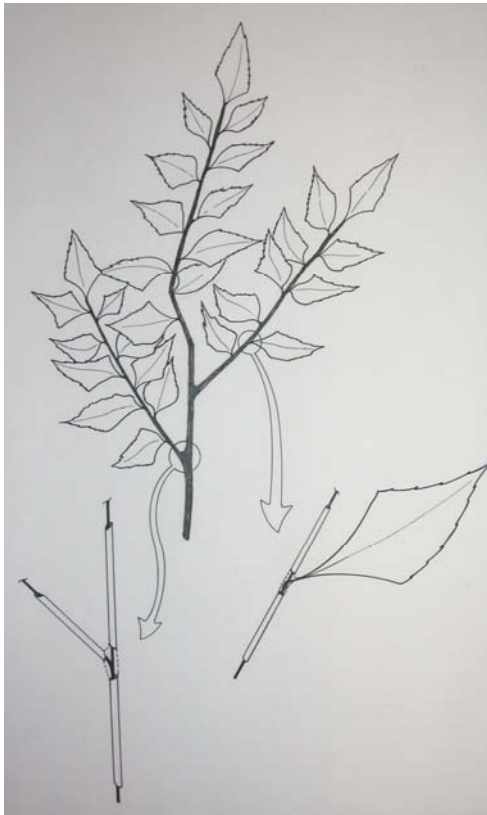


Figure 2a (left). Schematic drawing showing techniques of construction.  
Figure 2b (right). *Gentiana andrewsii*, Closed gentian #282 (1892).

For the most part, the Blaschkas' early work used clear commercial glasses to create the model parts. The reflective glassy surfaces were reduced with coatings of animal glue, gum Arabic, or other applied varnish. Paint and organic binders were used to show details like venation on leaves, pubescence on stems, or bark on branches, particularly on the early models (Fig. 3).



Figure 3. *Phyllitis scolopendrium*,  
Hart's tongue fern #710 (1903).

Over the decades, many of the Blaschkas' techniques and colorants changed dramatically (Fig. 4). From archival records we know that Rudolf Blaschka was interested in developing workable red-colored glasses to replace fugitive red pigments used on the earlier models (Pitman 1994). At the beginning of the 20<sup>th</sup> c. he began experimenting with home-manufacturing of small batches and, by 1906, he was using a six-crucible iron furnace specially designed for his home studio. A blueprint of the furnace, books on glass formulas, his correspondence, and glass cullet he left behind testify to his experimental zeal and his varied successes and failures (Fig. 5). Ultimately, he created well over one hundred colored glasses in roughly half-pound batches or smaller. Many of these were opaque greens, yellows, and reds that captured the subtle nuance of shades necessary for reproducing various leaves, flowers, fruits, and insects. These colored glasses were softened, stretched or blown into their base-forms, or crushed into enamel slurries that were fused in the flame for realistic surface detail. Rudolf Blaschka's experimental work was so successful that by 1928, when Mary Lee Ware, the financial benefactor, visited him, she reported in her October 3<sup>rd</sup> letter from Dresden that he was making "a large part of the glass and all of the enamels, which he powders to use as paint" (Ware, 1923).



Figure 4. *Erythrina crista-galli*, Cockscomb #104 (1889).



Figure 5. Rudolf Blaschka's glass cullet, ca.1913.



### Condition, Conservation and Preservation

The Blaschkas' early techniques worked well for over a decade of botanical model making, but many of the thin broad leaves and petals of the earlier models (pre-1895) were not stable over time. They are prone to de-lamination and splitting as a result of shrinkage of a problematic surface coating identified as animal skin glue (McNally and Buschini 1993) that is known to be dimensionally unstable in fluctuating environments (Fig. 6). To date, nearly 30 sets of models have been removed from exhibit because of this ongoing deterioration.



Figure 6. Cactus leaf showing surface delamination of the glass caused by shrinkage of animal glue coating.

With the passage of time, even some of the glass formulas used after the turn of the 20<sup>th</sup> C. have become unstable and opaque discoloration on some parts (Fig. 7). Over the years, broad seasonal changes in the gallery environment have exacerbated the problem by providing favorable conditions for this slow but steady degradation process. This visual change can be explained as the re-crystallization of hygroscopic constituents in the glass, mostly lead compounds, that now appear as a whitish efflorescence (Pantano et al, 1998). Out of approximately 250, about 64 models from Rudolf Blaschka's later work are affected with this condition (Fig. 8). Initially, an accurate identification of glass corrosion was impeded because the models were created to depict stages of fungal disease in common orchard fruits such as apples and pears. The purposefully rendered "blights" appeared similar to corrosion-related efflorescence, and the true cause was only realized later when healthy fruit were recognized as being affected by the same efflorescence phenomenon.



Figure 7. *Malus pumila*, Apple #609 (1933), closeup showing lead salts efflorescence.



Figure 8. Blaschka's "diseased" fruiting branch, *Malus pumila*, Apple #813 (1932).

To better understand the Blaschkas' work methods and glass formulations, several projects have been undertaken to analyze the material characteristics affecting the collection. In 1991, conservators from the Center for Conservation and Technical Studies, Harvard University Art

Museums, undertook the first conservation survey of the Glass Flowers (McNally and Buschini 1993). Their seminal study included technical analysis of the materials used to make the models, environmental recommendations, and conservation treatment proposals for a select group of the models. Their investigative groundwork confirmed several details related to the Glass Flower's structural and chemical stability:

- The glass used was a binary alkali “soda” glass commercially made w/ silica, sodium and a smaller amount of potassium.
- Pre-1895 glasses were cold-painted and varnished w/ various organic binders and coatings to create realistic effects (with some overlap into post-1895).
- Post- 1895 models are generally characterized by experimentation with colored glasses and lead glass enamels using various metal oxides as colorants.
- A number of adhesives were identified ranging from the original use of animal glues, to cellulose nitrate and more modern adhesives used for repairs.

Later compositional analysis by the Botanical Museum using EDS-microprobe and XRD further contributed to an understanding of the changes in palette and materials used over a 50 year span (Pantano et al 1998). A parallel (unpublished) study in 1995 by Timothy S. Hughes at Pennsylvania State University using a hot-stage microscope, helped to correlate some of the original glass formulas used and their associated glass-transition temperatures (Hughes 1995). In 1998, a comprehensive condition survey was undertaken in conjunction with the Peabody Museum Conservation Department and an outside conservation consultant. Ultimately, the survey became useful as a background checklist for determining their suitability for traveling.

### **Traveling the collection**

Given the fragile nature of this collection, loans have always been of utmost concern. The original packing design from the late 1880's included materials that by our current standards would be considered inferior, including acidic paper- pulp board, cork and crumpled tissue paper. Although the archives do not mention any specific damage or loss in shipment, virtually the same packing methods and materials were used repeatedly for 50 years (Fig. 9 a, b). There is no way of knowing, but the Blaschkas and their clients at the time may have held in common a somewhat post-industrial attitude about the shipping of what were seen as replaceable objects, a view different from that of museums. Tacitly, they may have agreed, for instance, that 5-10% breakage was an acceptable loss and priced the models accordingly.

The primary conveyance from Germany to America between 1886 and 1935 was by ocean-going freighter. One can use one's imagination with regard to the bone-jarring transport preceding the voyage, including horse-drawn carts over rough roads, followed by rail cargo to a port, and then loading by hand into the cargo hold of a ship. Undoubtedly, en-route across the Atlantic, conditions in the hold would have produced massive low-frequency vibration from the ship's turbines for durations up to a week. Although the Blaschkas typically shipped the models during seasons when the seas were calmer, the exposure to shock from rough waters was also a reality.





Figure 9a. Original packing ca. 1890's (a).



Figure 9b. Original packing ca. 1890's (b).

Sending examples of the Glass Flowers to France in 2000 offered a unique opportunity to broaden public exposure for an international audience. The loan was a noteworthy event in the history of the Glass Flowers because it marked the 100<sup>th</sup> anniversary since they first traveled to France. In the life-time of the collection, only a small selection of models have been loaned since they were first commissioned in 1886. The venues included the 1893 World's Columbian Exposition in Chicago, the Paris Exposition of 1900, and the 1904 Louisiana Purchase Exposition in St. Louis. Three other significant loans of the Glass Flowers were granted more recently,

including a 1991 exhibit at the Corning Museum of Glass, the 10th anniversary exhibition at the Andy Warhol Museum in Pittsburgh (2005), and, as addressed in this paper, the extravagant Millennium exhibition in Avignon. Because of the complex issues (variations of size, weight, shape) involved in packing twenty Blaschka glass models for air-travel, preparations and packing design of necessity involved close collaboration between conservator and art packaging professionals.

The challenges faced in taking the loan to Avignon are not entirely comparable to conditions surrounding the historic journeys by ocean-going freighter, but they are not necessarily less risky for the models, including:

- High frequency vibrations of jet travel.
- Sudden drops and jerks in landing and by way of airport fork lifts.
- 500 miles of overland truck travel from Paris to Avignon.
- Unloading at Avignon with the rigors of trundling across cobblestone to the inner sanctum of the Palace complex.
- Unexpected circumstances including the absence of a freight elevator to the exhibit area, one flight below a winding staircase.
- The reality of a two-way shipment with the repetition of similar conditions on the return trip.

### Criteria for Lending

A standard for lending the Glass Flowers was designed to exempt the most significant and fragile models from the loan. Only the more stable specimens whose physical condition and chemistry were better understood were considered as possible candidates. These criteria were developed by both the administrator for the Glass Flowers and the project conservator, with further input from the curator and exhibit designer which influenced the final selection.

In consideration of the didactic value of the collection and the possibility of damage or loss, the chosen models needed to be well represented by species or genera in the rest of the collection. In addition:

- Travel mounts for the models had to double as exhibit mounts to minimize handling risks and to simplify installation.
- The models chosen had to be of relatively simple construction with low weight-mass and with few elevated or extended parts that would be subject to flexing en-route.
- Stabilization treatments had to be straight-forward; repairs would ideally contribute to an evolving methodology of treatment procedures and materials for the collection.

In preparation for the loan to *La Beauté*, basic conservation treatments for the chosen set of models ranged from a light dusting with a soft brush, to reattaching a separated part, in-painting disfiguring old repairs, or, for one model, replacing an element of missing glass with pigmented Japanese tissue to reintegrate an obvious void (Fig. 10).



Figure 10. *Lathyrus magellanicus*, Lord Anson's Blue Pea #144 (1890) during treatment.

### Packing for Avignon

The models were mounted on travel pallets made of black Gatorfoam, which doubled as exhibit mounts with the models already secured in position. For additional support, small individual cushions were cut from black Plastizote and were attached to the pallet, under the models, at strategic points. A stem, for example, may have required three or more small, carefully placed cushions under the tie-down points to bolster and cradle the model against movement. The positions of the mounting wires were marked and holes were drilled with a flexible shaft drill (Fig. 11). These primary and permanent foam supports were tacked in place with hot-melt glue. Silicone tubing covered the wires to protect the model while it was secured to the pallet.



Figure 11. Packing design and travel mounts: drilling holes in foam-core for wires.



A secondary series of removable foam supports and pillows made of high-density polyethylene sheet filled with polyester batting were tailored to fit under the parts that projected from the body of the model (Fig. 12). These temporary supports were placed at the vulnerable points to provide additional cushioning. Each support was numbered using color-coded dots. The exact positions of the supports were documented using photographs to aid in repacking the models for the return trip (Fig.13). Small pieces of double-sided archival tape held the pillows and supports in place while traveling, but were easily removed without damaging the surface of the pallet surface at the time of installation.

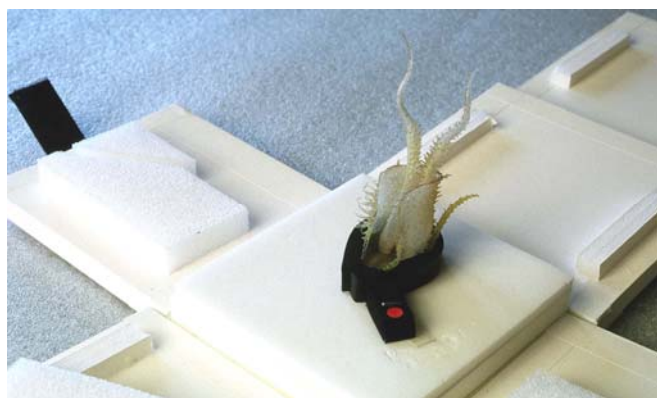


Figure 12. *Passiflora caerulea* L., Passion Flower #775 (1923), detail of “pillow” supports.

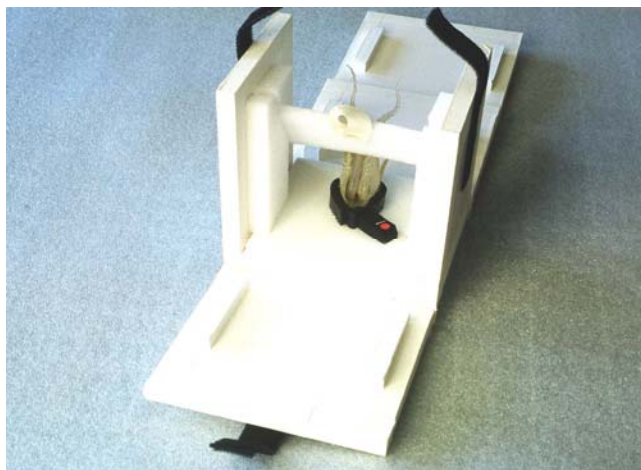


Figure 13. *Utricularia purpurea*, Purple bladderwort #638 (1898), close-up of documentation method using red labels and foam supports.

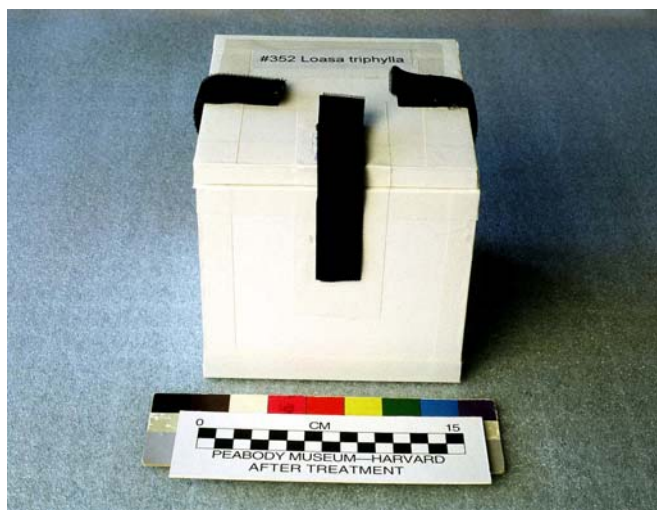
Working in collaboration with Fine Arts Express of Boston, the overall packing design was based on the principle of double-crating. It was intended that the objects would be supported in an inner crate that was in turn cushioned against shock and vibration by the outer crate, using separate foams of differing densities. The inner crates utilized housings of Gatorfoam board lined with Ethafoam 220 polyethylene foam sheet. These were designed to accommodate the pallets to which each model was secured. Most of the inner boxes held a single life-size plant model on a pallet, but several contained small models of plant parts or custom-designed housings for odd-shaped models (Fig.14 a - d).



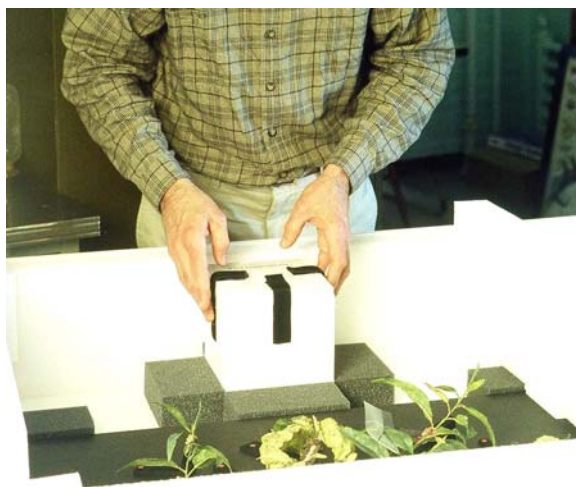
a.



b.



c.



d.

Figure 14a-d. Four steps in the packing of a magnified plant part, *Laosa triphylla*, #352 (1893).

The two outer crates were of uniform size and designed to be front-loaded to allow efficient access to each of the drawer-like inner boxes when the front panel was removed. At the corners and on the sides of a crate, blocks of urethane foam were glued in position to snugly cushion the load and to prevent movement of the inner packing crates (Fig. 15).



Figure 15. Outer crate showing interior foam cushioning.

### **Conclusion: Managing risk against the benefits of exhibition**

From the beginning of the loan review period, it was understood that there was a significant degree of risk involved with this loan. It was acknowledged that minor unexpected damage was likely to occur, and, despite our concerted efforts to prevent it, ultimately some damage did happen. There were isolated small losses of painted surface detail on select models, probably from high-frequency vibration in-flight; and there were two failures of old glue joins of leaves to a stem. With this, fortunately, there was no collateral damage and the model was repaired on-site in Avignon (Fig. 16).



Figure 16. *Prunus persica*, Peach #798 (1929), detail of repair.

Damage resulting from loans can sometimes be difficult to characterize, let alone identify, and there are many questions that need discussion:

- How do we define damage?
- To what degree is alteration of the original considered acceptable?
- At what point do pigments or particulates left behind on packing materials alter an object's identity?
- Can we accept some damage if the object doesn't appear different?

In anticipation of lending a fragile collection, the dilemma to loan or not between the lender and the borrower, is collectively shared and, unavoidably, becomes an exercise in compromise for each. Responsible risk management often requires finding the middle ground and, if managed well, the risks will be off-set by the benefits gained in introducing the collection to a broader public.

### **Acknowledgements**

The authors are indebted to numerous colleagues whose participation over the years significantly contributed to our understanding of the conservation needs of this unique collection, including: Henry Lie, Rika Smith McNally and Nancy Buschini Lloyd of the Straus Center for Conservation and Technical Studies, Harvard University, for the seminal conservation survey of the Glass Flowers; David Lange for his microprobe work and the late Lawrence C. Pitman Harvard Department of Earth and Planetary Sciences, who analyzed the non-glassy materials; Don Pfister, then the Director of the Botanical Museum – Harvard University Herbaria and T. Rose Holdcraft, Administrative Head of Conservation at the Peabody Museum Conservation Department for their helpful input. We are also indebted to Hillel Burger for his photographs and Wayne Meyer for the schematic drawing of glass model construction; Carlo Pantano, Director of the Materials Research Institute, Pennsylvania State University, who analyzed the data and generously advised on issues related to glass chemistry; Dennis Piechota, private conservator, for in-depth discussions on the physics of package design; John Bailey of Fine Arts Express, Boston, for the design and construction of the packing crates for the trip to France; Brian Waldron of Masterpiece International of Boston and his French counterparts at Andre Chenue S.A. who led us through the travel maze; Esther Chao and Liza Leto Fulton, whose editing and digital management skills added finishing touches to this presentation; and lastly to our French colleagues Jean de Loisy, Commissaire General of “*La Beauté*” and Yves Le Fur, Curator, whose vision included Harvard's Glass Flowers.

### **Suppliers**

Gatorfoam:

Charrette Office Supply, P.O. Box 4010, Woburn, MA 01888-4010, (800) 367-3729

Paraloid B-72:

Conservator's Emporium, 100 Standing Rock Circle, Reno, NV 89511, (775) 852-0404

Hand tools, brushes:

Talas, 20 West 20<sup>th</sup> Street, New York, NY 10011, (212) 219-0770

Ethafoam, Plastizote:

United Foam Plastics, 172 E. Main Street, Georgetown, MA 01833, (978) 352-2200

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## **48 PIECES: REASSEMBLY OF AN ANCIENT GREEK MARBLE LION USING AN INTERNAL ARMATURE WITH REVERSIBLE MECHANICAL COMPONENTS**

Joe Rogers and Dale Benson

### **1. Abstract**

Purchased for the 1933 opening of The Nelson-Atkins Museum of Art in Kansas City, Missouri, the *Attic Lion* is considered one of the finest sculptures in the Museum's antiquities collection. Carved from white Pentelic marble, the sculpture was used as a funerary object to protect the dead and stands an impressive 46 inches in height, 82 inches in length and weighs 3,006 pounds. Dating to 325 B.C., the life-size sculpture arrived in Kansas City after being "repaired" from recently found fragments near Athens. Unfortunately, during a gallery renovation in 1993, it was discovered that large sections of the sculpture were beginning to separate. After careful examination and extensive gamma-radiography, it was determined that internal pressure from corroding iron supports held with plaster of Paris used in the previous restoration was contributing to the problem. A complete disassembly of the 48 pieces was necessary to stabilize the sculpture by removing iron supports.

Key objectives of the treatment were: disassemble the sculpture and remove the corroding internal iron armature used in the previous restoration; develop an internal stainless steel armature to hold the three largest fragments of the sculpture together using compression forces rather than difficult to reverse structural adhesives, avoid drilling new holes; and eliminate an external, visually obtrusive mount that ran from the torso to the base. Most importantly all the new repairs should be as reversible as possible. With the assistance of a mechanical engineer a unique, adjustable, reversible armature incorporating compression cramps and threaded tie bars was developed to bring the stone surfaces together for maximum surface to surface contact. Even with fragments weighing in excess of 1,100 lbs, the internal armature and adhesive now support the massive amount of weight, offering tremendous shear and tensile strength.

### **2. Introduction**

*Mr. Rosen tells me that he cannot make an estimate for repairing the Lion without seeing it, but does not think it would cost more than Two to Three Hundred Dollars. It has to be set together with bronze dowels, as iron or steel would rust and split the marble, and the missing part of the legs will have to be carefully modeled in plaster and a pedestal made.*

When purchased in 1933 from antiquities dealer Joseph Brummer the sculpture had already been restored, as noted in the Nelson-Atkin Museum archives. These few words are the only reference to this restoration. They were written on May 7, 1932, (eleven months before the Museum's purchase) by Harold Woodbury Parsons, Art Adviser to the Museum, and addressed to Mr. J. C. Nichols, Trustee of the William Rockhill Nelson Trust.



Figure 1. Image of Attic Lion during original gallery installation.

For nearly sixty years after the purchase the sculpture was prominently displayed in the center of the Museum's "Classical Hall" becoming the symbol of the institution with its image on everything from the cover of the Museum Handbook to library bookplates (Fig. 1).

In 1992 major gallery renovations were proposed for the entire west wing on the first floor of the Museum. The directive to the Conservation department was to move the *Attic Lion* because it was out of place chronologically.

In February 1993, Objects Conservators Kate Garland and Paul Benson began an extensive examination of the sculpture. Gamma-radiographs were taken revealing a corroded internal iron armature (Fig. 2) [1]. During the restoration of the sculpture in 1932 the internal iron armatures were used in combination with plaster of Paris. Direct exposure to moisture from the plaster caused extensive corrosion products to form on the iron armature.

The examination also revealed movement between two larger fragments of the sculpture. This was attributed to the expansion of the iron corrosion products on the armature exerting an outward force on the joint. Consulting structural engineer Tom Heausler of Burns and McDonnell, Inc. expressed concern that moving the sculpture in its current state with a weakened internal armature could lead to the possibility of collapse during the move to storage.

It was determined that there was simply no way to lift or move the sculpture whole without great risk of further damage. After nearly sixty years of rusting iron, gravity, brittle plaster, poor assembly and display techniques the sculpture could no longer be safely moved, prompting an extensive conservation treatment.

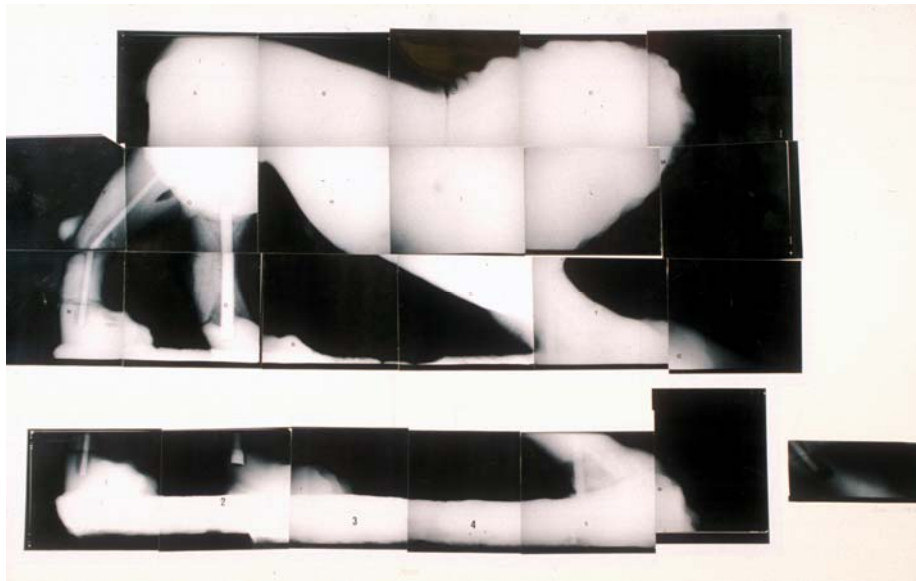


Figure 2. Photographic montage of Gamma-radiographs showing internal armature of rear legs.

### 3. Disassembly

During the 1932 restoration, plaster of Paris was used extensively. It was used to hold the iron armature in place, as an adhesive at the interface of all large fragments, as well as a fill material for losses on the surface of the sculpture.

During the disassembly in 1993, the sculpture was separated at the fractures by gently removing the plaster of Paris fills with scalpels, fine chisels, and dental tools. This allowed access to the iron armatures which were cut (using a hand-held metal cutting hacksaw) to facilitate the disassembly process. The sculpture was carefully supported with a system of padded nylon straps, chain hoists, and a large steel gantry to support and lift the weight of the sculpture (Figs. 3, 4). The fills were softened with distilled water which allowed easy distinction between fill material and Pentelic marble. Care was taken to prevent the distilled water from remaining in prolonged contact with the surface of the stone which could possibly affect the archeological patina.



Figure 3. Kate Garland and Paul Benson removing fill material during disassembly.



Figure 4. Exposed iron armature on proper left side of sculpture base.

After all of the fragments were disassembled, a small amount of dilute (20%) Paraloid B-72 in acetone was applied to the reverse of each fragment. The designated letter of each fragment was applied on top of the B-72 with a Pigma Micron marker.

During disassembly the most startling discovery was that no archeological patina existed on the interface of the marble fragments of the sculpture. The only archeological patina on an interface was on the rear legs, the top of each foot, and between both sections of the sculpture base.

It is probably safe to assume that the sculpture was broken into smaller fragments at the time it was found near Athens to help facilitate in the transportation of such a heavy object (Fig. 5).

During the disassembly a 1 1/4" diameter hole was discovered drilled almost completely through the sculpture on the proper left side. All of the large fractures radiate from this one central point (Fig. 6). It appears likely that the entire body, head and front legs remained whole and intact from antiquity until the very recent past.



Figure 5. After complete disassembly, fragments ranging in size from a few ounces to over eleven-hundred pounds.

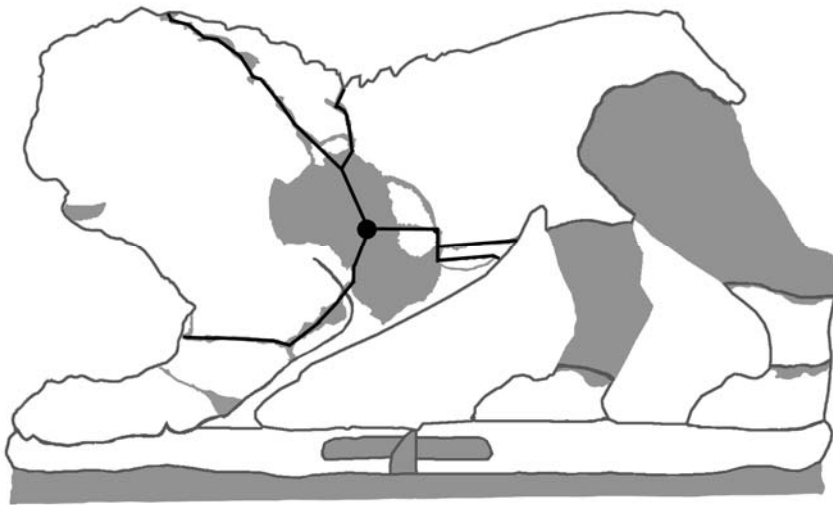


Figure 6. Diagram of major fractures radiating outward from the 1 1/4" hole drilled in proper left side.

#### 4. Structural Adhesive Methodology

Three modern synthetic resins were selected after testing. Each resin has different working properties and adhesive strengths which make it appropriate for use in different locations during the reassembly process. Paraloid B-72, 1:1 w/w in acetone, with an average strength of 214 psi



in shear tests (Podany, Garland, Freeman and Rogers 2001) and the most reversible of the three adhesives, was used to attach most of the small fragments.

The second adhesive system is a combination of Paraloid B-72, 22% w/v in acetone and Akemi polyester resin. Akemi has an average strength of 595 psi in shear tests. In this instance, the Paraloid B-72 was applied not as an adhesive, but as a barrier applied to both interfaces of the joint prior to the introduction of the Akemi polyester resin. The B-72 offers a more reversible interface between the polyester resin and Pentelic marble

Araldite AY103 resin with HY991 hardener was used as the structural adhesive at joints that were under tremendous shear and tensile loading. No barrier was used at joints that were under these conditions. Araldite AY103 resin with HY991 has an average strength of 688 psi in shear tests.

## 5. Reassembly of Sculpture

The key treatment objective of reversibility guided the reassembly process and led to the development of a unique adjustable armature incorporating compressive forces while minimizing the use of structural adhesives. When structural adhesives were required, they were placed near the outer edges of fractures to limit the distance solvent or solvent vapors would have to migrate to soften the adhesive during any possible future treatment (Fig. 7).

The authors would like to acknowledge the significant contributions of consulting mechanical engineer William R. Freeman during the reassembly of the *Attic Lion*. His knowledge of materials, interesting ideas, and important calculations were invaluable to the success of this project. The importance of proper engineering for projects of this kind cannot be overestimated. In many instances time and money was saved by not over-building the armature or applying too much adhesive. At the same time the armature was built with the proper tolerances ensuring stability for many years to come.

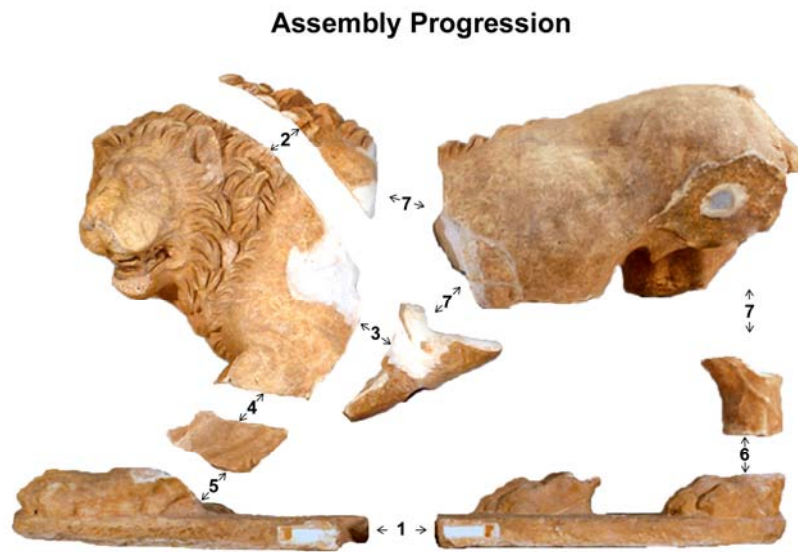


Figure 7. Exploded view of sculpture showing reassembly progression

### 5.1 Mounting Pallet

To facilitate any future relocation, a heavy gauge mounting pallet was designed and constructed to act as a foundation on which the entire sculpture could be assembled and attached. The mounting pallet was designed by consulting engineer Freeman to allow the sculpture to be lifted and moved while never placing undue stress on the sculpture. The mounting pallet was engineered with sufficient rigidity not to bend or torque during lifting and movement of the sculpture.

Starting with a ground up approach, both fragments of the sculpture base were attached to the mounting pallet (see section 5.2). The bottom surfaces of both marble fragments are smoothly carved but the thickness varies by 1 1/4" from side to side. It is not clear if the varying thickness was intentionally done by the artist or if it was a by-product of the carving process. If placed on a level surface, the uneven thickness of the marble sculpture base would cause the sculpture to lean to the proper left approximately 12 degrees. A curatorial decision was made to mount and present the sculpture vertical or plumb. Originally the base of the sculpture may have rested inside another larger marble block and was leveled by a bed of gravel or sand beneath the sculpture.

### 5.2 Mechanical Leveling Devices

A system of mechanical leveling devices was developed to attach both fragments of the sculpture base to the mounting pallet. Consisting of stainless steel coupling nuts, 1/4" threaded rods and

washers, the leveling devices allowed the two fragments of the sculpture base to be adjusted to compensate for the varying thickness of the fragments.

A dry masonry core bit was used to drill seven new 5/8" diameter holes into the bottom of both marble fragments, which were then cleaned with acetone. A barrier layer of Paraloid B-72 in acetone was applied to the interior of each hole and allowed to dry overnight. 316 stainless steel 1/4"-20 coupling nuts were adhered into each hole with Akemi Clear Flowing Polyester resin (Fig. 8).

Both fragments of the sculpture base were placed on the mounting pallet. The top surfaces of both fragments were adjusted and leveled with wooden shims. The sculpture base was removed and holes corresponding to the coupling nuts in the bottom of the sculpture base were drilled through the 1/4" thick plate steel on top of the mounting pallet.

A double layer of Parafilm [2] was attached to the bottom of the sculpture base. As the Parafilm was heated with a hot air gun it became lightly tacky. It was pushed into contact with the surface of the stone with a stiff natural bristle brush and allowed to cool. The Parafilm created a barrier between the stone and the bedding material.

Both fragments of the base were returned to the mounting pallet with the shims still in place on the pallet. The 1/4" diameter threaded rods were inserted from underneath the pallet and through the 1/4" steel plate and threaded into the new stainless coupling nuts in the sculpture base.

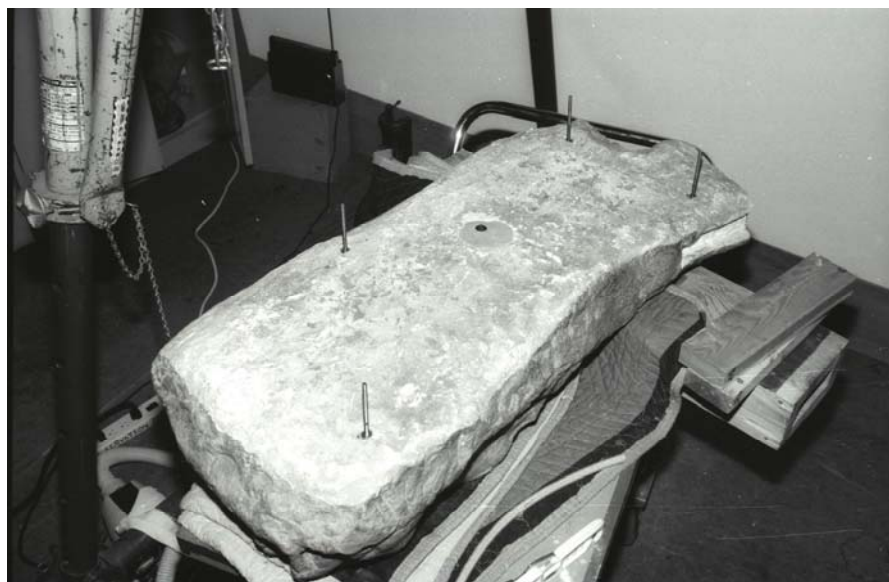


Figure 8. Leveling rods extending from coupling nuts in bottom of sculpture base.

Nuts and washers, used to adjust and level both fragments independently, were threaded onto the rods at the same time and were placed in contact with the top surface of the mounting pallet.



The wooden shims were then removed. The leveling rods were lowered back to their previously determined height and were locked into place with additional jam nuts underneath the 1/4" steel plate on top of the pallet, leaving the marble fragments level on the pallet.

### 5.3 Bedding Material

At this point both fragments of the sculpture base were literally suspended above the top of the pallet and secured in place by the seven vertical leveling threaded rods. This system worked well to adjust and level both sections, but offered no support between the leveling rods.

To create even support between the pallet and the bottom of the sculpture and to conform to the uneven, irregular surface of the bottom of both fragments, a bedding material was needed. Sonogrout 10K Shrinkage-Compensated Nonmetallic High Strength Grout was chosen because of the working properties of the product and, after curing, the loss volume due to shrinkage was less than .08 percent. The Sonogrout was mixed with water to a dry stiff consistency and applied. Small wooden forms were made to fit in the space between the sculpture base and pallet to contain the grout as it was being compressed into place with a wooden tamping tool. Care was taken not to tear the layer of Parafilm during this process.

Small Ethafoam forms were placed around each leveling rod and bolt prior to application of the Sonogrout. The Ethafoam prevented the leveling rods from being encased in the Sonogrout and restricting any further adjustment or removal of the leveling rods in the future (Fig. 9).

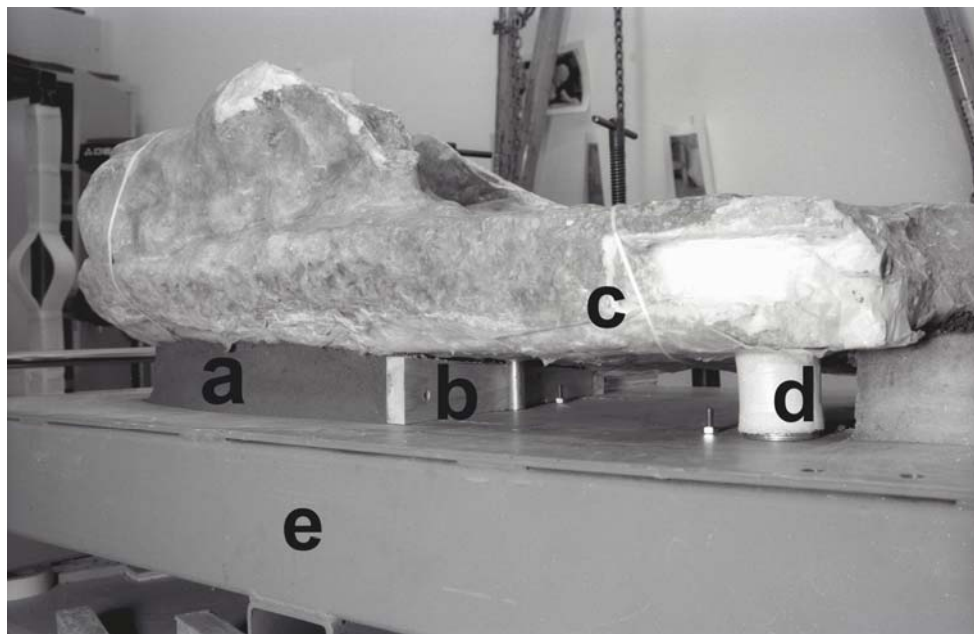


Figure 9. (a) Sonogrout bedding material; (b) Wooden form allowing bedding material to be compressed; (c) Parafilm barrier (d) Ethafoam form surrounding threaded leveling rod; (e) Steel pallet.

## 5.4 Support Frames

It was decided that the head and hind-quarters fragments of the sculpture should be supported by a steel support frame during the re-assembly process. The support frame was believed to have several advantages over a traditional gantry and chain hoist lifting system. The steel support frame was in two separate parts to allow independent movement of each large fragment by the use of the wheels.

The height and angle of each fragment of the sculpture could be adjusted when needed and maintained for extended periods of time. The frames were designed to allow limited but critical independent lateral adjustments of each section during the alignment process. The support frame offered rigid support and restricted movement during the times that the adhesives cured. The framework was fabricated of H: 3" x W: 2" x 1/8" wall, mild steel square tubing (Figs. 10 and 11). The framework was designed and engineered by Freeman.

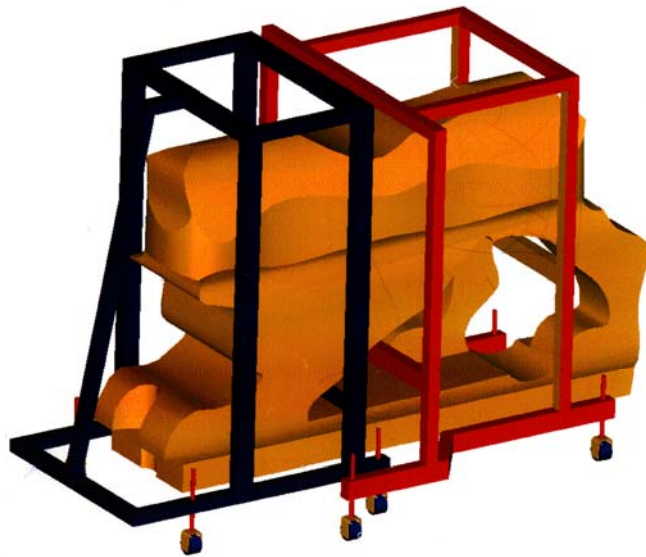


Figure 10. CAD generated drawings of support frames provided through Allied Signal's Technical Assistance Program which donated the design and engineering services during the treatment of the sculpture.



Figure 11. Support frames.

It became apparent during the preparation to attach the head and front legs to the sculpture base that the internal support for the front proper left leg and foot would have different structural requirements than those needed for the front proper right leg. The internal support would need to span the distance of the fragment of the lower leg (Fig. 15). The stainless steel tubing (Fig. 16) was inserted through the lower leg like a pearl threaded onto a string while the weight was borne by the upper portion of the leg and foot of the sculpture to prevent the lower leg from being crushed. Calculations made by the consulting structural engineer required removal of original material, taking into account the shear and tensile loading of the interface. Existing holes were deepened to provide more surface to surface contact between the internal support and stone.

### 5.5 Reassembly of the Head and Front Legs

To improve reversibility, a pin-and-sleeve armature (Figs. 12 and 13) was used to align the head and front legs. The pin-and-sleeve eliminated the need for adhesive in the center of a large marble interface (15 x 20 inches) making future reversibility less problematic. Adhesive was used in combination with the pin-and sleeve but only at four 2" diameter areas around the outer edge of the marble interface. These locations will limit the distance that the solvent or solvent vapor will have to migrate to soften the adhesive during any future treatment. The Araldite Epoxy Resin AY103 and HY991 hardener with the addition of fumed silica used as a bulking agent was used to make a thick paste [3]. Because of the weight of the head (1,115 lbs) and the shear stress created by the 25-degree angle of the marble interface, a barrier of B-72 was not used in this structural adhesive bond. Araldite AY103 with HY991 hardener has a strength of 2,300 PSI at 68 degF. Four 2" diameter areas of Araldite will yield 12.50 square inches of surface area of adhesive contact.

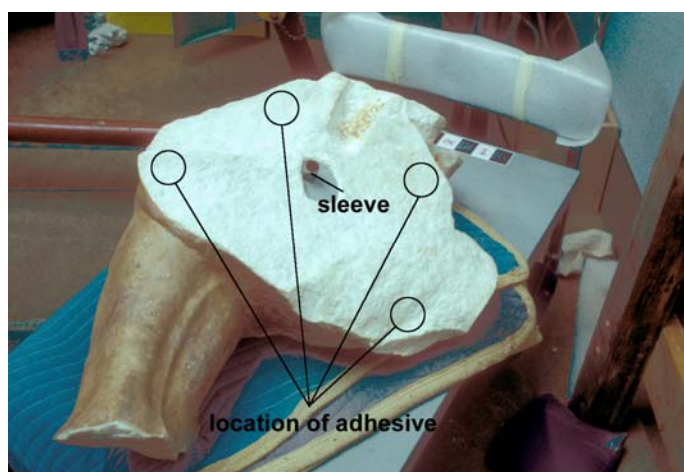
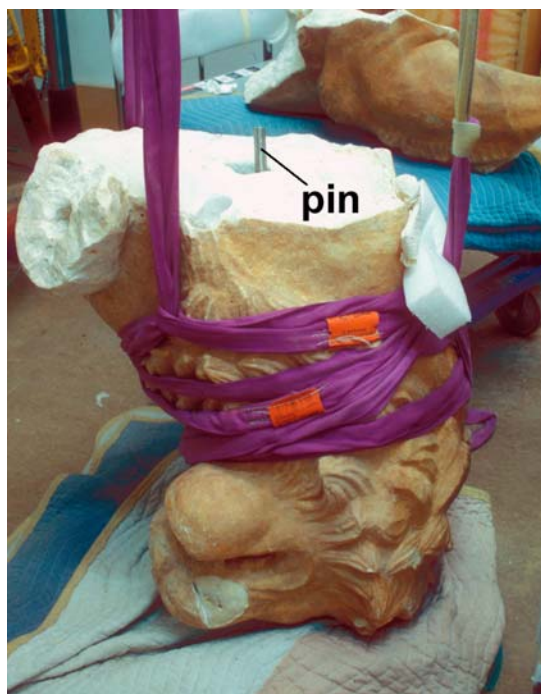


Figure 12 (left). Pin extending beyond break to be inserted into sleeve in Figure 13.

Figure 13 (right). Sleeve located in previously existing hole with Pliacre fill material surrounding sleeve. Circles indicate location of adhesive.

## 5.6 Modified Internal Front Leg Supports

It was decided that the interface of the front proper right foot and leg (Fig. 14) should be the focus during the alignment and registration process between the body and base of the sculpture. When the fragments were aligned during a dry run, there was good topographical registration at the marble interface. The correct alignment of this join would determine the alignment of all other major fractures.

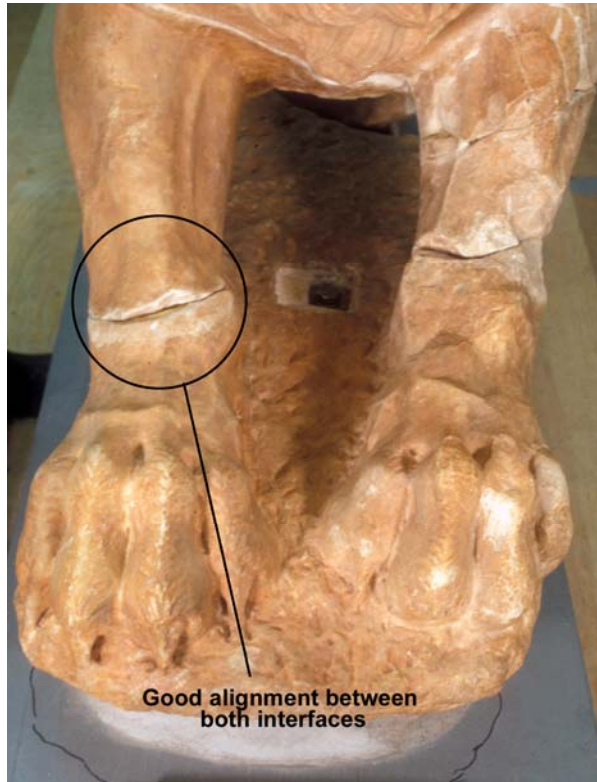


Figure 14. Interface between proper right leg and foot.

It became apparent during the preparation to attach the head and front legs to the sculpture base that the internal support for the front proper left leg and foot would have different structural requirements than those needed for the front proper right leg. The internal support would need to span the distance of the fragment of the lower leg (Fig. 15). The stainless steel tubing (Fig. 16) was inserted through the lower leg like a pearl threaded onto a string while the weight was borne by the upper portion of the leg and foot of the sculpture to prevent the lower leg from being crushed. This required the removal of original material at this interface.





Figure 15. Outline of proper left leg support spanning the lower leg. The weight is transferred from the upper leg to the foot of the sculpture preventing the lower leg from being crushed.



Figure 16. Modified front leg stainless steel supports.

The front proper left leg and foot support was fabricated from #304 stainless steel tubing (Fig. 16). A number of modifications were made to the support to aid in any future disassembly of the sculpture. Several 1/16" diameter holes were drilled through the wall of the support where adhesive was to be applied. Two of the holes in the support were intentionally placed at the interface of the fragments to allow solvent to be injected into marble interface, then into the interior void of the support to aid during any possible future disassembly. Both ends of the support were capped with Pliacre epoxy putty to prevent the adhesive from being forced into the interior void.

The area of the support to be inserted through the fragile fragment of the lower leg was covered with a single layer of 4 mil Mylar to prevent any adhesion between the support and the stone. Three 1/4" wide x 1/8" thick strips of Volara, a pure polyethylene cross-linked foam, were placed on the lower 7 1/2" and upper 4" of the outer wall of the support. The Volara is intended

to provide channels of soft, easily removable material, where solvent can be injected during future disassembly and also to allow room for the epoxy to swell during removal.

During the reassembly process the holes in the stone and both supports were thoroughly degreased with acetone and a cotton swab. The Araldite resin was placed into a small commercially available hand pump with an 8"-long flexible plastic tubing that allowed the adhesive to be injected into the bottom of each of the four holes at the interface between the front legs and feet of the sculpture. This prevented large air bubbles from becoming trapped in the adhesive when the supports were inserted into the holes.



Figure 17. Joe Rogers, Dale Benson during reassembly of head and front legs to sculpture base.

The supports were inserted into both front legs of the sculpture and lowered into place. Care was taken to remove any excess adhesive at the interface. After the fragments were placed and aligned in the proper position, it remained supported with the nylon slings attached to the chain hoist. An adjustable stand which had been fabricated to offer additional support and adjustability was located under the chest behind the front legs (Fig. 18).



Figure 18. After head and front legs fragments were attached to sculpture base. Adjustable stand under the chest behind the front legs offered additional support during reassembly.

## 5.7 Reversible Mechanical Internal Armatures

To attach the head, hind-quarters and rear feet fragments, several stainless steel components were custom designed and fabricated to incorporate reversible mechanical elements that allowed the sculpture to be brought into compression and remain so after assembly. Bringing the fragments into compression created friction at the interface and reduced the amount of adhesive required to securely hold the fragments in place.

The compression components varied in complexity of design and fabrication. One of the simpler armatures fabricated in-house consisted of inserting stainless steel pins into opposing fragments of the sculpture then connecting the pins with threaded rods which were used to draw the fragments of sculpture into compression (see Fig. 20 b-d).

Another compression mechanism design was a variation of the cramp used traditionally in sculpture restoration. Two pieces of stainless steel flat stock with upturned flanges in the middle creating two “Z” shaped fixtures were fabricated. The upright flanges were drilled and tapped to accept threaded bolts drawn tight to bring the adjoining fragments of sculpture into compression (Fig. 19), unlike the traditional cramp.



Figure 19. The “compression clamp” allowed two fragments of sculpture to be brought into compression. To maintain maximum strength in stainless steel flat stock the flanges must be cold formed, not welded or heat bent.

### 5.8 Attachment of Hind-quarters Fragment

The central mechanical attachment between the head and hind-quarters is a 1 1/4” diameter x 12” long solid stock stainless steel rod (Fig. 20 a) which was attached horizontally to the head section, inside an interior void created during the previous restoration. The rod was attached with four separate 1/2” diameter x 3” long stainless steel pins that were inserted through the 1 1/4” rod and into the marble. Each new hole was drilled at a different angle to cause the pins to bind and prevent them from being pulled out when in compression. The locations of the vertical rods were determined by the compressive force of the threaded rods to be inserted into the vertical pin (Fig. 20 e). Ideally, the vertical pins should be loaded in a direction 90 degrees to the axis of the horizontal 1 1/4” diameter x 12” long solid stock stainless steel rod (Fig. 20 a) reducing the reliance on adhesive strength. Each pin was surrounded in each direction by at least 4” of marble to maximize strength.

Extending from both ends of the 12” long rod are 5/16” diameter stainless threaded rods. The horizontal threaded rods (Fig. 20 b) were threaded into 5/8” diameter x 4” long rods that were inserted vertically into the hind-quarters section. The two 5/16” diameter threaded rods have nuts on the obverse of the 1 1/4” diameter rod to allow adjustment and create the mechanical attachment (Fig. 20).



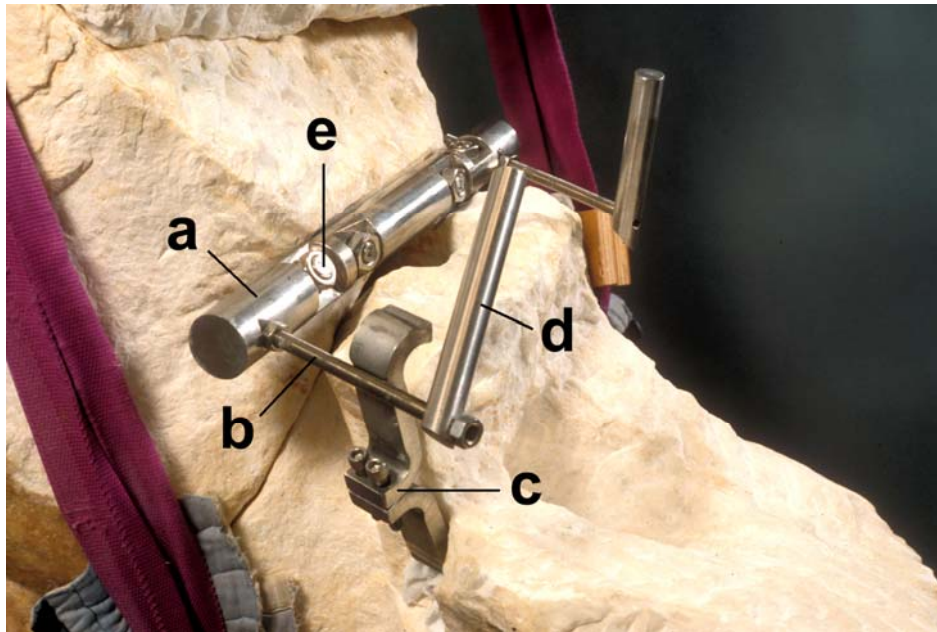


Figure 20. Reversible mechanical components used to attach the head and hind-quarters (before assembly): (a) 1 1/4" diameter x 12" long solid stock stainless steel rod; (b) 5/16" diameter stainless threaded rod; (c) compression cramp fabricated of two pieces of 3/8" thick stainless flat stock; (d) 5/8" diameter x 4" long rod; (e) 1/2" diameter x 3" long stainless steel rod.

The most challenging join during the reassembly process was the hind-quarters to the head and rear feet because it required aligning three major fragments at the same time.

The mechanical components attaching the hind-quarters to the rear feet were fabricated from 1 1/2" diameter 303 stainless steel solid round stock. They both have a bolt hinged, two-member fork and tang design, which allows 135 degrees of adjustment during the assembly process (Fig. 21).

They have a 1" diameter x 10" long threaded rod that was inserted into a 1 3/4" diameter 3/8" thick wall stainless steel tubing, which is the upper portion of the rear leg structure. The threads have a nut at the base and a thick walled tube inserted over the threads. The 1" nut could be adjusted as needed during assembly to increase the overall length to assure that the top member of the armature is properly seated into the hole of the rear legs and feet.



Figure 21. The rear leg support's bolt hinged two-member fork and tang design allows 135 degrees of adjustment.

The holes for the rear leg supports needed to be widened and deepened; it was critical that the hole be at a precise angle. An accurately angled hole was achieved by using a PVC pipe guide of the correct inside diameter, to help direct our drilling path. Pliacre epoxy putty was used as a temporary adhesive to hold our PVC guide in place (Fig. 22). Since we coated the marble surface with a 30% solution of B-72 in acetone, the Pliacre was easily removed after softening with a heat gun.

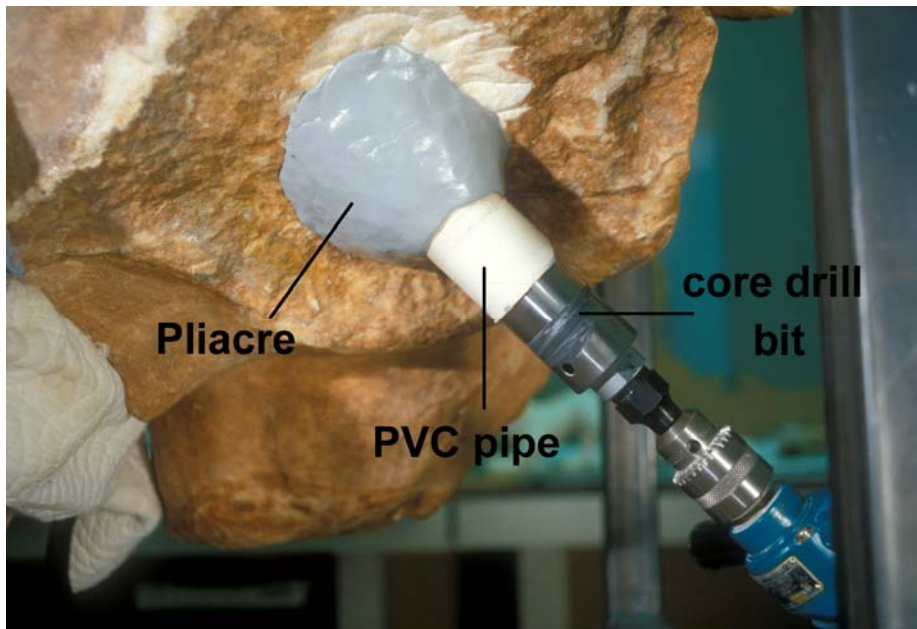


Figure 22. PVC pipe guide for drilling accurately angled holes in rear leg.

The holes in both rear legs and feet of the sculpture were thoroughly cleaned with acetone and Araldite AY103 was injected into the bottom of each hole. The lower rear leg mechanical components were thoroughly degreased with acetone and inserted into both rear feet and excess resin was removed.

Small daubs of the adhesive were applied to the end of the two vertical 5/8" diameter x 4" long (Fig. 23 d) solid rods at the interface of the head and hind-quarters sections. The 5/16" diameter threaded rods were threaded into the 5/8" diameter rods and both were inserted into the hind-quarters section and temporarily held in place with tape.

Adhesive was applied to six 2" diameter areas on the outer edge of the interface between the head and hind-quarters. Care was taken to apply the epoxy close to the outer edge of the marble interface to limit the distance that the solvent or solvent vapor will have to migrate to soften the adhesive during any future treatment.

Adhesive was injected into the top of the holes in the rear legs. The stainless steel tubing and threaded members of the rear leg supports were inserted into the legs and temporarily held in place. The hind-quarters were then moved into position with the head and rear feet.

The 5/16" diameter rods at the interface of the head and hind-quarters were inserted through the holes of the 1 1/4" diameter horizontal bar stock (Fig. 23 a) and the nuts and washers were threaded onto the rods.

The members of the rear leg supports were aligned and bolted together at the fork and tang joint. The 1" nuts on the threaded member of the rear leg support were adjusted to force the tubing member of the armature into contact with the marble at the bottom of the holes in the rear legs and feet.

The 5/16" diameter threaded rods were tightened as the final adjustments were made in the placement of the hind-quarters.

The compression cramp on the proper left side was attached (Fig. 23 c) and tightened after final adjustments were made. Pliacre was used to fill the voids in the marble surrounding the flanges of the compression cramp to prevent any movement.

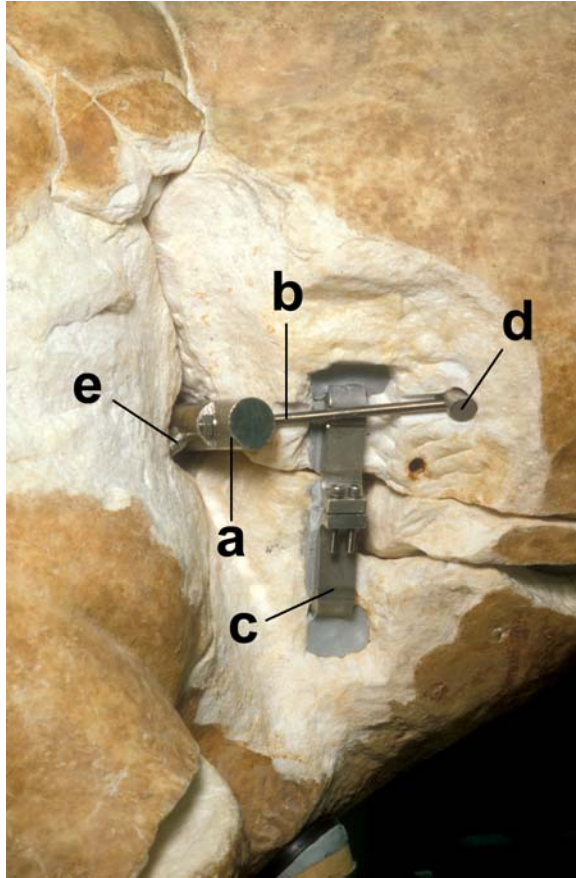


Figure 23 (left). Reversible mechanical components used to attach the head and hind-quarters (after assembly).

Figure 24 (right). After assembly in support frame and gantry, the hind-quarters were supported and left in the steel support frame for two weeks to allow the adhesive to fully cure. The lower temperature of the marble reduced the cure rate of the epoxy.

While still in the support frame, triangular gussets fabricated of 1/4" thick stainless steel plate were added to each side of the fork and tang joint of both rear leg supports. The gussets were added to secure each rear leg support at the exact angle obtained during the assembly process. The gussets were attached to the supports with 1/4" diameter stainless steel nuts and bolts, inserted through 1/4" diameter holes in the armature (Fig. 25).





Figure 25. Detail of gusset added to each side of both rear leg armatures. The gussets locked each rear leg support at the exact angle obtained during the assembly process.

After the gussets were attached to the rear leg supports and securely tightened, the support frame was removed. The lower rear horizontal crossbar of the support frame between the rear leg supports had to be cut and removed with an electric reciprocating saw (see Fig. 24).



Figure 26. After reassembly. Note flexibility of design of rear leg supports. By varying angles and length of threaded rods inserted into the stainless steel tubing at the rear leg support the sculpture can be adjusted.



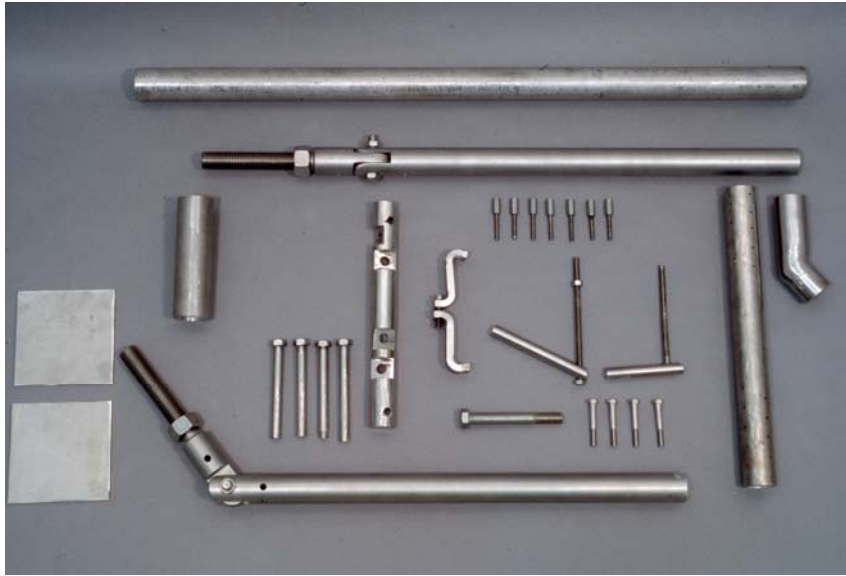


Figure 27. Stainless steel armature used to reassemble entire sculpture.

## 6. Reattachment of Smaller Fragments

Four of the larger fragments on the proper right side were reattached in their original locations with Akemi Knife Grade Polyester Resin over a barrier of Paraloid B-72. The remaining 36 fragments were reattached to their original locations with Paraloid B-72 in acetone.



Figure 28. Proper right side of sculpture after fragment reattachment and compensation of losses.

## 7. Compensation of Losses and Reconstruction of Rear Legs

After considerable research and discussion, a curatorial decision was made to reconstruct the missing rear legs and a portion of the proper left side as closely as possible to the artist's original carving.

High density Ethafoam was used as the bulk of the missing legs. It was machine cut to the approximate size of the missing leg. The forms were fabricated in two pieces, an outside and inside, and channeled out to accommodate the stainless armature. The pieces were then melt-bonded to one another using a heat gun, allowing for a strong bond without using an additional adhesive.

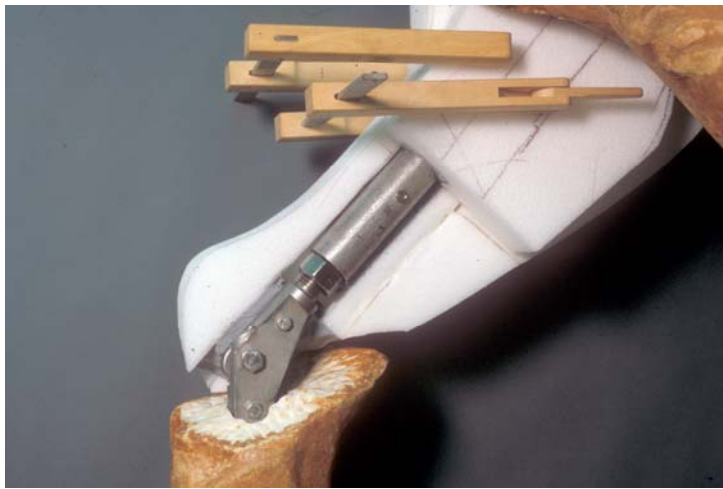


Figure 29. High density Ethafoam form built around rear leg support.



Figure 30. Completed Ethafoam form of proper left rear leg prior to loss compensation.

The Ethafoam forms were then hand carved using knives and rasps to better duplicate the desired forms. The forms were carved approximately 3/8" to 1/2" smaller than the actual thickness needed. This would allow room for the application of the final layer of Poly-filla. The Ethafoam surface was roughened using a rasp to allow for a better attachment of the Poly-filla.

Poly-filla was used as a final layer for detailing the surface texture and features of the lion's legs. The Poly-filla was toned with dry pigments prior to use to closely match the original white color of the Pentelic marble. It was mixed in small batches and applied in layers. The surface was dampened with distilled water before each additional layer of the Poly-filla, allowing for a better bond between layers. Areas were reconstructed detailing hair, veins, and surface imperfections as determined by the curator.



Figure 31 (left). Rear legs after loss compensation.



Figure 32 (right). Rear legs after inpainting with Charbonnel Restoration Colours.

## 8. Inpainting

Charbonnel Restoration Colours [4] were chosen as the inpainting medium because of durability and they best matched the appearance of the archeological surface of the stone when dry.





Figure 33. Proper left side of sculpture after loss compensation.



Figure 34. Proper left side after inpainting with Charbonnel Restoration Colours.

## 9. Documentation of Treatment

Accurate documentation was an important aspect of the treatment. The following is a list of products and techniques used in the documentation process. Before disassembly, the entire sculpture was radiographed by Professional Service Industries, Inc. of Omaha, Nebraska [5].

The photographic documentation before, during and after treatment was with 35 mm Kodak T-Max 100 ASA Black and White negative film and 35 mm Kodak Ektachrome 64T ASA Tungsten color reversal slide film.

Complete instructions for the disassembly of the *Attic Lion* are kept on file should any possible future treatment be necessary.

## Endnotes

1. The exposure source Cobalt 60 was 85.2 curies at the time of exposure. Cobalt has an intensity of 14.7 roentgen per hour per curie at one foot. The total radiation intensity at the lion was 389.29 roentgen.
2. Parafilm is a 4 mil thick moldable polyethylene, polyisobutylene thermoplastic translucent film.
3. 100 parts resin to 40 parts hardener to 30 parts fumed silica by weight.
4. Restoration Colours are a mixture of butyl methacrylate and ketonic acrylic resins. The dried film is soluble in ethanol.
5. The type of film used is unknown.

## Acknowledgements

### Financial Assistance:

Beatrice Davis and the Louis & Elizabeth Flarsheim Charitable Trust  
Allied Signal, Kansas City, MO

### Art Historians:

Dr. Robert Cohon, Curator, Art of the Ancient World, The Nelson-Atkins Museum  
Marc Wilson, Menefee D. & Mary Louise Blackwell Director/CEO, The Nelson-Atkins Museum

### Conservators:

Kate Garland, Conservator, Objects, The Nelson-Atkins Museum  
Paul Benson, Associate Conservator, Objects, The Nelson-Atkins Museum



Forrest Bailey, former Chief Conservator, The Nelson-Atkins Museum  
Elisabeth Batchelor, Director, Conservation and Collections Management, The Nelson-Atkins Museum  
Scott Heffley, Conservator, Paintings, The Nelson-Atkins Museum  
Paula Hobart, Pre-program Intern, The Nelson-Atkins Museum  
Scott Nolley, 3<sup>rd</sup> Year Intern, The Nelson-Atkins Museum  
Jerry Podany, Chief Objects Conservator of Antiquities, J. Paul Getty Museum

**Engineers:**

William R. Freeman, Mechanical Engineer, Allied Signal  
Tom Heausler, Structural Engineer, Burns and McDonnell

**Administrative Assistance:**

Betse Ellis, former Conservation Administrative Assistant, The Nelson-Atkins Museum  
Dinah Henderson, Conservation Administrative Assistant, The Nelson-Atkins Museum

**Suppliers**

Akemi Clear Flowing Polyester Resin and Akemi Knife Grade Polyester Resin:  
Akemi Plastics, Inc., P.O. Box 40, Eaton Rapids, MI 48827, supplied by Johnson Granite, 700 East 16th St., N. Kansas City, MO 64114, 816-421-4500.

Araldite AY103 epoxy resin and Araldite HY991 epoxy hardener:  
Ciba Polymers, Duxford, Cambridge, U.K. (For this project, free samples were received from Ciba Polymers.)

Charbonnel Restoration Colours (acrylic and ketonic resins, manufactured by LeFranc & Bourgeois); Fumed Silica, bulking type; Mylar film (DuPont Chemical Co.); Orvus (sodium lauryl phosphate, non-ionic detergent); Paraloid B-72 (ethyl methacrylate/methyl acrylate copolymer; Rohm & Haas Co.); Pigma Micron archival ink pen; Renaissance Micro-crystalline wax (Picreator Enterprises Ltd., London, England):  
Conservation Support Systems, P.O. Box 91746, Santa Barbara, CA 93190-1746, 800-482-6299.

Ethafoam HS 900 Brand Plastic Foam Plank (Dow Chemical Co.):  
Foam Products Corporation, 2525 Adie Road, Maryland Heights, MO 63043, 314-739-8100.

Parafilm polyethylene, polyisobutylene:  
Fisher Scientific, Pittsburgh, PA, 800-766-7000.

Perma-Fill™ (also known as Poly-filla): acrylic VeoVa-PVA copolymer, internally plasticized [vinyl ester of Versatic 10, a synthetic saturated monocarboxylic acid mixture of highly branched C<sub>10</sub> isomers]; cellulose thickeners, boracide preservative, higher alcohols, glycol ether, amine to

raise pH, as additives. Bondfast Company, Bridgewater, NJ 08807, supplied by Conservation Support Systems, P.O. Box 91746, Santa Barbara, CA 93190-1746, 800-482-6299.

Pliacre (pliable two-part epoxy putty):  
Philadelphia Resins Corp., P.O. Box 454, 20 Commerce Drive, Montgomeryville, PA 18936;  
215-855-8450.

SonogROUT 10K Shrinkage-Compensated Nonmetallic High Strength Grout:  
Chemrex, Inc., Shakopee, MN 55379, 612-496-6000.

Volara (fine-celled, irradiation crosslinked foam):  
Reilly Foam Corp., 1101 Hector St., Conshohocken, PA 19428, 610-834-1900.

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**THE 2004-2005 TREATMENT OF ALEXANDER CALDER'S LAST AND LARGEST MOBILE, *UNTITLED* 1976.**

Michael Belman, Abigail Mack and Shelley Sturman

**Abstract**

Alexander Calder's last and largest mobile, *Untitled* (1976) has gently rotated in the air currents of the atrium of the East Building at the National Gallery of Art since its opening in 1977. At Calder's request, artist and engineer Paul Matisse fabricated the mobile out of then cutting-edge materials to be both lightweight and durable. Over the course of the mobile's 29 year history, two separate attempts were made, through the application of thermal spray hardfacing coatings, to combat the persistent divot shaped depressions that formed between the contact points of the aluminum hooks and loops. The mobile was exhibited with its original molybdenum coating for 11 years. In 1989 a new two layer coating of nickel-molybdenum-aluminum plus a titanium dioxide top-coating was applied that lasted another 15 years until 2004, when further treatment was required.

The depressions that formed between 1989 and 2004 were much deeper on some of the aluminum hooks than those that formed during the first decade, possibly because a longer period of time elapsed between treatments, increased movement from air currents in the atrium as the air handling systems were updated, and oil that leaked onto the mobile from its hanging assembly on the roof. Nearly all of the aluminum hooks and loops exhibited depressions with the degree of damage being proportional to the lessening load at each junction. A few of the aluminum hooks that were connected to steel elements were subject to preferential wear.

Through consultation with experts in the field of friction science and the use of an ASTM test for thermal spray wear resistance, a better understanding was obtained of the wear mechanisms occurring on the mobile and a treatment plan was devised using newly developed hardfacing materials. Treatment of the sculpture involved aluminum TiG weld-filling of the worn depressions, adding steel liners to four sensitive aluminum and steel junctions, complete replacement in steel of one structurally compromised aluminum element, and application of a tougher hardfacing coating: tungsten carbide with cobalt applied by High Velocity Oxygen Fuel to select hook and loop contact points. The design and execution of the treatment was performed through close consultation with Paul Matisse. After repainting using the same manufacturer's paint as originally applied, the mobile was returned to its soaring state.



Figure 1. *Untitled*, Alexander Calder, 1976, painted aluminum, steel, 358 1/2 x 912 inches. Gift of the Collectors Committee. Photo courtesy of Board of Trustees, National Gallery of Art, Washington.

## 1. Introduction

Alexander Calder's last and largest mobile, *Untitled*, has rotated in the air currents of the atrium of the East Building at the National Gallery of Art since its opening in 1977 and has become one of the iconic symbols of the Gallery's East Building. Calder worked on this commission in collaboration with the visionary architect I.M. Pei, as the mobile was meant to provide the finishing touch to Pei's design of the East Building (Marshall and Sturman 1991). For clarity throughout the rest of this paper, *Untitled* will be referred to simply as "the mobile".

Calder made only a small scale model of the mobile, and entrusted its enlargement to Paul Matisse, (son of his dealer, Pierre Matisse, and grandson of the painter, Henri Matisse), owing to complications with the mobile's projected weight. In the National Gallery Archives, a note handwritten by Calder to Matisse states: "You go ahead and build the thing and I'll come and see it when it is finished"(Calder 1975).



Figure 2. Calder working with Matisse during the enlargement of his model. Photo courtesy of National Gallery of Art.

In order to make the mobile light enough so that it could move freely on the slightest air currents, Matisse used cutting edge aircraft grade materials such as aluminum honeycomb panels and heat treatable 6061 aluminum alloy tubing which achieves its strength through heating rather than work hardening. Although Calder was able to approve the construction and final appearance of the work, he died shortly before the mobile was installed and was never able to see the completed work in the intended space (Marshall and Sturman 1991).

## 2. Nomenclature for the Elements of the Mobile

Matisse developed a nomenclature for the mobile that groups the parts into the general categories of “blades,” “planes,” “wings,” and related “arms.” (see Fig 3). The mobile consists of six red (ovoid shaped) vertically oriented blades, five black (chevron shaped) horizontally oriented wings, and two large (triangular) planes, one blue, the other black, also horizontally oriented (Matisse 1976).

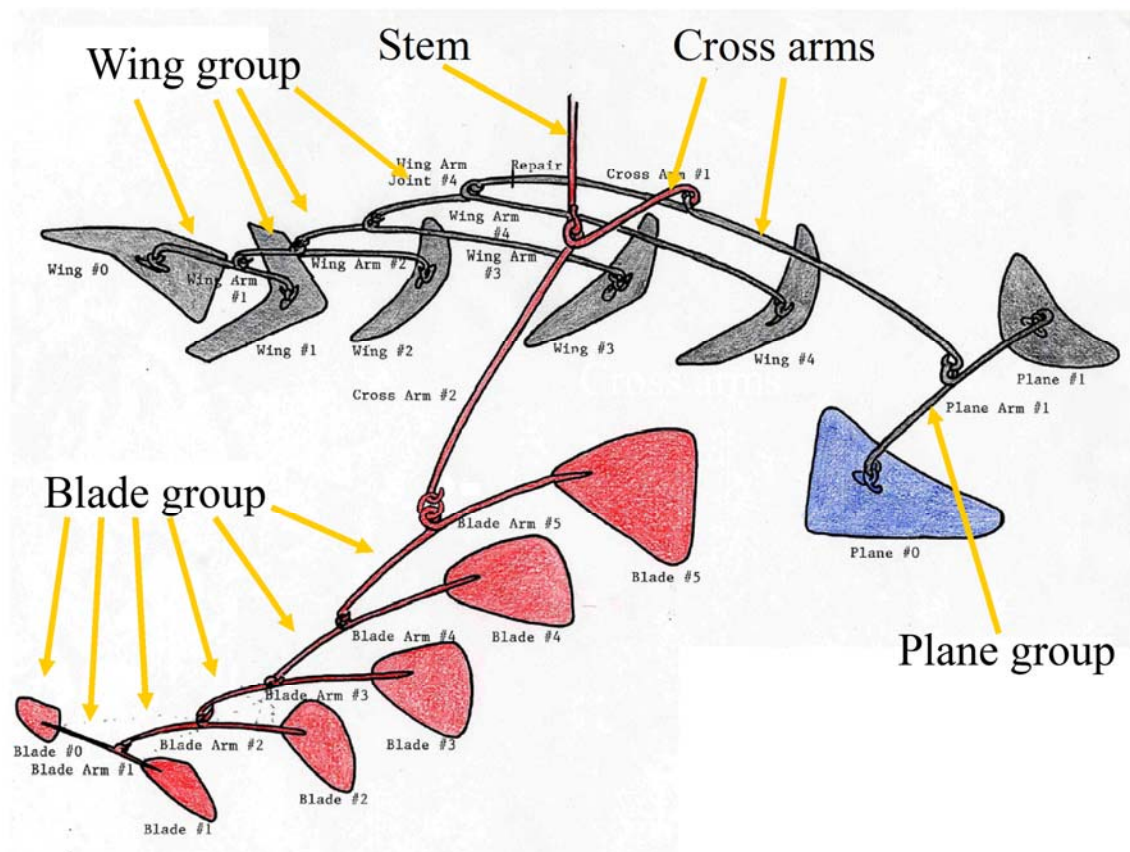


Figure 3. `Mobile diagram with the wing, plane and blade groups and arms labeled.

The mobile’s blades, planes, and wings are suspended from a red central “stem” which fits into a housing on the roof containing ball bearings in an oil bath. The entire mobile rotates and



individual parts pivot from the hook and loop interfaces in the air currents of the atrium.

There are two large central cross arms from which the blade, plane or wing arms are suspended. The nomenclature classifies “hooks” at the ends of each arm and “loops” in the center of the arms, referred to as end hooks and center loops respectively (see Fig. 4).

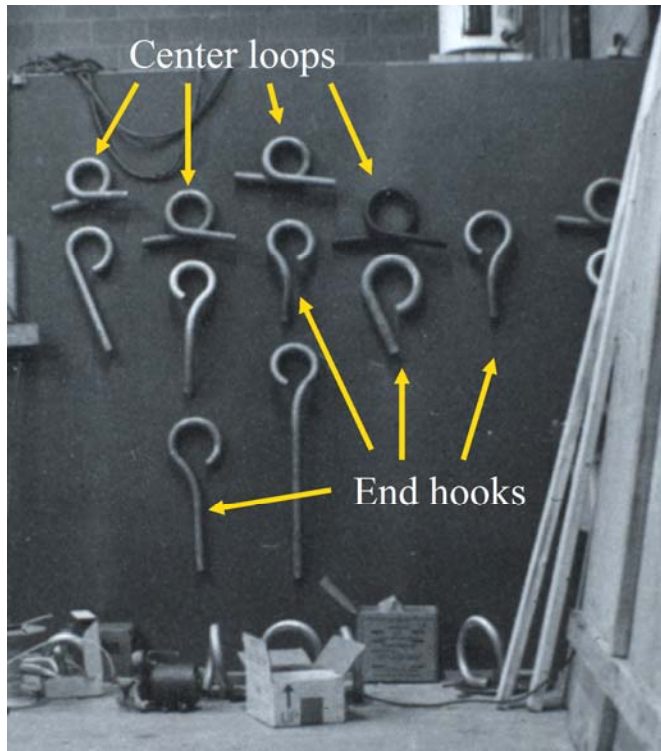


Figure 4. Image of mobile parts in Matisse's studio in the 70's. Photo courtesy of National Gallery of Art.

### 3. Making the Mobile

#### 3.1 Materials Details

Matisse constructed the mobile to be as robust and at the same time as light as possible. He used steel tubing for five of the center loops that bore the most weight and attached them to the tubular aluminum arms with solid steel splices and epoxy adhesive.

The blades, wings and planes on the mobile are made of aluminum honey-comb panels with shaped epoxy putty edges (see Fig. 5). When complete, the mobile was 76' feet long, 54' wide and 29' feet deep, and weighed a total of 920 lbs (Marshall and Sturman 1991).

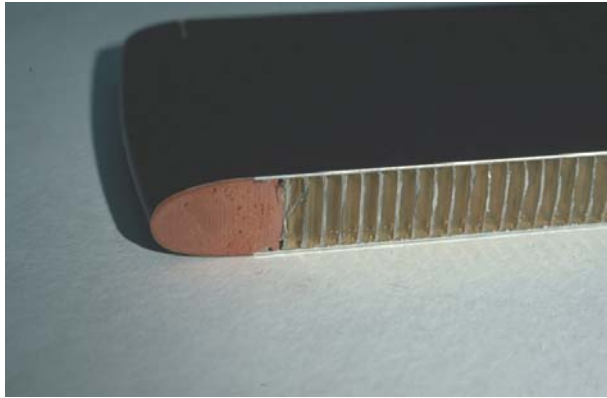


Figure 5. Cross section of a honey-combed aluminum panel prototype.

### 3.2 Thermal Spray Technology in the Mobile's Construction

To mitigate wear on the hook and loop join surfaces which bore an intermediate amount of weight, Matisse applied a thermal (plasma) sprayed hardfacing coating of molybdenum. (Marshall and Sturman 1991) [1].

Thermal sprays can create very tough and dense coatings of both mechanically and physically bonded particles owing to the lamellar structure created by the spray process and the different types of particles within the coating— both flattened and spheroidal (see Fig 6). Metal particles that are still molten when they strike the substrate flatten or splatter on contact, while other particles solidify into spheroidal shapes while traveling through the air and become embedded in the molten particles (England 2004).

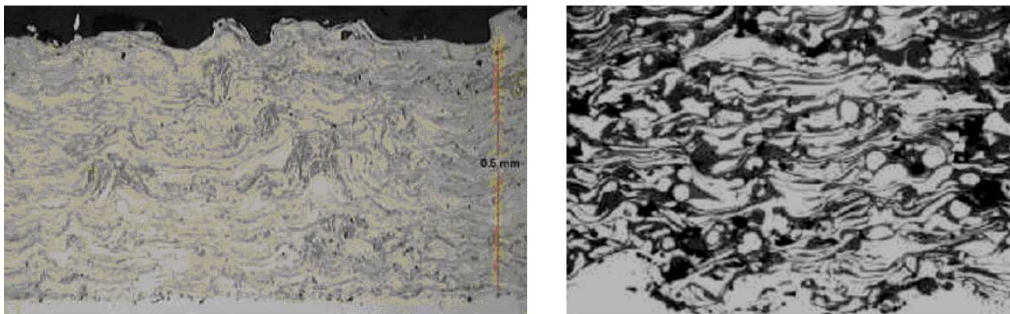


Figure 6. Photomicrographs of thermal spray coatings. Note the scale in the left image which shows that the coating is half a millimeter thick. Images are from [www.gordonengland.co.uk](http://www.gordonengland.co.uk)

#### 4. 1988 – 89 Conservation Treatment of the Mobile

As is expected with kinetic sculptures, some parts of the mobile exhibited wear over time and needed to be repaired or replaced in order to allow the sculpture to move as originally intended. Following its installation in 1977, the mobile hung for over 11 years until divots in the aluminum tubes at the hook and loop interface from the constant motion were discovered during routine maintenance.

To correct the depressions forming on the loops and the associated loss of mobility, the mobile was deinstalled in 1989 for major conservation treatment (Marshall and Sturman, 1989 and 1991). Depressions in the bearing surfaces of 5 loops and hooks were filled with TiG welded aluminum filler rod [2], and a total of 16 loops and hooks were hardfaced using a then state of the art hardfacing system: a bond coat of a nickel, molybdenum and aluminum alloy followed by a top coat of titanium dioxide, a type of ceramic coating chosen for its extremely hard and smooth surface (Snow 1988).

#### 5. Recurring divot formation on the bearing surfaces of the end hooks

Following treatment the mobile was reinstalled and hung for another 15 years until 2004 when once again, movement became inhibited and depressions had reformed, but this time they were significantly deeper than during the previous examination. Given the nature of the materials used in the fabrication of the mobile, it was clear that the damage was likely to be recurring, and a new approach was sought that would mitigate the need for a major treatment every 10 to 15 years. The sculpture was de-installed in April of 2004, and all parts were carefully examined.

Each one of the aluminum hooks and loops exhibited some depressions with the degree of damage being determined by several factors. Most damaging was the preferential wear of the aluminum bearing surfaces in contact with the five steel center loops.



Figure 7. The aluminum end hook of blade arm 5 (left) and the aluminum ring (right), both areas of aluminum to steel contact, were the most badly damaged.

The end hook of blade arm 5 exhibited the worst damage from aluminum to steel contact as the divot had actually penetrated the wall of the aluminum tubing (see Fig. 7, left). Several significant depressions, also from aluminum to steel contact, were worn in the aluminum ring that connected the end hook of cross arm 2 and the entire upper portion of the mobile with the lower blade group section. In fact, the entire inside surface of the aluminum ring was damaged to the extent that its replacement became a major consideration.

## **6. Analyzing the wear system on the mobile**

The recurring damage posed a potentially serious safety problem, in that the mobile is suspended 60' in the air above the public. Also troubling was the fact that several new divots formed in areas that had been re-hardfaced in 1989.

Another factor affecting the degree of damage was the proportional lessening of the load and the amount of movement at each junction on the blade group, which is subjected to nearly constant back and forth movement on the slightest air current. Depressions were also observed on end hooks at aluminum to aluminum interfaces. These decreased in size as the blades arms themselves decreased in size and supported less weight. Very little damage was seen in the hooks and loops at the horizontally oriented wing and plane groups, which have a more of a gentle up and down movement, rather than the more aggressive wear of the blade group.

Another possible cause of the increased damage was an oil leak from the bearing housing on the roof that dripped onto the lower hanging red blade group (see oil stained ring image in Fig. 7). The oil acted as a lubricant and caused greater mobility at the hook and loop interfaces. Further exacerbating the problem, the oil trapped particulates such as paint, aluminum, and hardfacing particles which acted as abrasives thereby cutting the divots even deeper. The oil also dripped onto the blades, wings, and planes, covering them with oily tidelines.

In addition to structural repairs, the other major component of the treatment was to find a more durable thermal spray hardfacing that could better protect the hook and loop interfaces than the coatings used in the previous treatments. Initial research involved friction scientists at the US Naval Research Laboratory in Washington, DC. After examining the components they observed that the hook and loop interfaces were basically two cylinders lying perpendicular on top of one another, making contact in one small point, known as a point load (see Fig. 8).



Figure 8. Diagram showing the point load of the mobile's hook & loop interface. The wear scar is typical of this type of wear system.

A critical observation was that the softer aluminum became compressed under its steel counterpart causing the hardfacing at the surface to fail. The back and forth movement of the hook and loop joints on the point load (fretting wear), created the distinctive craters in the center of the "x" shaped wear pattern (Singer 2004). It was also observed that the steel elements withstood the wear system much better than the aluminum ones and exhibited virtually no damage.

## 7. Investigating Potential Treatment Options

It was feared that the structural integrity of the perforated aluminum end hook of blade arm 5 and the heavily abraded aluminum ring might be compromised to an extent that they warranted replacement. One promising option was to replace the aluminum ring with steel tubing of the same exterior dimensions, but with slightly thinner walls so that the appearance and balance of the mobile would not be affected.

Repairing the end hook of blade arm 5 was more complicated and the initial ideas were unacceptable as they relied too heavily on the strength of a single weld or involved extensive alterations to original material. Of concern was the possibility that repairs involving heat would anneal the work hardened state of the heat treatable aluminum and diminish its strength even further. Results of radiography demonstrated that replacement of the perforated end hook of blade arm 5 with a newly fabricated one of the same aluminum alloy, or with thinner walled steel, was not a viable option. X-radiographs of the end hook revealed that the internal splice attaching the end hook to the rest of the blade arm travels deep inside the arm tube beyond the join (see Fig. 9). Replacing the end hook would require cutting the blade arm tube above the splice, refabricating an entirely new end hook, and reattaching it with a new aluminum splice



and epoxy bond as in the original manufacture.

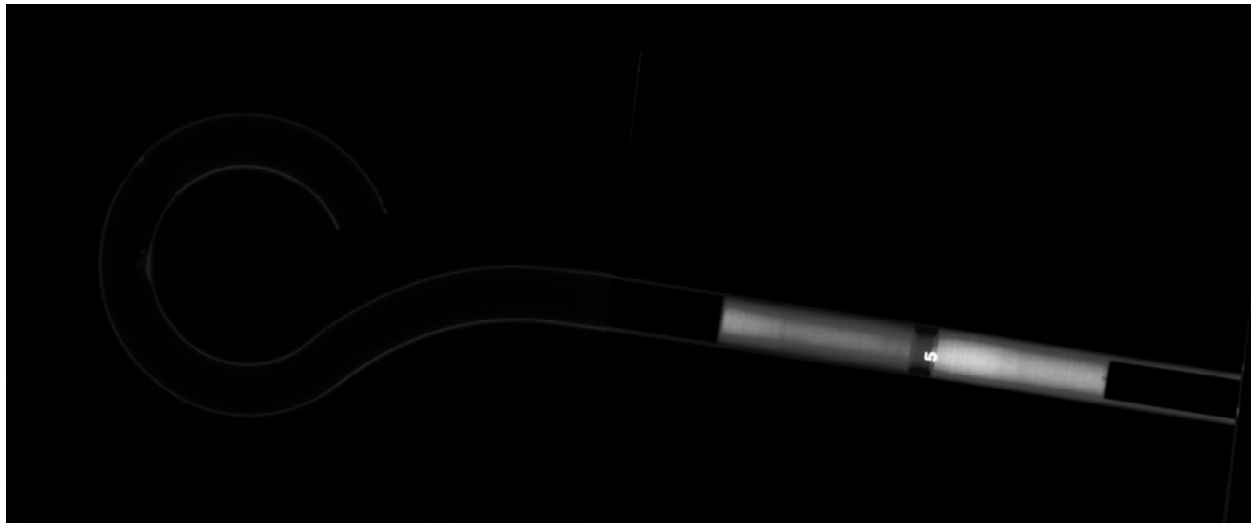


Figure 9. Composite x-ray of the epoxied aluminum splice that attaches the end hook of blade arm 5 to the rest of the arm.

Replacing an original epoxied join was seen as an overly aggressive approach and one that could critically alter the balance of the piece. It was ultimately decided to replace the aluminum ring with a thinner walled steel ring and to adhere custom formed steel liners to the two most seriously damaged aluminum end hooks (blade arms 5 and 4), following TiG weld filling of the depressions as had been done during the previous conservation treatment. The liners would act to stiffen the aluminum bearing surfaces against the pivoting steel and aluminum counterparts and considerably reduce the future formation of depressions. Steel liners were also planned for the aluminum end hook of cross arm 2, to protect it from the steel interface of the newly fashioned steel ring and for the aluminum hook of the supporting stem that also has an interface with a steel center loop of cross arm 2.

The engineer originally involved in the fabrication of the mobile was consulted and he calculated that the projected less than 1% of added weight of the new ring and liners would not affect the balance and or provide any structural complications. The engineer also determined that the small amount of very localized heat involved with the TiG welding and thermal spray made any changes in the temper of the heat treatable aluminum unlikely (McCoy, 2005).

## 8. Fabricating Replacement Pieces

### 8.1 The Steel Ring

A search was conducted via standard metal fabricators and pipe bending specialty companies that supply parts to dairies and oil refineries to fabricate the new steel pieces. Surprisingly, the curve radius required in bending the replacement pieces was tighter than any of these shops had previously encountered.

The replacement steel ring (1018 alloy) of the required dimensions was produced from two 180° bends by Osage Piping & Fabricating of Steelton, Pennsylvania. Although the option of making the ring in three pieces was offered to the workshop because the original mobile ring had been made in three pieces, it was reasoned that fewer welds lessened the chance of future weld failure.

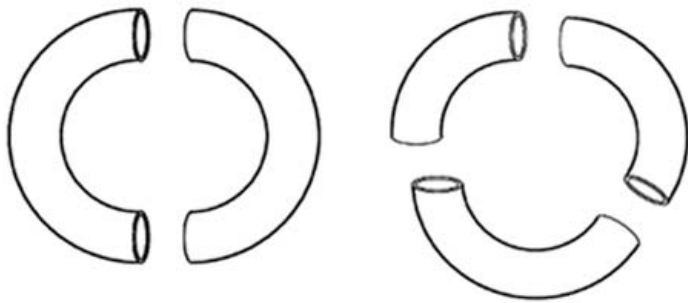


Figure 10. Drawings showing possible methods of making the thinner walled, steel replacement ring.

### 8.2 The Steel Liners

The liners proved to be far more problematic to make than the ring. The Steelton shop did not have the bending equipment needed to meet the required specifications nor did any of the companies they consulted on behalf of the National Gallery. As a last resort the workshop produced a set of four steel liners with faceted curve surfaces but these were impractical because of the excessive amount of additional smithing that would be required to fit the individual end hooks.

A freelance museum mount maker experienced with fabricating custom formed metal pieces, was able to make the liners to the needed specifications [3]. To provide him with the closest possible dimensions, epoxy casts of the damaged end hooks were made together with rubber templates for the liners that completely covered the wear scar (see Fig. 11). The liners were fashioned from pre-bent 1018 steel alloy tubing, then heated and smithed into the proper shape. The epoxy forms were sufficiently durable that the steel could be shaped and hammered directly on the epoxy casts.



Figure 11. Epoxy casts of the damaged end hooks and the corresponding rubber templates were given to the mount maker for exact fitting of the steel liners.

## 9. Hardfacing Component of Treatment

### 9.1 Hardfacing Research

Since the 1989 treatment, many new developments have been made in the field of thermal spray hardfacings including less invasive application methods and the formulation of more durable materials. Consultation with experts in the thermal spray field led to two promising hardfacing alloys considered the toughest coatings available: Armacor M, a high chrome steel with a Rockwell C hardness of 70; and tungsten carbide with cobalt, a cermet, or ceramic/metal coating, with a Rockwell C hardness of 62 (see Fig. 12). Both of these coatings are commonly used on coal crushers, aircraft landing gear and brick dies (Berndt 2004). The original molybdenum coating had a Rockwell B hardness of 36 and is not on the Rockwell C scale, which is another magnitude harder.

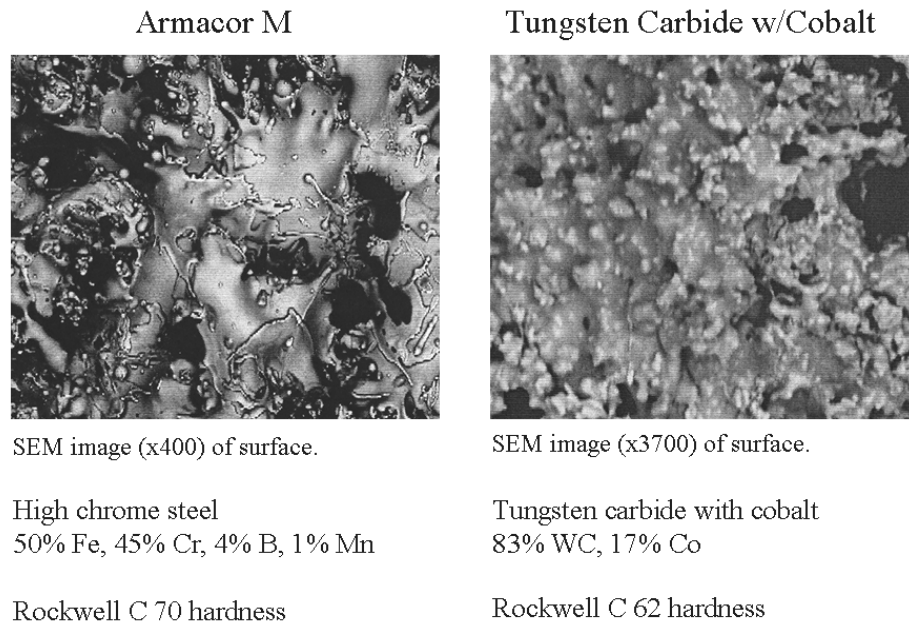


Figure 12. SEM images of aluminum coupons with as-sprayed coatings, and material data of Armacor M and tungsten carbide with cobalt.

## 9.2 Comparing the Durability of Select Thermal Spray Coatings

It was decided to compare the performance of the two recommended coatings with the ASTM standard test F1978-00 for thermal spray wear resistance [4]. The test made use of a Taber Abraser (see Fig. 13) that involves dragging weighted, abrasive stone wheels in a circular pattern around test coupons coated with the two hardfacings (Woods, 2004). The change in the weight of the coupons was recorded after each revolution [5].



Figure 13. Image of the Taber Abraser along with a diagram of the abrading action. Image courtesy of Taber Industries.

According to the test results, the tungsten carbide with cobalt is the tougher of the two hardfacings, as it lost less material in weight and dimension than the Armacor M (Pepke 2005). Further, the tungsten carbide with cobalt had a smoother surface texture than the Armacor M in the “as sprayed” condition. Because of the favorable test results and appearance, together with recommendations from experts in the field of friction science, the tungsten carbide with cobalt was chosen for the thermal spray treatment of the hook and loop interfaces.

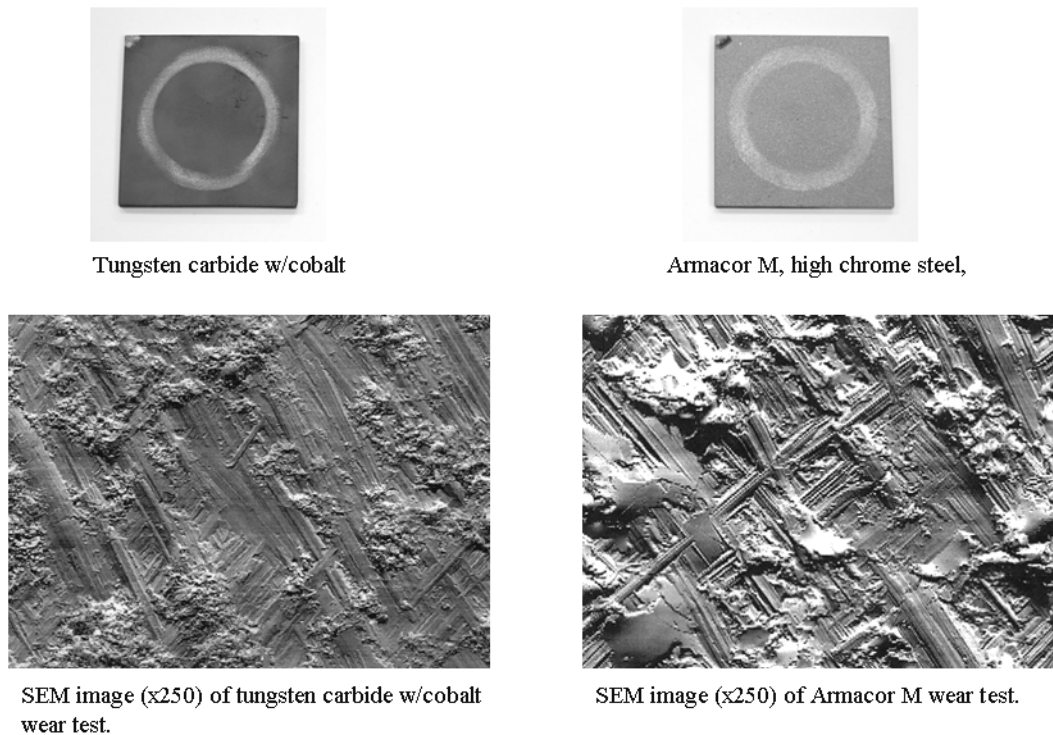


Figure 14. Images of the coupons after testing with the Taber Abraser. The SEM images show the micro-patterns ground into the surfaces of the coatings.

## 10. 2004-05 Treatment and Reinstallation

### 10.1 TiG Welded Repairs

The depressions in the hooks and loops, the majority of which were minor, were filled by TiG welding using 4643 aluminum filler rod, which is specified for heat treatable 6061 alloy aluminum (Craig 2005). The filled areas were smoothed with rotary sanders and the structurally compromised aluminum ring was replaced with the new steel ring, formed from the two 180° bends, of the same weight and dimension.





Figure 15. Images show the end hook of blade arm 4 after TiG weld filling and grinding, and the attached replacement steel ring.

## 10.2 Imparting the Blast Profile

Prior to hardfacing, the hook and loop surfaces, including the steel liners and the new steel ring, were air-abraded with aluminum oxide to impart the necessary surface texture, known as a blast profile. The join surfaces of the four hooks fitted for liners were also air-abraded to provide a surface texture for adhering the liners in place with epoxy.



Figure 16. A surface detail of the blast profile.

## 10.2 HVOF Application of Tungsten Carbide with Cobalt

The HVOF, or High Velocity Oxygen Fuel application method was chosen after researching the many different thermal spray processes [6].



Figure 17. The HVOF process in action.

The tungsten carbide with cobalt hardfacing was applied to the standard 10 mil thickness on the surface of 25 hooks and loops, including the 4 steel liners, and the replacement steel ring. The thermal spray process is extremely loud and is usually performed in a sound tight booth, but the nearly 30 foot length of the largest arms made it necessary to do the work outside in back of the thermal spray contractor's workshop [7]. After the treatment, an eddy current measuring device was used to gauge the thickness of the coating [8].

As noted earlier some thermal sprayed coatings can have a rough texture. However, the surface of the tungsten carbide with cobalt had only a slight surface texture that proved beneficial in providing the appropriate amount of "tooth" prior to painting and would in no way interfere with the free movement of the mobile.



Figure 18 (top and bottom). Images show the steel liners coated with tungsten carbide with cobalt with their corresponding epoxy form. Note minimal surface texture imparted by the HVOF application.

## 10.2 Attaching the Steel Liners

After testing a number of epoxies rated for metal bonding, the liners were attached using Belzona 1111 metal filled epoxy putty (see Suppliers). Edges were carefully built up and smoothed to eliminate any visible profile on the surface.



Figure 19. Image shows a hardfaced steel liner being adhered to an end hook with an epoxy putty bulked with metal powder.

### 10.3 Repainting the mobile

Owing to the already faded and stained condition of the paint, it was decided in consultation with the curatorial department, the Calder Foundation and Paul Matisse, to repaint the entire sculpture using the original paint formulation: Keeler and Long Flat Poly-Silicone. One of the colors is actually named Calder Blue by the paint company.



Figure 20. Repainting the mobile arms.



## 10.4 Reinstallation

After more than a year of extensive collaborative efforts among conservators, engineers, machinists and fabricator, NGA staff met at 5 am on the re-installation day to begin the delicate, choreographed process of reassembling the mobile. Twenty minutes before the museum opened, the mobile was raised to its final position and museum staff, watching silently from various corners of the atrium, cheered the long awaited return of the grand icon.



Figure 21. The re-installation of the mobile after over a year of collaborative effort.

## Acknowledgments

The authors wish to thank several individuals at the National Gallery of Art for their support throughout this project, including Michael Palmer, Conservation Scientist and Dr. Jeffrey Weiss, Curator of Modern and Contemporary Art; as well as Judy Ozone, Daphne Barbour, Katy May, Caitlin Jenkins, and Julia Sybalsky of the Object Conservation Department, without whose help and enduring patience, the treatment could not have succeeded. We appreciate the advice and consultation offered by Dr. Irwin Singer, Head of Tribology Section, US Naval Research Laboratory; Dr. Chris Berndt, Head of Thermal Spray Engineering, Stonybrook University; and John Pepke, Laboratory Tester, Taber Industries. Finally, we are grateful to Paul Matisse, Kalliroscope Corporation, for his guidance and encouragement at every step.



## Endnotes

1. Plasma spray is a thermal spray process. Thermal spray is a general term for depositing a material in powder or spool-fed wire form onto a substrate through a pressurized super-heated gas jet. Metal alloys, ceramics, metal/ceramic composites, and polymers are materials commonly used in thermal spraying. The substrate is first prepared by air abrading with abrasive grit to impart the necessary surface texture, or blast profile to enable the coating to stick. Hardfacing is only one of the uses of thermal spray, in which a substrate is made stronger by coating it with a harder or tougher substance (Herman 1988).
2. TiG welding, or tungsten inert gas welding, is an arc welding process that uses a tungsten electrode, alternating current and a filler metal, usually in rod form to produce the weld. The weld area is protected from atmospheric contamination with a shielding gas such as argon or helium. TiG welding is particularly effective with welding aluminum, which forms a refractory oxide layer within minutes of exposure to air. This oxide layer must be removed for welding to occur (Craig 2005).
3. Paul Daniel, 2010 Clipper Park Rd, Baltimore, MD 21211, 410-366-5072, tdaniel@bcpl.net
4. The ASTM standard test F1978-00e1 for measuring abrasion resistance of metallic thermal spray coatings by using the Taber Abraser was originally developed to characterize coatings used on surgical implants (Woods, 2004).
5. Taber test was performed on a Model 5130 Rotary Abraser with H-22 wheels. A 250g weight was applied to each wheel. The coupons were seasoned in a test atmosphere of 70° F and 47% RH for 24 hours and then tested for a total of 500 cycles, with the change in weight being measured every 72 cycles (Pepke 2005).
6. Lower energy methods such as twin wire arc spray and flame spray were also considered because they could be performed in the immediate Washington, DC area at lower cost. Ultimately the HVOF method was chosen because it can produce extremely dense coatings with negligible porosity through the high velocity of the pressurized, super heated gas stream which reaches 1500 meters per second (Berndt 2004).
7. An HVOF applied coating is considered to be a cold application because the flame jet only touches a localized area, and the increase in temperature of the surrounding aluminum is negligible (Berndt 2004).
8. Eddy current measuring is a common non-destructive method used for testing the thickness of thermal spray coatings. The device measures the magnetic field created by the interaction of a conductive probe under alternating current and a conductive test surface (England 2004).

## Supplier

Metal filled epoxy putty (Belzona 1111):  
Belzona Inc., 2000 N.W. 88<sup>th</sup> Court, Miami, FLA 33172 (www.belzona.com)

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## **RESTORING THE *M.R. 1750* PUBLIC CLOCK: HISTORY, ANALYSIS, EXPERIMENTATION AND RE-CREATION**

Steven W. Dykstra, Donald Saff and Lee W. Badger

### **Abstract**

When the *M.R. 1750* tower clock mechanism was acquired for a specialized private collection, examination revealed that it had alterations and adaptations that left it in barely in working order. The problems included a shortened pendulum and missing parts for hour strike and quarter-hour strike operation. Restoring the clock to full and complete working order required horological analysis and the skills of an artist-blacksmith.

The authors present a brief history of timekeeping machines of this type, providing contexts and precedents that determined and informed the clock's restoration. They explain detection and correction of the clock's operational deficiencies including the pendulum modification and calculation of the correct pendulum length. Prototype replacement parts were created to adjust and test mechanical details of the missing pieces. To avoid anachronistic appearances in the functional restoration, modern materials, methods and techniques were used to imitate the style and patination of the existing 18th c. work. The authors also address differences between stringent conservation and preservation treatment goals and those that primarily seek to restore a mechanical object to operating functionality.

### **1. Contexts of the Restoration**

#### **1.1 The Saff Horological Collection**

A clock is a mechanical apparatus to segment time. It evolved in an effort to regulate, indeed control, public routines. Municipal and church tower clocks, with their large dials, bells, and occasional astronomical displays, most effectively facilitated this mission. The Saff Collection of tower clocks in Oxford, Maryland, began from a small private collection in 1970 and was organized to demonstrate the technical innovations in public timekeeping from the 15<sup>th</sup> century to the present day.

A clock escapement is a mechanical device that releases the latent power of suspended weights incrementally. Over many centuries, clockmakers have endeavored to improve the accuracy of clocks by means of new and more precise escapements. The pendulum determines the duration of the increments of the escapement's motion. It too had numerous iterations of refinement in efforts to reduce the effects of temperature and humidity on pendulum length. The Saff Collection comprehensively represents applications of wrought iron, cast iron, iron alloys and brass, to ever more efficient gearing, escapement and pendulum design.

## 1.2 Context of the *M.R. 1750* Clock in the Saff Collection

The earliest church clock in the Saff Collection was produced by Laurentius Liechti of Winterthur, Switzerland in 1541 (Fig. 1). The time and strike mechanism of this clock is controlled by the first known type of mechanical escapement. Comprised of a crown wheel, verge, and foliot (a pivoting horizontal bar with moveable weights on both ends), it was developed in 12<sup>th</sup> Century monasteries and applied to clock mechanisms for approximately 500 years.

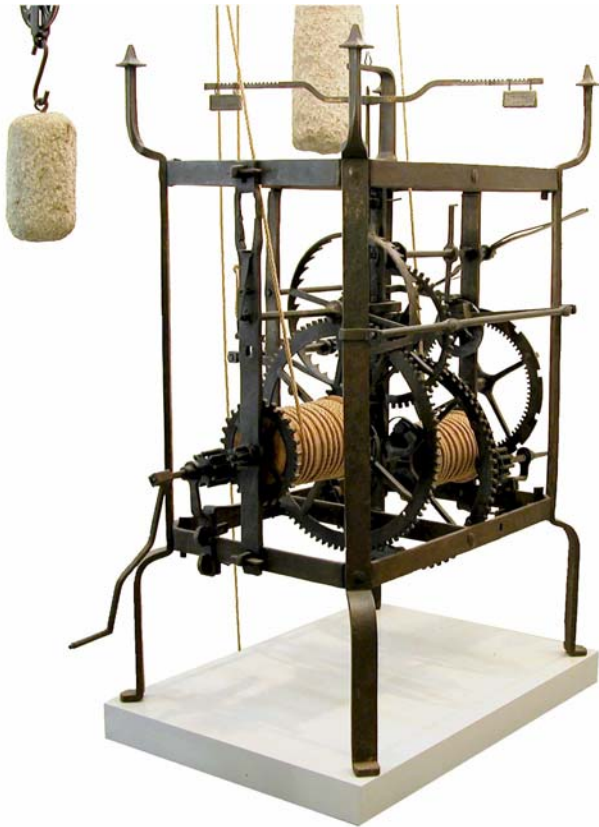


Figure 1. The Saff Collection's Laurentius Liechti 1541 clock with a verge and foliot escapement.

With the application of the pendulum to timekeeping in the 17<sup>th</sup> century, theoretically conceived and attempted by Galileo and brought to mechanical success by Christiaan Huygens in the 17<sup>th</sup> century, accuracy improved from fifteen minutes per day to two minutes per day. The new system, replacing the foliot, merged the verge and crown wheel with the pendulum. A Dutch clock which dates to about 1670 in the Saff Collection is an example of this short-lived hybrid system (Fig. 2).

In about 1670, Joseph Knibb and/or William Clement invented the recoil (anchor) escapement. This innovation in escapement design allowed time keeping accuracy to leap to about two minutes per week. In the 18<sup>th</sup> c., this dramatic improvement spurred widespread conversion of earlier clocks from the use of foliot escapements to the anchor and pendulum. Few clocks were spared this conversion, which accounts for the rarity of the foliot in surviving clocks of the period. The German-made clock monogrammed "M.R. 1750" is representative of an early foliot



clock, with a back-to-back gear train layout, that was converted to a recoil escapement (Fig. 3). Although it is a matter of speculation precisely when this clock was originally constructed, it was probably made during the 16<sup>th</sup> Century and it is the conversion to the anchor type recoil escapement with pendulum that accounts for the 1750 date.

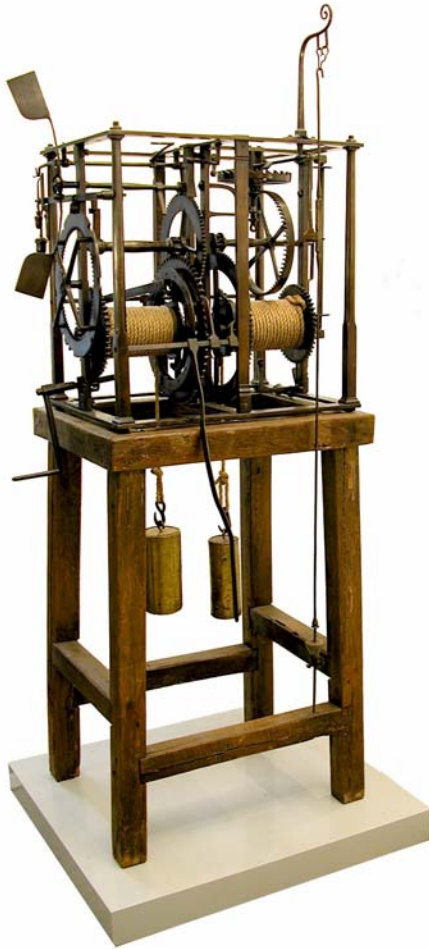


Figure 2. The Saff Collection's Dutch 1670 clock with a crown wheel escapement.

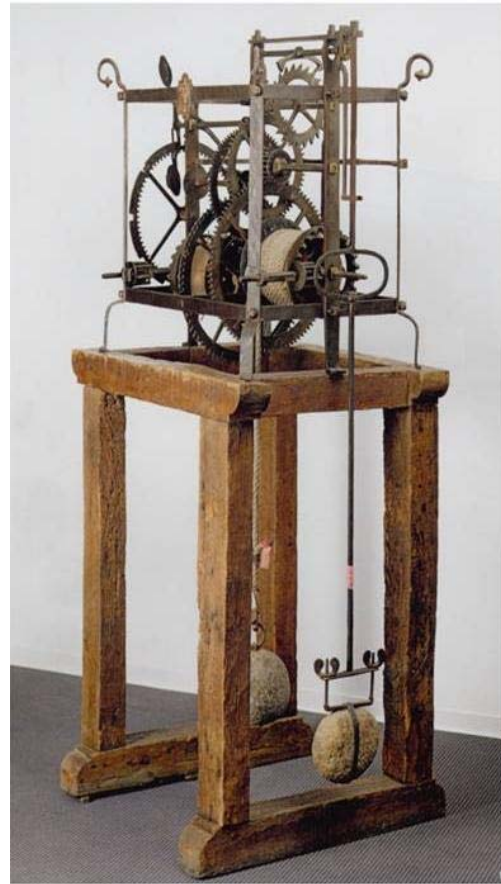


Figure 3. The *M.R.* 1750 clock before treatment, as it appeared at the time of its acquisition.

## 2. Analysis of the *M.R.* 1750 Clock

After the acquisition of the *M.R.* 1750 clock, it became obvious that crucial parts were either missing or altered, and experimental test operation of the clock revealed gross time-keeping dysfunction. Missing parts included an hour strike release arm, the entire quarter-hour strike assembly, a weight to drive the strike train and several less functionally critical fittings; a winding crank, a frame brace and several spacers and washers. Horological analysis of the clock's operation included direct observation of its mechanical operation and the introduction of

experimental prototype pieces to determine the functional form and configuration of missing pieces. Most of the analytical observations and the development of prototype replacement pieces revolved around fundamental observations leading to the conclusion that the time train barrel on which the time keeping weight is wound and its integrated great wheel were intended to rotate exactly once each hour. Analysis of the clock's functioning revealed two highly compromising alterations; shortening of both the pendulum rod and the hour lift pin on the time barrel great wheel.

## **2.1 The Strike Train**

### **2.1.1 The Hour Strike Release Arm**

The hour strike release arm was missing from the existing hour strike release arbor. In full operation, this arm would be lifted each hour, rotating the arbor to release the hour counting and striking portion of the clock. A hole in this arbor indicated the location of this arm whose alignment demonstrated that it should be lifted by a pin on the time barrel great wheel.

Unlike most striking clocks in the 18<sup>th</sup> C., the *M.R. 1750* hour strike system did not incorporate a "warning" feature. A strike train with a warning system strikes a warning bell prior to releasing the hour strikes. It also partially unlocks the strike train and remains poised to allow the correct strike count to begin exactly on the hour. The warning feature was intended to alert listeners to the upcoming hour strikes, allowing them to count them accurately with full attention. In the *M.R. 1750* clock, the warning function would be accommodated more simply by a quarter-hour strike tolling just before the hour count.

The absence of a separate warning strike and hour count release system in the *M.R. 1750* clock required an hour strike release arm that would not dwell on the down (waning) side of the hour lift pin after reaching its apogee. If the arm remained elevated in the release position, the hour count wheel would continue to allow the counting of subsequent hours beyond the one marked at the apogee of the hour lift pin. To obviate this problem, the hour strike release arm would need an articulated foot. This drop-foot device is occasionally found in Dutch striking clocks and is called a "goat's foot," or "nag's head." Once the lever reaches the highpoint of the pin, the goat's foot drops and the lever immediately falls rather than remaining elevated in the release position while riding down the backside of the pin. All lengths and angles of the missing arm were determined by extensive prototyping and testing, resulting in the development of a precisely functional prototype hour strike release arm (Fig.4).



Figure 4. The prototype hour strike release arm.

### 2.1.2 The Quarter-Hour Strike Lever

The rim of the clock's time-barrel great wheel carried four evenly spaced lifting pins ostensibly for accommodating a quarter-hour passing strike. However, the quarter-hour strike lever, arbor, hammer pull, and bearing brackets were missing. The original location of the bearing bracket tenons was marked by holes present in the vertical angled corners of the clock's frame. These bracket tenon holes located the missing quarter-hour strike assembly just above the hour strike assembly. The existing hour strike assembly, consisting of a pair of bearing brackets, an arbor and a lift lever/hammer pull arm would serve as an example for developing the form and configuration for the missing quarter-hour strike assembly.

The quarter-hour strike lever was the most complicated piece missing from the clock. It needed to be lifted by a pin on the great wheel in the time train portion of the clock, rotate on an arbor mounted above the hour strike assembly on the strike train portion of the clock and incorporate a quarter-strike hammer pull. In addition, it would need a feature to prevent it from falling too far into the time train where it could miss being lifted by pins on the great wheel on their upward arc.

Furthermore, the combined quarter-strike and hour warning function would require the lift-arm portion of the lever to be released from the lift pin precisely for accurately timed striking by the hammer pull. This would be accomplished by the traditional method of forming the ends of lift arms with reverse bevels, providing a sharp and sharpenable point at its critical tip. Again, the lengths, bends, shapes and angles of the missing arm were determined by extensive prototyping and testing, resulting in the development of a precisely functional prototype quarter-hour strike release arm (Fig. 5).



Figure 5. The prototype quarter-hour strike lever.

### 2.1.3 Great Wheel Quarter-Hour and Hour Strike Pins

As previously noted, the rim of the existing great wheel carried four evenly spaced lifting pins for activating quarter-hour strikes. A full rotation of the great wheel each hour would also be required to lift the hour-strike release arm once each hour, therefore one of the four pins on the great wheel would also have to act as an hour lift pin. An important part of the hour-lift pin's function, as worked out with the prototype replacement pieces, is for both the hour strike release arm and the quarter-hour strike arm to be lifted together on the same pin each hour. This would have to be accomplished by one pin long enough to lift both arms at the same time. However, all four pins on the great wheel were the same length. Possible reasons for this alteration are unknown.

Close inspection of the great wheel and its four pins revealed that the back of one pin, where it was peened over its point of insertion through wheel, was somewhat larger and rounder than the others, and more significantly, marked with a small dimpled punch mark (Fig. 6). These differences in this pin were taken to identify it as the original hour lift pin to be extended to functional length.

## 2.2 The Pendulum

Observation of the mechanical features, configuration and operation of the clock's time train indicated that the time barrel and great wheel needed to travel one revolution per hour. On test, it traveled at a rate of almost two revolutions per hour. The error proved to be the product of a

pendulum that had been significantly reduced in length. Although some similar clocks may have been casually displayed without their awkwardly long pendulums, the *M.R. 1750* clock has a stone pendulum weight, unique and unusual in its shape, support and method of attachment to the pendulum rod (Fig. 7). When the clock was removed from service, it was likely placed in a

home as a display artifact requiring a pendulum length that did not exceed the height of the clock and its stand.



Figure 6. The back of one of four pins on the hour wheel showing a punch mark indicating it as the likely hour lift pin.



Figure 7. Detail of the weight end of the existing shortened pendulum showing the unique weight stone and wing nut assembly for fine adjustment of pendulum length.

A contemporary weld in the pendulum rod was readily discernable, indicating the location where a length of original rod was removed and the pieces rejoined in a convenient shortening. The operationally functional pendulum length was calculated by multiplying the wheel teeth and dividing by the number of pinion trundles using the principles and the mathematical formula relating the period of a pendulum to its length and the acceleration of gravity, as applied by Huygens in the 17<sup>th</sup> c (Rawlings 1948). The amount of time it takes for a pendulum to go back and forth once, its period, is related only to the length of the pendulum and the acceleration of gravity. Since gravity is considered to be constant at any given spot on the planet, the length of the pendulum is the only thing that affects its period. Neither the weight of the pendulum nor the length of its arc of swing have any consequence in this calculation. The re-computed pendulum length was tested by attaching temporary improvised extensions to the pendulum rod. After the clock was made to keep accurate time by these provisional methods, a clear specification could be made for correcting the length of the shortened pendulum rod.



## 2.3 The Time Weight, Stand and Miscellaneous Fittings

Several other features would be necessary to return the *M.R. 1750* clock to timekeeping operation. The mass of the missing strike weight was determined by incrementally increasing experimental weights until the least necessary weight was determined for insuring dependable train motion. The wood stand, though historically correct in its outward appearances, was too short unless the clock was originally installed with its pendulum swinging through an opening in the floor below. Alternately, the original clock stand may have been a supporting frame which was integrated into the clock's host structure, with a ladder-like arrangement of beams, shelves and platforms to facilitate access and maintenance. The existing iron frame of the clock includes a center support with an attachment foot, but the existing stand acquired with the clock provided no cross brace or other support for the iron foot. Additionally, the clock lacked a winding crank to enable re-winding the time and strike train weights as well as several bearing washers necessary to hold moving parts in optimum working alignment.

## 3. Development of Treatment Goals

### 3.1 Functional Purpose

The primary consideration in developing treatment goals for the *M.R. 1750* clock was operational functionality. A fundamental purpose of the clock's host collection is the demonstration of innovation and advance in horological technology. With few exceptions, the principal property of clocks in this collection is their demonstrable ability to keep time within the constraints of their particular technology. Especially for this clock and the related 1541 and 1670 public clocks that give it context, there was no other original function or purpose outside of timekeeping operation; they were not originally valued for any other reasons, artistic, aesthetic or material.

As historical objects, some public clocks are valued as representatives of the work of a specific clock maker (such as the previously mentioned Laurentius Liechti 1541 clock), as accessories specific to a particular structure or location (such as the Salisbury Cathedral clock discussed in Section 3.3, below), or as individually distinguished standard-setting timepieces. However, the *M.R. 1750* clock enjoys no such historical celebrity.

The clock also lacks unique or unusual significance in the methods or materials employed in the construction or in any aspects of its condition or state of preservation. Furthermore, the clock's existing materials exhibit no signs of destructive corrosion, active deterioration or inherent vice. Consequently, the present treatment was not conceived as a comprehensive conservation effort addressing all aspects of the object's condition and preservation as a historic artifact. Immediate treatment goals were oriented only toward the restoration of full and historically accurate timekeeping functionality.

### 3.2 Historical Consistency

A functional object can experience a working history of modifications that defy pinning it to a single specific date. The object's users may make repairs and modifications to maintain or enhance its functionality whenever convenient or necessary, and often without documentation. Any particular date in the lifetime of a functional object may not accurately reflect its past or future form or configuration. This is especially true of technological objects - those objects whose practical use can be improved through successive alterations and modifications.

In order to avoid creating a misleading combination of features from various and unconnected parts of the object's history, the restoration of a technological object requires specific understanding of the particular object as well as the history of the technologies it demonstrates. Specifically, it is necessary to analyze the historical sequence of repairs and modifications the object received, and to understand the character and function of parts and pieces that may have been replaced or discarded in the alterations. Any accurate restoration must attempt to represent a particular time period in the history of the object, and it may often require the introduction of appropriate facsimile or re-created pieces.

Like other clocks in its category, the *M.R. 1750* public clock is a clear example of a technological object that was repeatedly subject to repairs and significant functional modifications. This clock's role and context in its host collection identifies it with the utilization of recoil escapements from the late 17<sup>th</sup> century through the mid 18<sup>th</sup> century. Therefore, in order to maintain historical consistency and avoid anachronistic representation, the goal of restoration treatment was to recreate functionality and appearance compatible with the clock's likely configuration circa 1750. This treatment goal would require the reversal of some alterations and the recreation of several missing pieces.

### 3.3 Treatment Precedents

The Salisbury Cathedral clock is the oldest functional clock in Great Britain. As is common with public clocks, the clock's keepers occasionally replaced worn pieces and implemented technological improvements as they became available. The earliest records of the clock's use are dated to 1386, and it continued in operation through three or four centuries before it was taken out of service. By the time it was retired in the later 18<sup>th</sup> c. it had been fitted with a contemporary escapement and updated with a number of other functional adaptations.

When this clock was restored to functionality in 1956, the national authority responsible for the project removed and replaced several crucial parts of the mechanism and pursued other alterations in order to achieve a representation of how the clock looked and worked in its first decades of operation. Before and after treatment photographs illustrate the extent to which the existing clock was altered to represent its late 14<sup>th</sup> century configuration (Fig. 8). Although this may be an extreme example of the degree of re-creation necessary to represent a functional object at a particular date in its history, this treatment was considered as an important precedent because the Salisbury Cathedral clock and the *M.R. 1750* clock have many categorical similarities. Additionally, in the field of horological repair and restoration, critically worn,

broken or lost parts and pieces are commonly replaced with replicas, either exact facsimiles or simply functional copies.

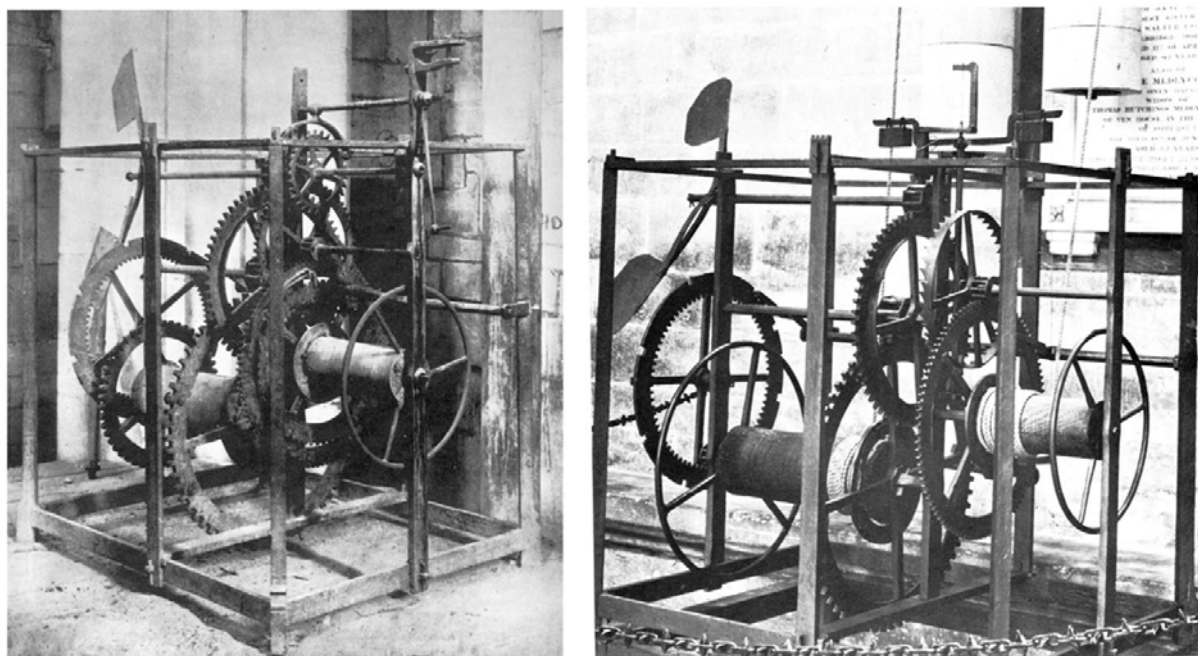


Figure 8. Before (left) and after (right) treatment photographs of the Salisbury Cathedral clock. The arrows indicate the old 18th c. escapement on the left, and the new reproduction 14th c. escapement on the right.

#### 4. Restoration, Re-creation and Patination of Parts

Because the treatment goals were focused on restoration of operable functionality and historical consistency in both functional configuration and appearance, treatment required the services of an artist-blacksmith with knowledge, experience and sensitivity in the preservation and restoration of historic iron objects. The blacksmith selected for this project also had references and experience in historic horological projects in addition to appropriate training, skills and credentials in historic and reproduction iron work. The *M.R. 1750* clock was removed from its stand and placed on temporary supporting skids and moved to this blacksmith's studio and workshop to facilitate the necessary work.

According to the established treatment goals, all altered and re-created pieces would be required to match in appearance both the historic craftsmanship and current patina and condition apparent in the existing clock. However, treatment was not intended to create false authenticity that would tend to obscure or deny the restorations. Therefore, modern methods and materials would be used to imitate historic appearances - no historically genuine production processes or iron alloys would be used in the restoration. In this way, if treatment documentation should ever become lost or separated from the clock, simple and direct material analysis would allow the restored and

re-created parts and pieces to be distinguished from their historic counterparts.

In addition to re-creating pieces in a metalwork style harmonious with the 17<sup>th</sup> and 18<sup>th</sup> century craftsmanship evident in the existing clock, the project blacksmith was also responsible for patination of the new pieces to match existing parts. He recognized that the existing surface texture was due primarily to traditional hand forging, hammering and filing and the existing patina could be matched subsequently with commonly available modern products. Historically traditional methods would need to be combined with modern methods and materials to achieve the desired result.

All re-created parts were made from standard and commonly available mild steel cut from stock mill sizes, roughly formed and shaped by grinding and filing, then heated to working temperature in a propane forge and hot hammered and filed further in successive approximations until the finished form with matching surface texture was achieved. A proprietary 40% hydrogen peroxide solution was used to remove scale and establish a uniform, finely etched and oxidized surface to prepare the finished steel pieces for final patination. Interestingly, this oxidizing solution is marketed for the hair salon industry, but it has been adopted by taxidermists and metal smiths who favor its additional phosphate rinsing agents and extended shelf life. The project blacksmith used this solution with cotton rag poultices, repeatedly wet with the solution until achieving the desired degree of oxidized etch. Following a thorough water rinse and drying, proprietary solutions for gun bluing and "plum brown" gun barrel finish were mixed a drop or two at a time and applied with a small folded pad of clean cotton rag to achieve the desired color effect on the prepared steel. Then, after additional rinsing and drying, a proprietary paste wax provided a traditional and appropriate final protective finish and sheen.

#### **4.1 Restoration of the Hour Lift Pin**

The first step in restoring the *M.R. 1750* clock was to add the length to the hour-lift pin that was removed in the past, as described in section 2.1.3, above. The length and diameter of the pin extension was determined by measurements taken in-situ from the prototype lever arms and the existing pin, and a piece of mild steel was cut and ground to the appropriate dimensions. The extension piece was welded to the existing pin using a MIG welder.

Contemporary metal-inert gas (MIG) welding uses an electric arc to apply and fuse metal alloy to conductive substrates within an envelope of inert gas. Control of the electrical current determines the length and heat of the arc. Feed controls vary the speed at which wire alloy is introduced into the arc as the positive electrode. Inert shielding gases protect the welding area from nitrogen and oxygen, which can cause fusion defects if they come in contact with the electrode, the arc, or the substrate metal. Control of these variables and selection of these materials determine the nature and quality of the weld in various applications. (Cary and Helzer, 2005). The project blacksmith selected Stargon CS, a widely available commercial blend of argon and carbon dioxide gas and .035" (0.9mm) diameter welding wire conforming to ASME SFA-5.18 for compatibility with both wrought iron and mild steel. Electrical current and wire feed settings were adjusted to achieve a small quick weld of minimum size and heat. After filing the weld smooth to match the diameter of the pin, it was tested successfully with the prototype

levers and patinated to match the great wheel and existing pins.

#### 4.2 Re-creation of the Quarter-hour Strike Lever and the Hour Strike Release Arm

Restoration treatment required re-creation of the entire quarter hour strike assembly including bearing brackets for attachment to the clock frame, an arbor bar and lever arms. The prototype quarter hour strike assembly provided a model for dimensions and configuration while the existing hour strike assembly (Fig. 9) served as an example to illustrate the characteristics of materials and manufacture necessary to avoid a mismatched or anachronistic appearance.

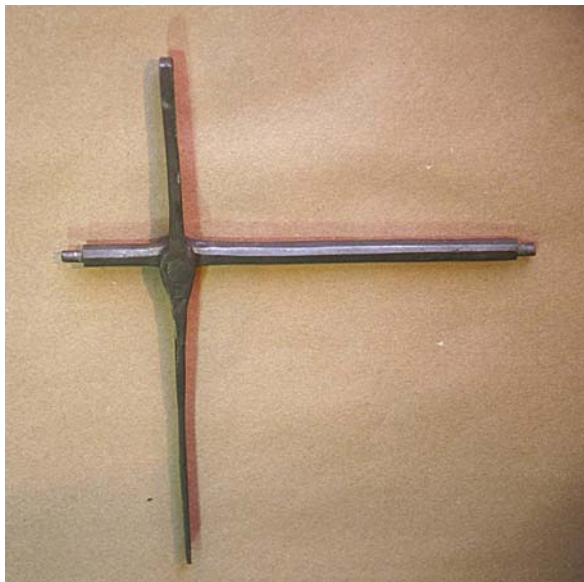


Figure 9. The existing hour strike lever showing characteristics of form and manufacture to be matched in a re-created quarter-hour strike lever.



Figure 10. The re-created quarter hour strike lever showing the functional configuration and dimensions of the prototype (Fig. 5).

Existing bracket attachment holes in the clock frame indicated that the original bearing brackets were attached by hot peening cylindrical shafts on the brackets over the backs of the round holes. However, in the process of making and fitting the re-created brackets, it became apparent that a



hot peened attachment was not desirable for both brackets. If both brackets were attached by this method, a long and arduous sequence of clock frame disassembly and reassembly would be required for each step in subsequent fittings and adjustments of the remaining pieces for this assembly. An alternative method of attachment was found on existing bearing brackets supporting the hour strike release lever. One of these brackets was attached to the frame through a square hole with a square mortised shaft and a cotter wedge. Because similar mortised wedge attachments also exist throughout the frame of the clock, this method was reproduced for one of the quarter hour strike lever brackets. In this way, a more practical removable bracket was created allowing for easier fitting and adjustment of the entire assembly.

The dimensions and configuration of the prototype hour strike release arm permitted little speculation on the original characteristics of its manufacture. The individual features of the mortised wedge attachment to the existing arbor bar were also easily apparent in wear patterns at the attachment point. The resulting re-created arm was also easy to fit and adjust by simple methods (Fig. 11).



Figure 11. The re-created hour strike release arm.

#### 4.3 The Re-Created Strike Train Drive Weight

The absence of a weight to drive the strike train posed a separate set of problems for restoration treatment. For clocks in this category, stone weights were not uncommon, and matching granite spheres or cylinders were the normal types. However, the force required to drive a strike train commonly differs from the force required by a time train. In the *M.R. 1750* clock the existing time train weight is a granite sphere, and it is likely that the strike train would also have a matching weight of a different size. Horological experimentation described in section 2.3 above indicated the mass necessary to drive the strike train, and the established treatment goals required a re-created weight of the proper mass and appearance. Practical problems in identifying the particular type and source of granite used for the existing weight led to consideration of alternative types of stone. Limestone was chosen to re-create the missing weight because it is easily worked and accepts a wide variety of color and texture finishes. Additionally, an artificially colored and textured limestone weight is in keeping with the treatment goals to avoid falsification or confusion between original and re-created parts. The resulting strike train

weight accurately suggests the appearance of an original weight without deceptive imitation (Fig. 12).



Figure 12. The existing granite time train weight (right), and the re-created strike train weight (left), sculpted from limestone, textured and colored to match.

#### 4.4 Restoration of the Pendulum

After determination of the correct pendulum length, described in section 2.2 above, inspection of the pendulum rod showed one forge weld consistent with 17<sup>th</sup> or 18<sup>th</sup> century manufacture and one electric arc weld (Fig. 13). Electric arc welding came into practical industrial use in about 1920 and became widely available for common metal fabrication purposes in the 1950's. Therefore, the newer weld marked the location where a section of the original pendulum rod was removed and the cut ends re-joined, sometime in the 20th c.

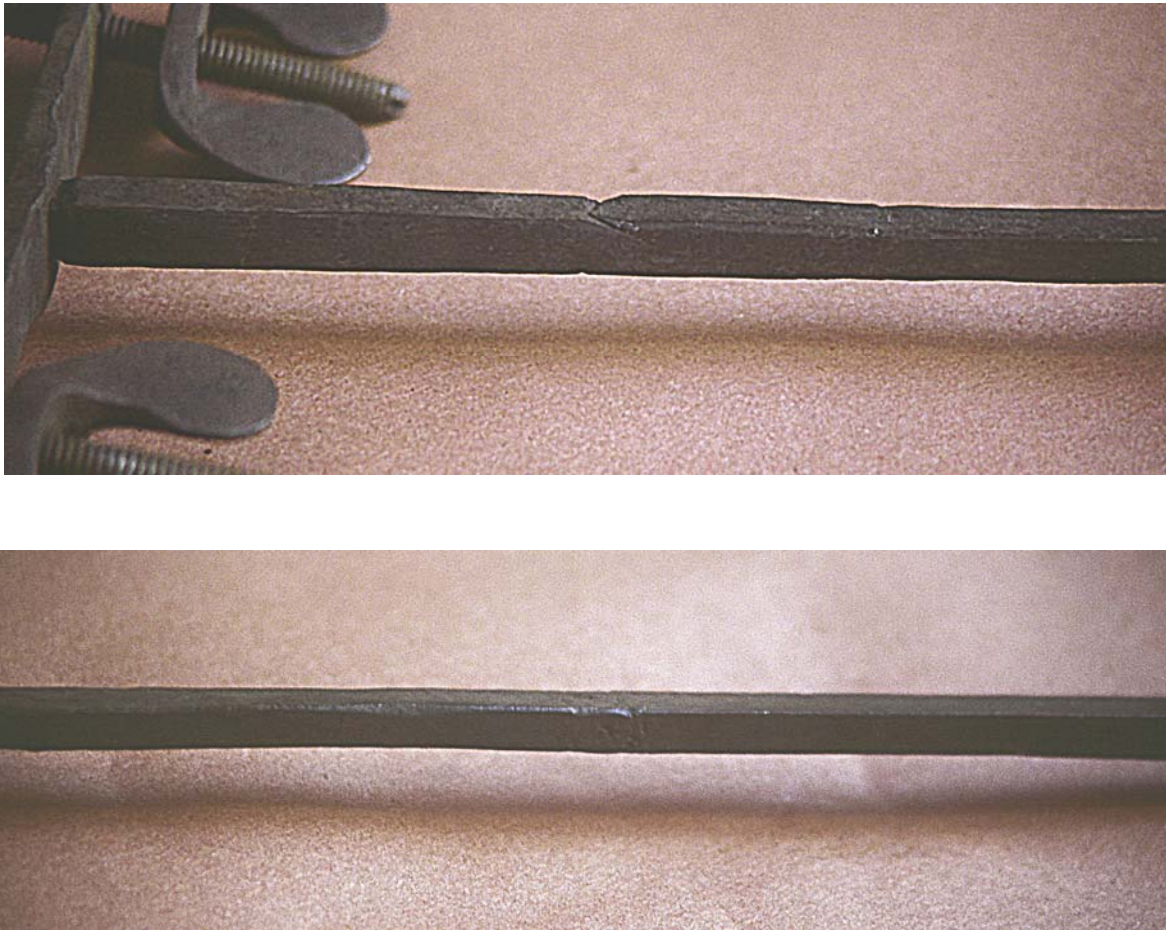


Figure 13. Existing welds on the pendulum rod: An older forge weld (top) and a 20<sup>th</sup> Century electric arc weld (bottom).

In order to lengthen the rod, a matching extension piece was created and the rod was cut at the newer welded point. The extension piece was inserted at the cut with two new welds. Again, the welds were accomplished using Stargon CS and .035" (0.9mm) diameter MIG welding wire conforming to ASME SFA-5.18, with welder settings adjusted to achieve a small quick weld of minimum size and heat. To create the appearance of a continuous original pendulum rod, the new MIG welds were heated with a propane torch and hammered on an anvil to alter their surface texture and to form them more closely to the dimensions of the existing and replacement sections of the pendulum rod. Additional draw filing by hand was necessary for final adjustment of surface texture before patination. The finishing and patination treatment of the extension welds yielded excellent results, unnoticeable to the casual observer (Fig.14).



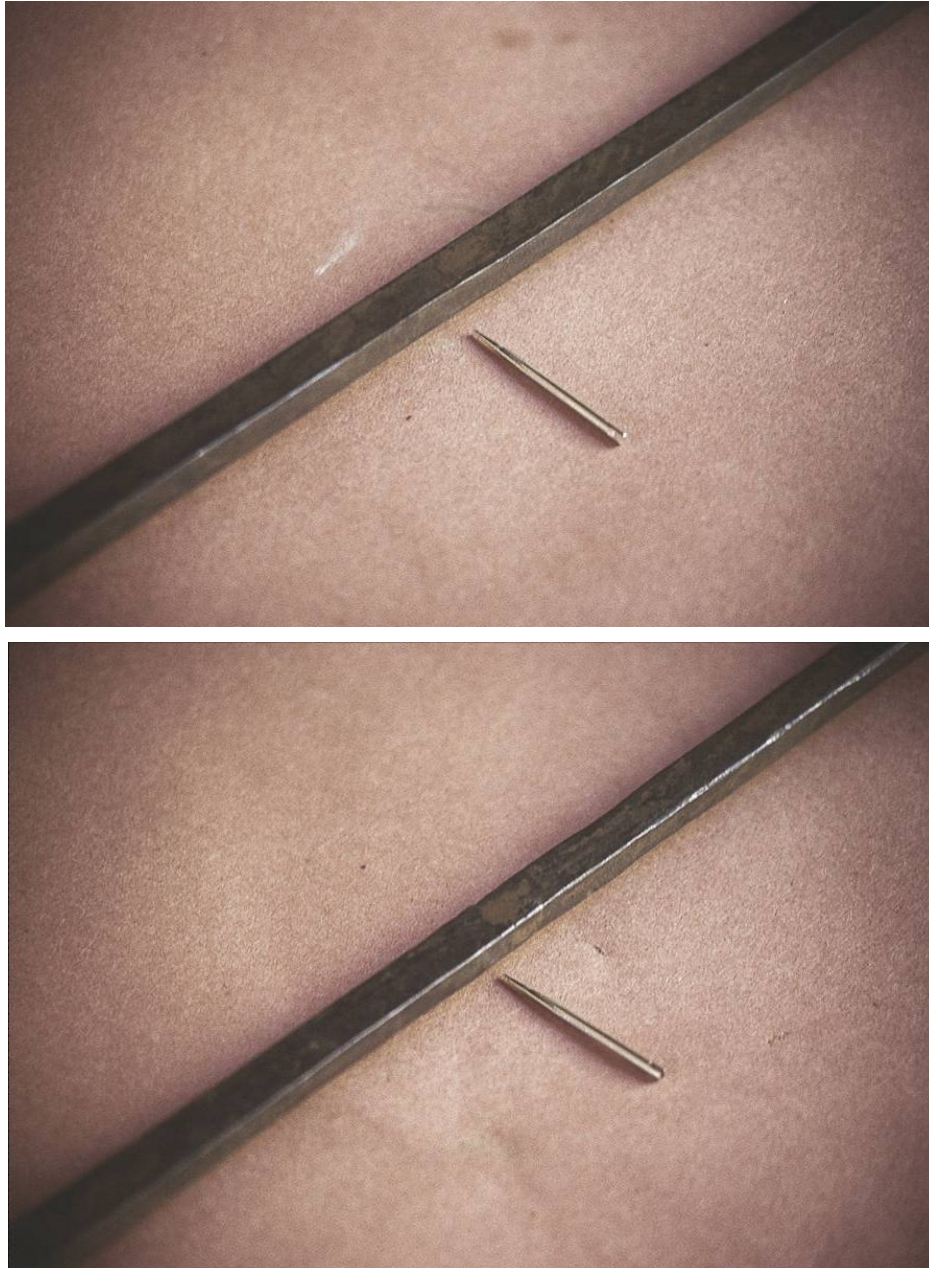


Figure 14. Locations of new welds showing the points where a section of re-created pendulum bar was inserted to restore the pendulum to proper operating length.

#### **4.5 Restoration of the Stand and Provisions for Functional Operation**

Because the *M.R. 1750* clock could be installed in a Saff Collection space allowing the pendulum to swing freely over the edge of a split-level floor, the existing stand was modified for re-use by disassembling it and re-fitting its pieces with dowels and lag screws for additional strength and stabilization. The project blacksmith provided a horizontal forged steel cross brace

for the stand, fabricated and patinated to match the clock frame's center support and support foot. The Saff Collection space also allowed for overhead pulleys and adequate lengths of rope to be wound on the time and strike barrels providing the necessary drop length for functional operation of the clock's weights. The project blacksmith also designed and fabricated a compatible crank to fit both barrel's rewinding shafts. The terminus of the crank handle was forged to match finials on the clock's frame indicating the dedicated function of the crank as a necessary accessory particular to this specific clock. The functionally restored clock has historically correct operation consistent with its likely configuration in 1750, and its operation is the subject of continued demonstration, adjustment and testing within the representational and research purposes of the Saff Collection (Fig. 15). In periods of operation during the first year of its demonstration in the Saff Collection, *M.R. 1750* has proved to be a reliable and dependable, easily adjusted and maintained clock, never stopping due to friction or design deficiencies, striking accurately without missed or miscounted, premature or delayed strikes, and demonstrating timekeeping accuracy within the 2 min./week expectation for well-functioning clocks of its historical period and type.

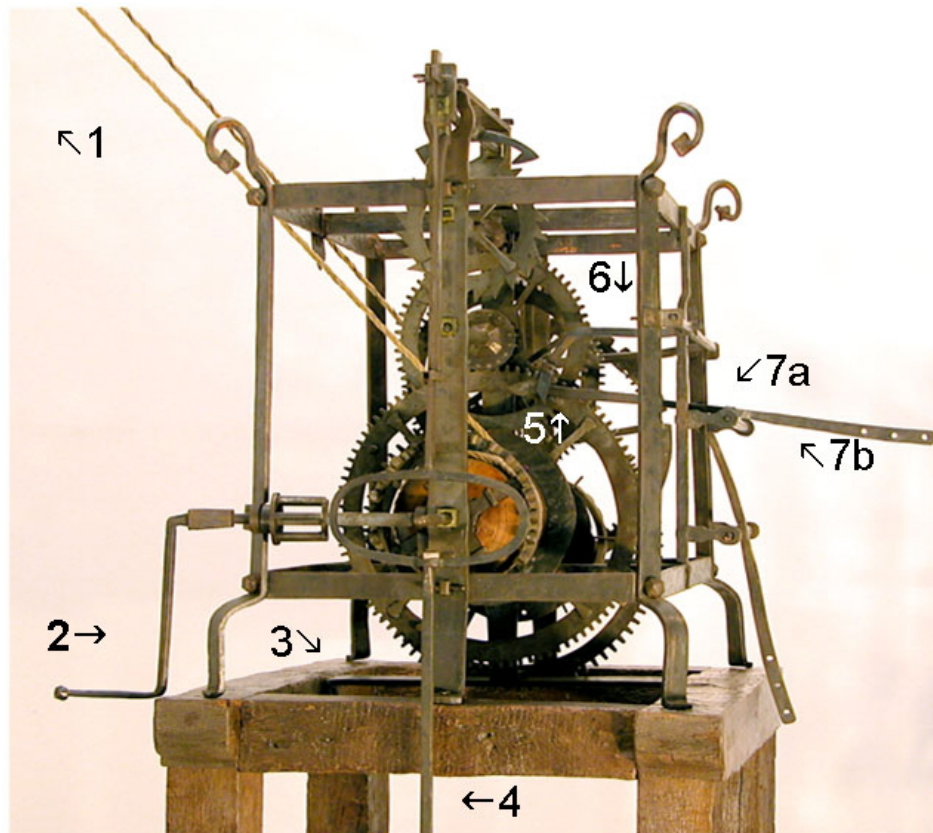


Figure 15. The *M.R. 1750* clock after treatment. Arrows indicate locations of: 1. Re-created strike train weight; 2. Re-created winding crank; 3. Re-created stand brace and center support; 4. Restored pendulum; 5. Restored hour lift pin; 6. Re-created hour strike release arm; 7a. Re-created quarter hour release assembly - brackets and arbor bar; 7b. Re-created quarter hour release assembly - quarter strike lift arm and hammer pull.



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## Suppliers

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Paste Wax (Butcher's Boston Polish Amber Paste Wax):  
The Butcher Company, Marlborough, MA 01752

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## PRESERVING THE MOUNTAIN

Gerri Ann Strickler

### Abstract

Outdoor sculpture in New England requires a financial commitment of annual maintenance that is difficult for some owners to bear. A unique sculpture in Lenox, Massachusetts, by Gaston Lachaise, *La Montagne*, is a good example of this kind of commitment. The larger than life concrete sculpture is the last in a series of reclining female figures by the artist.

Years of exposure have created a challenging multi-phase conservation project. Virtually no documentation about the original condition of the sculpture was available. The earliest phase consisted of an investigation into the artist's materials and methods, followed by stabilization of the delaminating and friable concrete material. The future of the sculpture is yet to be fully determined. Issues surrounding the treatment include restrictions of the site, the unique nature of the deterioration stemming from method of construction and the artist's intent, acceptable amount of annual maintenance, and degree of deterioration expected in a damp wooded environment. The most recent phase of treatment included designing a mount to both support the sculpture in-situ, as well as during transport if moved indoors in the future.

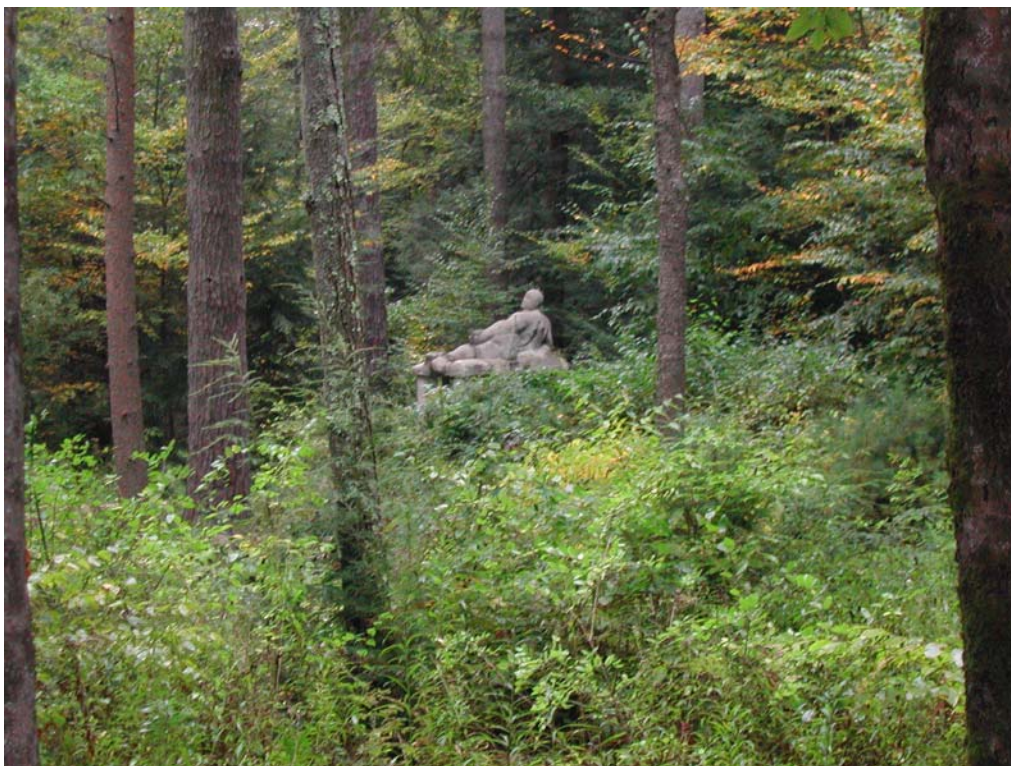


Figure 1. *La Montagne* as seen on the grounds of the Frelinghuysen Morris House and Studio, 2004.

## 1. Introduction

The outdoor concrete sculpture *La Montagne*, by sculptor Gaston Lachaise, is a reclining female nude. The hollow sculpture is larger than life, measuring approximately 9 x 4 x 3.5 feet and sits six feet high on six concrete pillars. The sculpture resides in Lenox, Massachusetts, on the forty-six acre estate of abstract American artists George L. K. Morris and Suzy Frelinghuysen. Lachaise established a friendship with Morris that led to discussions beginning in 1933 of a commission for a large outdoor figure cast for his country studio and house. Visits to the grounds together allowed Lachaise and Morris to both choose the exact location for *La Montagne*. The sculpture sits among tall pine trees and is separated from the house and studio by a stream (Fig.1).

There is considerable tree growth between the house and the sculpture. However, it is likely that the sculpture was originally more visible from the upper floor of the house. In his book *Gaston Lachaise*, Art Historian Gerald Nordland wrote, “Lachaise and Morris had intended the work to become a part of the forest like the great Indian temples, and so it has become” (Nordland 1974, 117). This idea of the artist’s intent and original setting remains a valid point, though debatable in terms of the ideal environment for this one-of-a-kind sculpture.

In 2001, the sculpture was to be moved from its present location to a holding area in the barn on the estate to prevent any further weathering. The conservation center was first included in the project discussion on the day of the move without clear information about the history or future of the sculpture. The owner had engaged a general contractor to move the sculpture by constructing a wood pallet fitting under the sculpture in between the pillars, after which a crane would lift the pallet from six points with strapping. The pillars were then to be cut away and the sculpture strapped down onto the bed of a truck. The service road which provided access to the sculpture was too narrow and the foundation too weak to accommodate the large truck, and the ground proved too wet and soft to successfully allow for the transport that day. The truck was embedded in the mud, unable to drive its own weight off the site.



Figure 2. *La Montagne*, Before treatment, October 2001.

Since the sculpture was in poor condition and could not withstand the amount of vibration and pressure proposed during travel, it was recommended that the client allow time for a thorough examination and stabilization of the sculpture before addressing the task of transport (Fig. 2). During this time, WACC conservators could investigate the history of the sculpture and its importance within the artist's body of work.

## 1.1 History

Letters that Lachaise wrote to his wife Isabel and her son Edward Nagle establish the inception of the sculpture for Morris and the importance of its location. Lachaise began to execute the model on September 4, 1934, on returning from Morris's Lenox estate to his New York City studio. He completed the plaster model by November 29 (Lachaise Papers). The concrete was cast sometime prior to the inclusion of the sculpture in the first retrospective given to a living sculptor at MoMA, held two months later from January 29 through March 7, 1935 (Nordland 1974, 54).

Prior to his visit with Morris at his estate on August 30, 1934, Lachaise envisioned one cement sculpture of four possibilities. Upon his visit, he called the grounds "superb" and decided to cast a large "Mountain" sculpture surrounded by soaring pine trees and uplifted by six posts. The posts and foundation were to be placed by Morris. Lachaise made a full size sketch that he and Morris carried to the spot for consideration (Lachaise Papers; correspondence dated Aug. 14, 30, 31, 1934). Goodall refers to a letter from Lachaise to Edward Nagle containing a smaller sketch of the proposed concrete figure among the pines (Goodall 1969, 667).

*La Montagne* was the last of a series of reclining female nudes entitled *Mountain*. There are eight documented *Mountain* sculptures in stone, bronze, and concrete, made during the years 1913-1934 consisting of four different poses (Goodall 1969). The pose of *La Montagne* is unique to the others, as she is the only one with an outstretched arm. A drawing in the artist's journal has an inscription: "La Montagne, sold in stone to Scofield Thayer" (Lachaise Papers). Intriguingly, the drawing has the proper left arm of the figure extended and the head fully turned in profile towards the feet, more similar to the concrete *La Montagne* than the actual table top Thayer stone sculpture.

Lachaise considered the large concrete figure one of his greatest pieces. "You may say that the model is my wife. It is a large, generous figure of great placidity, great tranquility" (New York Herald Tribune, Jan. 23, 1935). Lachaise is known for the voluptuous female figures inspired by his wife. He died October 21, 1935, and so this sculpture was one of his last completed commissions.

Lachaise worked primarily with stone and bronze. Though his female figures were controversial in conservative circles, he was admired for his carving and modeling skills during his lifetime. It is also worth noting that few of his contemporaries were casting in cement. There are three documented cement projects by Lachaise: *La Montagne* (1934); *Garden Figure*, (1935; a series of five); and large cement reliefs titled *Four Seasons* (1923), for the house of the architect



Welles Bosworth, Locust Valley, Long Island NY (Goodall 1969, 86; Nordland 1975, 28). The first and second casts in the series *Garden Figure* have been preserved within museum collections (Smith College Museum of Art since 1982 and Portland Museum of Art, Maine, since 1961 respectively) and show less deterioration than *La Montagne*.

## 1.2 Fabrication

The method of the construction of *La Montagne* has been pieced together through visual examination of the sculpture and reviewing archives containing newspaper clippings and unpublished correspondence between Lachaise and his wife Isabel, and between Lachaise and Morris. In a telephone conversation with the author, the Lachaise Foundation knows of no existing model referenced in the artist's correspondence.

The sculpture was cast from the artist's model in Ettl Studios, New York City. It was then transported directly from Ettl Studios to the MoMA. This travel received some publicity along with the announcement of the retrospective in New York City newspapers. An article in the *New York Herald Tribune* stated that Ettl's studio was two miles from MoMA.

Seven men with a three-ton truck labored from 10 a.m. until 6 p.m. to bring "The Mountain" to the museum...The casting had to be made in five sections and the center was cast hollow by use of a wire-lathe...The casting floor is in a basement, so block and tackle had to be used to hoist the piece thirty feet into the air and then winchers and rollers were employed to get it into the truck...The transfer was made with only the cracking of one corner of the pediment near the feet of "The Mountain."...He (Lachaise) explained that it was in a medium rare in this country, but frequently encountered in Europe. He finds it highly adaptable to sculptural purposes...(*Herald Tribune*, Jan. 23, 1935)

A timeline of the construction can be made from the artist's correspondence. In a letter dated Sept. 4, 1934, Lachaise writes to Morris after returning to his New York City studio, inspired and proceeds directly to making card board models and an armature for the clay (Morris Papers). During the same time period that Lachaise is modeling the figure in his NYC studio, Morris is casting sculpture in Lenox with guidance from Lachaise. A letter from Morris to Lachaise (Oct. 25, 1934) regarding an armature made by his plumber should not be confused with the construction of *La Montagne*. One month later Morris visited the New York City studio to see the progress (Lachaise Papers; letter dated Oct. 11 or 12, 1934). Another letter to Isabelle dated Nov. 29, 1934, Lachaise wrote from his NYC studio, "I have the Mountain for Morris ready to mold in cement..."(Lachaise Papers). The casting at Ettl Studios occurred between the time of this letter and the day it was transported to MoMA, on January 22, 1935. Lachaise is known to have no assistance in his studio, though a letter to Mme. Lachaise refers to "Geegee who did all the hard preparations for constructing the armatures, etc." (Lachaise Papers; letter dated Oct. 19, 1934).

The Frelinghuysen-Morris Foundation has not confirmed the date of the Lenox installation,, but correspondence between Lachaise and Morris dated Sept.8, 1935, months after the retrospective,

indicates it had yet to be installed. Lachaise recommended Alex Ettl to do the installation, making a concrete pad and pillars. “I have send to Mr. Ettl a drawing which give to him all the direction for the setting of La Montagne...”. The September letter may be the last correspondence, as Lachaise died on October 18, 1935, in New York City. To date, there is no evidence in the Frelinghuysen-Morris Foundation archives of the letters or diagram from Lachaise to Ettl.

Ettl Studios moved from New York to Charlottesville, Virginia in 1940. Four years later Alex J. Ettl returned to New York City to establish Sculpture House Casting (Eriksen 1984). In an e-mail correspondence with the author on June 6, 2006, Sculpture House Casting stated no existing documentation about the fabrication of *La Montagne*.

Lachaise stated in a letter the use of a concrete “preservative” to be applied by Ettl for “durability” (Morris Papers; letter dated July 17, 1935). The use of a preservative or surface treatment was mentioned also in an unknown newspaper clipping among the documents contained in the AAA Gaston and Isabel Lachaise Papers. It is not known if or what treatment was done by Ettl or Lachaise to preserve the surface of the sculpture. Published literature concerning cement and concrete list possible applications of oil based coatings or thin washes of cement to fill in the pores of the surface to render it more water repellent (Ashurst 2002; Houghton 1911). The surfaces of the first two casts of the *Garden Figure* do not give clarification. The Portland *Figure* exhibits a discolored coating, however, the sculpture had been painted by the second owner of the Lachaise residence prior to its accession into the Museum (Barry 1995).

The method of concrete casting is limited to two options: dry tamping and a wet pourable method. The extent of weathering on the exterior surface of *La Montagne* lacks has removed manufacturing or casting information. The areas of loss exposed the layers of concrete, metal lathe and rebar used. An article in *Newsweek* reports that the “cement coat is only 2 inches thick” (*Newsweek*, Feb. 2, 1935). This likely refers to the top layer, as there are clearly several layers equaling more than two inches. A *New York Times* article described the sculpture as having an earth brown cement color (Jewell 1935). Today, the visible aggregate is of varying size and color. It is not known if a more brown colored top cement coat has weathered.

Lachaise preferred to finish his bronze sculptures himself and do all his own stone carving. Given his approach, it is very possible that he could have done some finishing to the cast cement sculpture once out of the mold. There are chisel marks visible along the backside of the figure. Though they are eroded to some extent, it is unlikely that such fine detail was cast-in. It is documented that Lachaise used an air chisel in 1930 (Goodall 1969, 148; Lachaise Papers, letter dated July 20, 1930); however, in the author’s experience, these marks lack the characteristics of an air chisel used on cured concrete.

## 2. Conservation Project

The project included a phase for examination, repair of the concrete pillars, and removal of biological growth (2002); a second phase for structural repair of delaminating concrete layers

and reconstruction of the feet (2003-4); and a final phase for long-term maintenance planning and possible mount design. Each phase was proposed separately, for incorporation into the budget for the following season. The proposal for the last phase is still being considered for approval. The rising cost of steel in our present economy has made this particular phase of treatment difficult to estimate.

Though the owner had maintained the sculpture to some extent, there were many structural problems. The significant problems identified were the loss of concrete to the pillars, edges, corners, and feet, surface erosion, failing previous repairs, cracking, delamination of layers, active iron armature corrosion, freeze thaw damage, disaggregation or weakening of concrete fabric, high moisture retention, and biological growth.

## **2.1 Phase One**

### **2.1.1 Radiography**

On-site radiography of the sculpture confirmed the presence of an interior armature for the otherwise hollow sculpture. Iron pipe with threaded ends, plumber's piping, exists inside along with iron rebar around the edges. Unfortunately, the radiography could not provide other pertinent information about its condition, such as hidden cracks or extent of delamination or movement of the interior layers. Other methods of monitoring are currently being investigated, such as ultra-sound mapping.

### **2.1.2 Examination**

The temporary wooden support of posts and plywood platform, installed by the owner, were removed to allow examination of the underside and drying of the sculpture. The plywood provided a steady supply of moisture.

There are three visible layers of concrete, and a possible fourth. There exists a topcoat containing different size and color aggregate, a brown coat, and a scratch coat with the metal lathe. Though the figure is hollow, the extent of cement, if any, beyond the scratch coat surrounding the pipe armature is not known. The metal lathe appears to be welded at intersecting points versus a cast lathe. The top layer is delaminating allowing water retention and moss growth. The exposed metal lathe and rebar were corroding. Huge quantities of loose material, like sediment, were falling away at the feet (Fig. 3). Loose portions of the concrete around the perimeter and feet of the figure were collected. Most pieces were determined to be repair materials and kept in storage by the owner instead of being reattached to the figure during treatment.

Pieces of lime migrated from the interior layers during carbonation of the concrete. As the cement in concrete cures, calcium hydroxide and calcium silicate hydrate form. As carbon dioxide, supplied by air and water, reacts with calcium hydroxide, calcium carbonate and water is produced. This is usually visible as efflorescence in new concrete. When calcium hydroxide is

removed from the cement paste, then the remaining calcium silicate hydrate will liberate calcium oxide or lime.



Figure 3. Before treatment showing partial loss of feet with inner layers exposed, October 2001.

The weak top layer is weathered, clearly exposing the aggregate. A more sheltered area along the back of the figure more clearly retains chisel marks.

Disaggregation, or sugaring, occurred underneath most modern repairs. These repairs were made with modern harder cements, which are not nearly as porous, lowering the water transition rate at the interface so that water was retained (Fig. 4). This also occurred where certain edges of the sculpture were coated with an unknown sealant in a previous repair attempt.

The sculpture was further probed to determine the extent of moisture content and concrete stability. A concrete pad at least two feet deep under the pillars was detected by probing the soil with shovels. The topsoil and damaging plant growth contributing to rising damp and staining of the pillars were removed.



Figure 4. Clockwise from top left: back corner with previous concrete repair; back corner with previous repair removed exposing degraded original material; back corner with new repair mortar.

### 2.1.3 Pillar Repair

Repairs were made to the two damaged corner pillars. The areas were first keyed with stone chisels and repaired using Jahn M90 concrete repair mortar. A 12-inch diameter Sonotube was used to shape the proper left front pillar, under the feet. High points where a slight squeeze out occurred along the edge of the Sonotube were taken down with a carborundum stone after curing.

### 2.1.4 Cleaning

The sculpture was cleaned using a dimethyl ammonium chloride based biocide (D2 Antimicrobial). A dilute solution was sprayed onto the surface of the figure and pillars, concentrating where moss growth was visible, using a garden sprayer. The surface was brushed where safely possible, and rinsed thoroughly using a hose. The pillars were further cleaned using pressurized water at 1500-1800 psi.

A silicon carbide stone was used to remove calcium carbonate efflorescence, probably liberated



during carbonation, from the front left pillar and around other cracks on the underside of the object. Removed salts were analyzed by FTIR after a series of solvent extractions and also confirmed the presence of unknown acrylics. The source of the salts previous repairs materials as well as calcium carbonate liberated during carbonation.

### 2.1.5 Drying

To reduce trapped moisture from the interior of the sculpture, eleven holes were drilled into the bottom using a Hilti drill and 3/4 in. bit: one hole between each pillar along the perimeter and several in the center. Two small battery powered fans were attached with temporary peel away caulk over the center holes, to pull moist air out of the interior and facilitate the drying process (Fig. 5). The sculpture was then sheltered from direct rainfall using a tarp supported by wood studs. The temporary shelter was in use for eight weeks. The combination of shelter and fans successfully dried the sculpture to the touch during the remaining three months of the season. The sculpture also was drier upon removal of the shelter the following spring.



Figure 5. Underside of sculpture showing ventilation holes and attached fans.

## 2.2 Phase Two

### 2.2.1 Repair of Delaminating Layers

Many delaminated layers were visible along edge losses and adjacent to cracks. After some initial in-lab testing of working properties, set time, and content, a suitable pre-made injection

grout was chosen (Jahn M30). Examination of the dry material under the microscope revealed many glass micro-balloons or similar material. An even weaker grout could be made with the addition of more micro-balloons.

Simple knuckle tapping assisted with locating air pockets. Holes 1/4 inch in diameter were drilled into the air pockets of delaminated layers of the sculpture. These were used to both displace air and receive the grout. The grout was injected with large syringes starting from one end while observing its exit from adjacent holes. Rope caulk was used to dam areas and plug entry holes where needed. After some curing, the holes were plugged with new mortar. Some air pockets remained in less accessible areas. Other possible areas for future injection grouting were documented for future annual monitoring.

### 2.2.2 Loss Compensation

Areas to receive repair mortar were cleaned and prepared by squaring off edges with stone chisels, as needed, and removing loose debris with a stiff brush. Exposed iron armature was cleaned of loose corrosion using a steel wire brush, and then coated with Paraloid B-72. Because an iron armature within concrete in a damp environment is particularly vulnerable to corrosion beyond the expiration of an alkaline concrete fabric, the resin may provide some measure of protection. New mortar was added to all four corners and along the edges where losses of original material had occurred. The area of loss below the feet was packed as much as possible with new mortar before attaching replacement toes and sealing up the edge. A thin coat of new mortar slurry was added to eroded areas on the front torso surface near the chest and proper left hip near the hand in attempt to consolidate and better seal the surface.

In-lab testing of new mortar samples to match tone and surface was performed using dry pigments with the ratio 1:30 parts by weight to dry mortar. Sand was pressed into the final surface with a float.

More reference material was needed in order to reconstruct the toes. In 1989, a rubber mold of the sculpture was commissioned jointly by the Frelinghuysen-Morris Foundation and the Lachaise Foundation. Later in 1991, Modern Art Foundry cast a series of five copies of the sculpture in bronze using the rubber mold commissioned by the Lachaise Foundation. One cast resides on the campus of Cedar Crest College, Allentown, Pennsylvania. A plaster cast of the figure's toes using the 1989 mold was acquired from Modern Art Foundry by the Frelinghuysen-Morris Foundation to aid in the reconstruction. Unfortunately, an aging mold could not give a good profile. The first four toes on the figure's right foot were further built out and reshaped using published photographs of the original, as much as possible. A new flexible polyurethane mold was made at the conservation laboratory from the new plaster cast. A plaster piece-mold and a wooden frame casting box were constructed for a final cast in new mortar.

Initial attempts to cast the toes in-situ were unsuccessful, as the flexible mold could not be keyed into the plaster cast enough to support the weight of the wet mortar. Instead, the toes were cast separately and attached to the sculpture with new mortar within twenty-four hours of curing. The new proper right large toe was attached with a horizontal 3/8" type 316 stainless steel tube.

Minimal shaping was done after curing per client consultation using stone chisels and a silicon carbide stone (Fig. 6).



Figure 6. After treatment showing reconstructed feet, September 2003.

### 2.3 Phase Three

After stabilization was addressed, long-term care including annual maintenance was outlined. The client had new foundation laid from the service road leading down to the sculpture prior to Phase 2. Regular clearing of plant growth from the ground pad was recommended to reduce staining on the pillars and rising damp. Addressing better drainage around the concrete pad by re-grading the slope from the service road and adding gravel was also recommended. It is clear that moisture will always be present on the site and within the sculpture. The goal is to allow the sculpture to dry itself more easily. Annual maintenance is necessary to check stability of repairs, new erosion or cracking, amount of retained moisture, and reappearance of biological growth to be removed. Though annual maintenance has been strongly recommended, the owner has yet to implement a plan.

The larger issues of the inherent limitations of the artist's materials, combined with continual weathering, has led to the design of an external support. The concrete lacks tensile strength along the bottom of the hollow sculpture, resulting in cracks and distortion between pillars. With a minimal amount of material, a strong steel support can greatly reduce further movement. A mount will not attempt to correct prior movement of the concrete, but prevent further slumping and cracks.

The mount consists of the following (Fig. 7): a conforming (perforated) support next to the bottom of the sculpture; 1 ½" x ½" type 304 stainless steel grating, cut to fit between and anchor

to pillars; 4" type 304 stainless steel I-beams (15.25 lbs/ft), 2 down the long length with four intersecting short beams; 8 type 304 stainless steel pipes 2" diameter, with adjustable threaded nuts and 1/2" stainless steel base plates, supporting the I-beams at each intersection, resting on the concrete ground pad. The mount can be keyed to the tops of the pillars and perforated to allow for air circulation and moisture release. Because the sculpture has some distortion, an additional removable conforming support (epoxy putty or similar material) will be used between the perforated plate and the bottom. The idea of a perforated plate and perforated epoxy putty must be further considered to allow air circulation. There will be four stainless steel adjustable pipes supporting the steel beams of the mount. The visible metal can be painted a similar color as the concrete to hide it as much as possible (Fig.8). The ground-to-sculpture supporting elements will be partially hidden by the pillars from certain viewpoints.

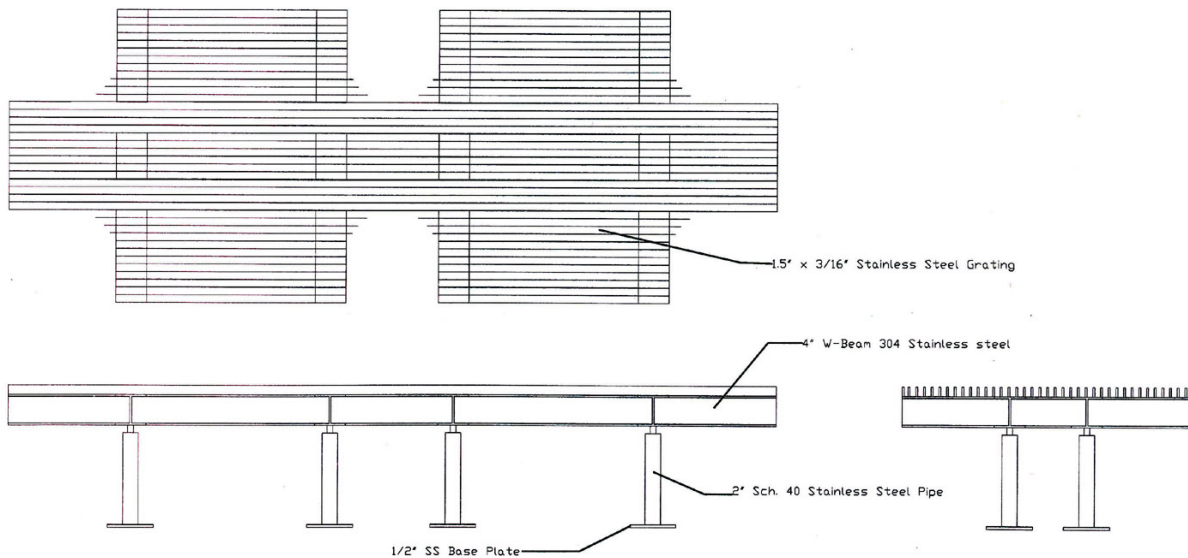


Figure 7 (above). Diagram of the mount. Two views of the plate underneath the sculpture and adjustable pipes supporting the plate. Not to scale.

Figure 8 (left). Simulation of proposed created with Adobe Photoshop. Not to scale.

The mount will be modified to a more efficient design with the smallest amount of raw material, and the smallest number of stainless steel welds, that can be used without compromising the strength and dual purpose of its intended use. A team has been assembled to address the final design, fabrication, and installation, consisting of WACC conservators, a metal fabricator, a consultant specializing in the preservation of historic structures, and a consulting structural engineer well versed in preservation.

Prior to the design of the mount, discussions with the owner and other professionals regarding an external mount versus internal strengthening were carried out. The weight of the figure requires a strong and durable support material without further straining the precarious concrete fabric. Adding irreversible material to the interior would be intrusive and was therefore not proposed. The support during installation will also increase visitor safety, as the sculpture is completely accessible for visitors to walk under it between the pillars as well as around it.

If the preservation of the sculpture is compromised to the point that it must be relocated indoors, the sculpture must be well supported during transport. The danger of collapse of the hollow figure is great during transport, caused by vibration and lifting. The lifting of the figure can be done either by crane and/or forklift via the steel beams in the proposed mounting support that would be keyed between the pillars and base. A replica made from a lighter weight material with the visual surface characteristics (which are lacking in the 1990 bronze cast) is recommended to replace the sculpture if moved indoors.

The cost of stainless steel has more than tripled since 2002 when conservation treatment of the sculpture was first started by WACC. The inclusion of type 304 stainless steel has therefore been reduced to type 304, which is less expensive. Though the design is likely to be modified, the most appropriate material continues to be stainless steel. The cost of this mount is therefore subject to the cost of stainless steel at the time of fabrication.

### 3. Conclusion

The sculpture resides in a damp area and retains a large amount of moisture year round, which perpetuates or causes some of its structural problems. It did not have a winter shelter for many years and suffered from freeze thaw damage. The maintenance of the sculpture had been, for years, more of a general approach to grounds maintenance. Low cost minimal concrete repair with readily available materials by the owner was done with good intentions, but without taking into account other important needs.

Though Lachaise thought highly of the preservation of cast concrete sculpture outdoors, William Zorach, friend and sculptor did not share his view. He wrote in his monograph *Zorach Explains Sculpture*, "Cast stone (crushed stone, sand, and Portland cement) can be permanent indoors but out of doors it has a tendency to crack and disintegrate" (Zorach 1947, 149).

The author suggests a limitation of artist's materials in this environment in addition to the added responsibility that perhaps the owner was not prepared to handle. The preservation of this



sculpture extends beyond the cost of most single outdoor metal or stone sculpture. Did the artist really intend for it to degrade in-situ? Though he had a great appreciation for classical ruins, he also thought the concrete would be durable. Around this same time in America, major structures had been erected using concrete. In addition, Lachaise had been receiving more architectural commissions.

Because it is quite an important work for this artist, a compromise between the two specialties of historic preservation and sculpture conservation is needed to maintain *La Montagne*. The goal of annual maintenance is to replace as little as possible. This will allow its life outdoors, as the artist intended, to be prolonged. The conservation center will continue to work with the owner to provide the best possible solutions for this unique sculpture.

### Acknowledgements

The author would like to thank the assistance of colleagues at the Williamstown Art Conservation Center during the conservation treatment and the Lachaise Foundation for assisting with historical research. The author would also like to thank the guidance of consultants, most importantly Bill Foulks, consulting historic preservation professional and adjunct professor at Rensselaer Polytech Institute, Troy, NY.

### Suppliers

D2 Antimicrobial (active ingredients of dimethyl ammonium chloride and alkyl dimethyl benzyl ammonium chloride), Jahn M30 (cement based injection grout without acrylic additives), Jahn M70 (cement based repair mortar without acrylic additives):

Cathedral Stone Products, Hanover, Maryland, (800) 684-0901, ([www.cathedralstone.com](http://www.cathedralstone.com))

Dry Pigments:

Kremer Pigmente, 247 W. 29<sup>th</sup> Street, New York, NY 10001, (212) 219-2394, (800) 995-9501

Paraloid B-72 (copolymer of methacrylate and ethyl methacrylate):

Conservation Support Systems, PO Box 91746, Santa Barbara, CA 93190, (800) 482-6299

Sonotube:

local hardware store

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## **THE CONSERVATION AND RESURRECTION OF SEVEN CLAY COFFINS FROM NIPPUR**

Julia B. Lawson

### **Abstract**

The collection of seven Assyrian, Seleucid and Parthian clay coffins in the Near Eastern collections of the University of Pennsylvania Museum of Archaeology and Anthropology were excavated at the Mesopotamian site of Nippur in the late 19<sup>th</sup> century. They were restored shortly thereafter for display in the Museum's Babylonian galleries where they remained until 1940, when reinstallations consigned the objects to sub-basement storage. They were largely forgotten and their physical condition gradually deteriorated. By the late 20<sup>th</sup> century, the original restorations were crumbling, the coffins were collapsing under their own weight and it was feared that soluble salts were greatly weakening the fabrics. An Institute of Museum and Library Services grant enabled the Conservation Laboratory to assess the condition of the objects, conduct treatment and provide storage supports.

### **Introduction**

The collection of Mesopotamian clay coffins from Nippur in the University of Pennsylvania Museum have a long and varied history. The coffins were uncovered in the late 19<sup>th</sup> century by the University of Pennsylvania's Babylonian Expeditions, conducted in four campaigns between 1889 and 1900 in what is today southern Iraq. These were the first American excavations in Mesopotamia, as well as the University's first expedition to any site outside of the United States. The prospect of large and significant shipments of artifacts from Nippur provided the impetus for the building of the University Museum, and the material from Nippur was the first major excavated collection to be housed and exhibited there. These Babylonian clay coffins are the only such artifacts known to reside in the New World.

The history of the University Museum, the Nippur excavations and the establishment of a Department of Archaeology at Penn are completely intertwined. Provost Dr William Pepper was instrumental in founding the archaeology department and accompanying museum almost simultaneously with committing the University to the Babylonian Expedition. He made a promise to the Expedition organizers that the University would provide proper accommodation for the excavated finds in a fire-proof building. The Museum officially began in 1889 as the Museum of Archaeology and Paleontology, which occupied a large room on the top floor of College Hall, with a variety of New and Old World casts and antiquities for the edification of the student population.

It quickly outgrew this space largely through the efforts of Pepper, a group of wealthy patrons headed by E.W. Clark, Sara Yorke Stevenson, Curator of the Egyptian and Mediterranean Sections, and Herman V. Hilprecht, Professor of Assyrian. Hilprecht urgently requested "objects illustrating the life and customs of the various peoples of the Old Testament to the growing

number of theological and philological students in the University.” (Bulletin 1897, 32) The Nippur excavations began to provide these, along with Hilprecht’s own efforts to obtain casts of Near Eastern objects from other institutions and private collectors. Late in the following year of 1890, the Museum expanded into several rooms and a stairwell of the new University Library. It was described as a place where students and the general public could view artifacts illustrating the “history of art, architecture, manufacture and of civilization in general among ancient peoples” (Jastrow et al. 1892, 18). The collections soon outgrew this space as well, and not surprisingly, the Library coveted the Museum’s space for its own collections. Hence, an ambitious and expeditious building campaign was begun in 1892 to erect the Free Museum of Science and Art, which would later reorganize as the University Museum.

### **The Babylonian Expeditions**

Meanwhile, in Mesopotamia, field notes and letters from the Babylonian Expedition are rife with tales of hardship - from days of scorching heat, dust storms, political strife, mud flies, fleas and disease to nights disturbed by shouting, gunshots, mosquitos, bedbugs, jackals and more illness. There is even an account of a plague of locusts. For this privilege, the excavators spent most of the first field season in Constantinople, as it was then known, entreating officials of the Ottoman Empire for excavation permits and permission to export their finds. The Expedition’s financiers understandably wanted to see crates filled with the most significant finds for the nascent museum in Philadelphia. Just as reasonably, at least by today’s standards, the Director of the Imperial Ottoman Museum and His Majesty the Sultan desired that all of the objects, no matter how humble or grand, become the property of *their* museum. Months of negotiations between Dr. John P. Peters, one of the originators of the Expedition and its director for the first two field seasons, and Hamdy Bey, Director of the Imperial Ottoman Museum, resulted in a firman or permit to excavate at Nippur with the stipulation that all material be sent to Constantinople (Peters 1897). Penn’s Museum, to their consternation, would be allowed first choice of material deemed superfluous to the Imperial collection.

With this uncertainty in the back of their collective minds, the Expedition made the long and winding six week journey to the backwater site of Nippur by horse and camel caravan. In subsequent field seasons much or all of the trip would be made by boat down the Euphrates and through the swamps of Afej, but for that first trip the business manager and photographer, John Henry Haynes, was demonstrating extra care with the budget while providing his superiors with a romantic experience. The first field season found no evidence of any spectacular objects with which to create a blockbuster exhibition at Penn, but they did uncover the beginnings of a trove of inscribed tablets. In keeping with the general air of misadventure, the Expedition was forced to beat a hasty retreat near the end of the first season when ill will between the camp’s Turkish military guards and the local Arabs flared into violent conflict. The field camp was burned to the ground and its equipment and funds plundered (Hilprecht 1904). Fortunately, the officers of the Department of Archaeology and the Babylonian Exploration Fund, who did not have to deal with any of this first hand, kept their enthusiasm for the excavations and persuaded Peters and Haynes to go back for a second season.

Haynes would lead the third and fourth campaigns and be largely responsible for the excavation

of the collection of clay coffins, despite a certain lack of enthusiasm for them by the Exploration Fund back home. He writes about a group of coffins in a letter sent from the 3<sup>rd</sup> field campaign:

Seven coffins are now prepared for transportation and await the possible addition of others to their number. Four of these are the so-called slipper pattern. One was coated with a pale blue glaze, which on exposure to the sun quickly faded to a pale green color. This coffin is richly decorated with a sort of rope ornament dividing the body of the coffin into four smooth panels, in the center of each of which is the well known female figure in high relief. Three of them are unglazed; are without trace of color, and show but little attempt at decoration of any kind..."(Haynes 1894).

He goes on to say,

It seems to me a matter of time expense and care, tempered with some skill, to collect and preserve all existing types of coffins to be found at Niffer, Warka, or any other place of extensive sepulture in Babylonia. Am I, therefore, mistaken in thinking that a complete and well arranged collection of such coffins would awake a deeper and livelier interest among laymen, and the general public, than collections of smaller objects, that are found at Niffer? I would not for one moment forget that the first and chief object of exploration is to establish authentic history by whatever feeble accents, and broken record it come to us from the remote past. Yet so far as it can be done incidentally and in subordination to the more important task of gathering inscriptions and works of art, the burial customs and accoutrements of any great civilized nation of antiquity are most valuable adjuncts to the proper study of history and Archaeology" (Haynes 1894).



Figure 1. Excavated slipper coffins in situ during the Fourth Expedition. J. H. Haynes. UPM Neg. #148755



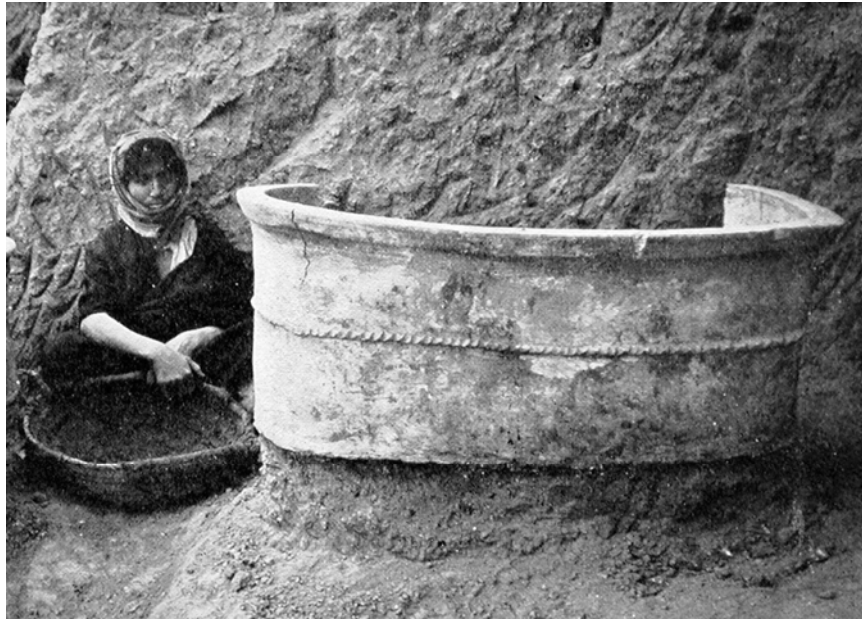


Figure 2. A bathtub coffin in situ with local laborer. J. H. Haynes (from Hilprecht 1904, 337).



Figure 3. Coffins being heavily faced with paper and glue in preparation for shipment to Constantinople. UPM Neg. # 148759

It was no easy task to salvage these large degraded clay objects, especially in an “incidental subordinate way”. Haynes often mentions that coffins are “badly broken.” Other descriptions mention that the “porous yellowish (green) terra-cotta is so rotten that although about 3/4 of an inch thick, it is easily broken in the hand.” Hilprecht noted that W. K. Loftus of the British

Museum, about forty-three years previously at the site of Warka, only succeeded in removing similar coffins after many fruitless attempts and the demolition of perhaps a hundred specimens. Haynes benefited from Loftus' experiments and experiences in coffin moving and employed his ultimately successful method of facing them inside and out with thick layers of paper and paste. At the time, Hilprecht, wrote of the facing that "When thoroughly dried, this hard mass became like a sheath, strengthening and protecting the enclosed coffin, which now could be lifted and handled without difficulty." He cautioned, though, that "It is by far wiser to save and pack all the fragments of glazed coffins separately and to put them together at home in a strictly scientific manner," as the facing method is "most damaging to the blue enamel" (Hilprecht 1904, 142-43). Presumably this refers to the difficulties of facing flaking corroding glaze that could also be poorly bonded to the clay substrate, both of which were observed one hundred or so years later during conservation. Despite all obstacles, Haynes sent at least twenty coffins to Constantinople in the 1893-94 season and over thirty large, well- preserved sarcophagi a year later.

### Coffins in the Museum

In the 1890s, approximately 5200 objects, including at least eight coffins, were shipped from the Imperial Ottoman Museum, now the Istanbul Archaeological Museum, to Philadelphia. Museum catalogue cards list the restorer as a William H. Witte. He was employed by the University Museum in various collections-related capacities and is better known there as the first Museum photographer. The image of the original gallery featuring material from Nippur was likely produced by him (Fig. 4).



Figure 4. Four slipper coffins can be seen in the Baugh Pavilion, c. 1899, one of two original galleries devoted to the Babylonian expeditions. UPM Neg. #22428

The new Babylonian galleries were a prime attraction in the new permanent Free Museum of Science and Art when it opened in the autumn of 1899, and the clay coffins remained as prominent fixtures in the Nippur exhibition for the next 40 years. During that time, the University's field work expanded to several other sites, including three more in the Near East: Beth Shean, Tepe Gawra and Ur. These discoveries received considerable popular attention throughout the late 1920s and 30s as well as scholarly study. The Great Death Pit of the Royal Tombs of Ur, with its media-conjured images of sex, violence and riches, particularly caught the popular imagination in a way that eclipsed the more staid governmental and religious center of Nippur. By 1940, the original Nippur galleries were considered dated from both an academic and stylistic viewpoint, so the Victorian displays were dismantled and the clay coffins sent to a sub-basement storage area to make way for a modern comprehensive display of Mesopotamian art and archaeology. There they were largely forgotten as older curators and other collections staff retired or moved away. Eventually an ambitious intern (now a registrar) conducting an early computer inventory tracked them down in the 1980s and was able to point them out a few years later to a relatively new Associate Curator inquiring after lost coffins. He was thrilled to finally see them, but horrified at their deteriorating condition. Recognizing the importance and rarity of such objects outside of Baghdad and Istanbul, he approached the Conservation Laboratory and suggested that the coffins be resurrected.



Figure 5. Coffins on the old shelves in the basement. Slipper coffins are on upper left and middle shelves, bathtub coffins are in upper right and trough coffins are on bottom shelves.

### Coffin Types

The coffins are of three distinctive styles, referred to as bathtub, trough and slipper coffins as befits their shapes. The bathtub coffins have flat bases and deep vertical sides with one rounded

and one square end. They usually had wooden lids and were either plain or very simply decorated. This is the oldest type, originating in Assyria, or northern Mesopotamia, in the mid to late 2<sup>nd</sup> millennium BCE. Its use spread south to Nippur, where they continued to be used into the 2<sup>nd</sup> century BCE, or the Seleucid period, named for Seleucus, success to Alexander the Great. Trough coffins came into use in Babylonia in the late Seleucid period. The troughs, as one might expect, are long and narrow with straight shallow sides, 2 rounded ends and no decoration. They originally had 2-part ceramic lids, though they are not extant in this case. Slipper coffins were introduced into Nippur by the conquering Parthians in the 1<sup>st</sup> century CE. Presumably the corpse was slid into the oval opening rather like a foot into a slipper. A rope tied around the ankles and pulled through the foot hole may have aided this process. Two of the Museum's slipper coffins are unglazed and have very simple modeled geometric or pinched rope-like decoration. A third is glazed and has a more distinctive design with four molded female figures in panels, possibly the deity Inanna, that seems to be exclusive to Nippur (Zettler 2002).

### Conservation

The treatment phase of this narrative is written with the caveat that no groundbreaking protocols were developed. The historical thread will continue along with observations about condition, treatment choices and necessary compromises.

To start with, one of the greatest challenges posed by the unglazed slipper and trough coffins was coaxing them out of the old three-tiered shelving which was set into a wall recess along a dimly lighted narrow aisle with pipes running across the floor. All seven coffins rested there with little or no clearance in any direction. When possible, each coffin was prepared for moving by bracing with pallet shrink wrap run longitudinally around the sides and transverse bandages of soft Tyvek spun bonded high density polyethylene sheet tied around them. Several able bodied assistants were then drafted to ease a Mylar covered board between the coffin and the shelf. Both were then slid from the shelf and placed on a cart, where the object was then wrapped more securely with pallet shrink wrap so that it could be lifted over the pipes, pushed up a steep ramp, maneuvered into a passenger elevator and eventually lifted onto a worktable.



Fig. 6. A trough coffin is seen with pallet wrap and Tyvek bandages after removal from the basement.

The project began with the smallest, most intact, most readily transportable coffin as a manageable subject with which to become familiar with the clay fabric, the old restoration materials and condition problems. What was first apprehensively seen as a friable exterior slip layer under a coating of grime turned out to be, upon closer examination, modern paint and gap filler used to obscure break joins, stains and accretions degraded by a water leak in sub-basement storage. Cleaning revealed two apparent campaigns of adhesive mending. Exterior surfaces were completely filled and inpainted, with the hard adhesive-like fill material extending well beyond the break joins and lacunae, completely obscuring several of the mends. It was marked by some shrinkage cracks, but was in generally stable condition except for the localized areas of water damage. Visible mends held a stable brown adhesive. Spot testing (Biuret test; Odegaard 2000, 144-45) indicated that the plain adhesive was a proteinaceous glue and the loss compensation consisted of animal glue bulked with a calcareous material (which effervesced in HCl) and paper pulp. The interior surfaces of the coffin presented a different picture. A heavily crazed and crumbling brittle yellow-brown adhesive, identified as a cellulose nitrate by spot-testing (diphenylamine test; Odegaard 2000, 164-65) and solubility, could be seen in many of the break joins. The joins were reinforced with staple-like non-ferrous wire ties that span the breaks and have their bent ends embedded in small drilled holes filled with a soft putty.

At first it was thought that the cellulose nitrate may have been used to consolidate old joins, perhaps when the object was shifted into or from the gallery, as such mends are not unusual in the Museum's collections. Further consideration and observation as the project progressed, however, led to the theory that the cellulose nitrate was applied in the field, though proof of this could not be found in the field reports or incomplete supply lists. If employed as a later consolidant, it likely would have appeared as accretions on at least some of the wire ties, but this was not observed. The adhesive's original claims to fame were its ability to be used straight from the can, long shelf life, relatively fast setting time, strength and waterproofness. It was marketed early on as repair adhesive for canvas and birch bark canoes and became popular with outfitters such as the Hudson's Bay Company. It could have been a natural for fieldwork by Americans beginning in the late 1890s.

Back at the new Museum, the restorer, William Witte, likely had access to the latest methods in museum restoration, the "strictly scientific manner" espoused by the Assyrian curator. Friedrich Rathgen of the Royal Museums, Berlin, recommended animal glues, shellac or sodium silicate for mending broken pottery and "stone cement" for gap filling. This consisted of Cologne (or hide) glue boiled together with shredded paper. It was to be stirred continually with a stout wooden rod while adding, in turn, sifted whiting, linseed oil and Venetian turpentine (Rathgen 1905). A variation of this, probably with little or no oil and turpentine, does indeed seem to be what was found compensating for losses both large and small in the coffins. It appears that Witte used animal glue to repair any joins that failed or new breaks that occurred during the arduous journey from the East, then reinforced all joins with the wire ties. He then filled lacunae and gaps with the stone cement, partially obscuring some of the ties. Lastly, each coffin was given several low conical disk feet of plaster and stone cement for exhibition purposes. These later became a destructive force in the large coffins, as they lent highly uneven support to the bases.





Figure 7. Underside of an unglazed slipper coffin after the mechanical removal of old black painted plaster and stone cement feet.

These observations provided welcome insight into the considerable problems of the other much larger and fragmentary bathtub coffin, which was also more seriously degraded. Many of the sherds were only held in place by gravity, some were tenuously attached with wire ties and many fragments had fallen from the sides of the object. The collections Keeper had gathered many loose fragments into trays over the years, including some picked up from the floor. At least its condition made it a relatively simple matter to load the various sections and sherds onto a Rubbermaid cart for easy transport to the Conservation lab, though treatment would be a lengthy process. Once again, the initial fear that the clay fabric may have been weakened by soluble salts, possibly to the breaking point, quickly dissipated. Almost all of the break edges were old weathered breaks with adhesive accretions. Spot testing showed that virtually all of the failed joins were made with cellulose nitrate, either plain or bulked with an inert white material, probably plaster. And again, intact joins held animal glue and glue-based stone cement. Thick powdery residues of degraded fill material coated everything. Cleaning of detached sherds in water baths after vacuuming yielded further evidence of past treatment, as many of the fragments quickly turned the water a clear amber color. Though this was not analyzed, a plausible explanation, given the object's history, is that it was a vegetable gum used as a facing adhesive, and perhaps applied more heavily in some areas as a sort of consolidant. Testing of soaking water for chlorides with the silver nitrate spot test indicated relatively low to moderate amounts. As no salt damage could be seen, it was decided that salt removal would be an unnecessary expense of time, which was not limitless, and could potentially cause more harm than benefit to the low-fired ceramic.

Old mends that were unstable but had not completely failed were undone. As with the first coffin, it was decided to leave the rest of the old mends in place and consolidate them with liberal applications of Paraloid B-72 in acetone and bulked B-72 where necessary to conserve both time and the often friable break edges. The wire ties were left in place in such areas, as they were causing no harm, are generally not visually disturbing as they are limited to the interior surfaces, and are part of the object's history. They were inpainted with Golden Acrylics acrylic

emulsion paints wherever they were deemed aesthetically intrusive. Oversized areas of reconstruction, mainly in the bull nose rim and corners, were pared down and surfaces obscured by it were uncovered. The coffin was then reconstructed from the base up, with much musing over fragment placement. It was readily apparent, after the lower half or so of the wall was reattached, that the side walls had all broken along the same point, slightly more than halfway up. A horizontal indentation encircled the coffin along with a slight angling of the sides up from this point. This appeared to be a seam where long slabs of clay were joined in the manufacturing process. One big slab formed the base, two long rectangular slabs formed the left, curved front and right sides and two shorter slabs formed the square rear side of the bathtub coffin. The rim was modeled separately and luted on. Not surprisingly, this object, and indeed all the coffins, failed along the seams. All had breaks around the perimeter of the base, and in this case, because of the much greater depth of the sides, at the seam in the side walls. The join between the heavy rim and the top of the sides was also unstable. Further evidence of fabrication could be seen in areas with impressions of plaited basketry or matting (such as seen here) on the exterior and fingermarks on the interior, particularly at the seams. This would indicate that clay slabs were likely patted out and handled on large reed mats, a common work surface in this part of Iraq well into the 20th century (Ochsenschlager 2004, Figs. 4.15, 7.3, 7.4).

Significant losses along many of the seam break edges and the straight unkeyed nature of several others above and below the seam made extra support necessary or advisable in some areas as the fragments were reattached. It was reluctantly decided that that a judicious number of dowels could meet this end, but they needed to be either flexible enough to bend or weak enough to break if the object met with accidental mechanical stress. Extruded acrylic rod of 1/8" and 3/16" diameter was chosen because it can be easily snapped in two and appears to be weaker than the ceramic, while still lending an extra dimension of support. The large gaps spanned by the dowels were then filled with plaster of Paris cast in place, while narrower gaps were filled with Paraloid B-72 bulked to a putty-like consistency with glass microballoons. Plaster was poured into large gaps in vertical side walls after making molds with Vigor firm green sheet casting wax, 16 or 18 gauge, held in place with non-drying modeling clay similar to Plasticine. Deionized water was brushed liberally onto surfaces adjacent to these lacunae before applying mold materials to avoid adherence of both oily clay and plaster residues. The ceramic was sufficiently textured to allow a secure mechanical bond.



Figure 8. The largest intact section of the 2<sup>nd</sup> bathtub coffin. Wire ties across break joins can be seen in the exposed interior surfaces.



Figure 9. Coffin during reconstruction showing breaks along the horizontal center seam (square back end is to the left, rounded end to the right).



Figure 10. Front of coffin during treatment.



Figure 11. Upper central fragment group held in place with acrylic rods prior to gap filling.



Figure 12. Object is nearing end of reconstruction. A sheet wax and modeling clay mold in the upper left corner is ready to help form a lost section of rim where old loss compensation was discarded.



Figure 13. Object after treatment. The center of the rim was deformed originally, apparently from handling during manufacture while the clay was still pliable.

Treatment of the rest of the coffins was conducted in much the same way; they proved to simply be oversized ceramics with the usual problems encountered in clay, but amplified by size.

After treatment, the coffins were each placed on their own dolly/storage support to facilitate transport to the Near Eastern collections storage rooms and allow them mobility within the space. These were constructed of  $\frac{3}{4}$ " plywood sealed with acrylic latex paint, fitted with six heavy duty 360° swivel casters and covered with  $\frac{1}{4}$ " Ethafoam closed cell polyethylene foam sheet. Both ends were given two large eye hooks so that double-ended dolly handles of braided

synthetic rope could be clipped on the front for pulling and the rear for guiding. Keeping the coffins on individual mobile supports in storage allows full access for research, teaching, etc. without the use of forklifts or other heavy equipment to move them on and off of shelving.

Conservators often are highly critical, if not derisive, of old restorations that cross our paths. While these coffins had their share of excess fill material and overpaint, and the metal ties may seem rather extreme, the original restorer of these objects is deserving of great respect. He used the approved methods and materials of the day, much as was done in this project, to complete a daunting task under a tight deadline. In the course of the project it was realized that the same basic process as Mr. Witte's was being repeated, with the substitution of contemporary synthetic materials. The opportunity to be part of the continuing history of these ancient objects was much appreciated and it is hoped that this treatment will sustain the coffins well into their third millennium.



Figure 14. The glazed slipper coffin in old storage.



Figure 15. A section of the coffin enters the Conservation Lab.





Figure 16. Reconstruction began with the base.



Figure 17. The oval head end of the coffin during reconstruction, but prior to removal of old discolored inpainting.



Figure 18. Foot of coffin during treatment.



Figure 19. Foot of coffin during treatment, showing the wax mold held in place by clay.

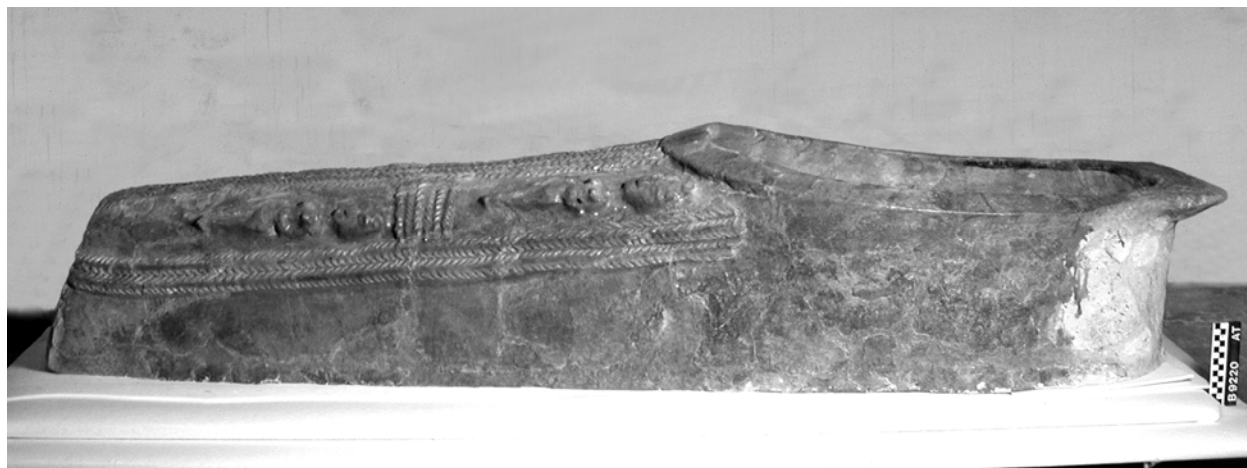


Figure 20. Glazed slipper coffin after treatment.

### Acknowledgments

Thanks to the Institute of Museum and Library Services, Virginia Greene and Dr. Richard Zettler for making this conservation project possible, and to Shannon White and Lynn Grant for their support, both moral and physical. Alex Pezzati, Kristine Paulus, Francine Sarin and Jennifer Chiappardi lent timely and cheerful assistance with the historical photographs.

### Suppliers

Acrylic rod, extruded:

Arch Street Plastics, Philadelphia, PA. 215-636-0890

Casters and accompanying bolts, nuts and drill bits:

McMaster-Carr Supply Company, New Brunswick, NJ. 732-329-3200, ([www.mcmaster.com](http://www.mcmaster.com)), and other hardware stores.

Dolly handles:

Clean Run Productions, LLC, Chicopee, MA. 800-311-6503, ([www.cleanrun.com](http://www.cleanrun.com))

Ethafoam (closed cell polyethylene foam):

Advanced Packaging, Inc., Baltimore, MD, 888-206-5250 and Foam Fair Industries, Aldan, PA. 800-796-3626.

Pallet shrink wrap:

Ship-It, Twinsburg, OH. 800-481-3600

Plaster of Paris (hydrated calcium sulfate, Diamond P grade):  
Samuel H. French & Co., Philadelphia, PA. 215-482-6770

Vigor sheet casting wax:  
Kingsley North, Inc., Norway, MI. 800-338-9280, ([www.kingsleynorth.com](http://www.kingsleynorth.com))

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## CONSERVATION AND EXHIBIT OF AN ARCHAEOLOGICAL FISH TRAP

Ellen Carrlee

### Abstract

In 1991, salvage archaeology rescued a 500-700 year old basketry fish trap in Juneau, Alaska. Preliminary treatment with polyethylene glycol (PEG) was done to prevent the collapse of the waterlogged wood, and the trap was held in conformation with an elaborate system of foam, mesh, Plexiglas, and slings that made study or exhibit impossible. The fragile spruce root lashings remained wrapped from salvage. The challenge was how to treat and exhibit an artifact that could not be set down on a flat surface, as it could not support its own weight. The conservator and mount maker worked as a team, each stabilizing areas to allow the other access. The materials used were Japanese tissue with a combination of wheat starch paste and PVA emulsion, bands of Tyvek attached with B-72 to secure lashings, and a three-part approach for overall support with Plexiglas, Mylar slings, and brass mounts.

### 1. Discovery

In 1989, Paul Kissner (retired from the Alaska Department of Fish and Game) was fishing in Montana Creek near its confluence with the Mendenhall River when he saw the top of an artifact eroding from the riverbank. He contacted Professor of Anthropology Wallace Olson (University of Alaska Southeast) and curator Steve Henrikson (Alaska State Museum) who removed the exposed section of what turned out to be a fish trap as an emergency measure to prevent its loss through erosion. Wallace Olson describes the discovery,

When the remains of the Montana Creek fish trap were first discovered, I was called and went to the site. What I saw was portions of something that appeared to be a fish weir or trap, protruding out of the silt in the creek. It was drying and falling apart as it was exposed to the air and sun. I immediately went to a local hardware store and bought every plastic “tie” they had in stock. I secured the pieces as best I could in their original position. The next day, Steve Henrikson, of the Alaska State Museum, came out and helped secure the remains. All we knew was that it was the top part of a traditional fish trap. As we finished salvaging the remains, Steve saw, and realized that it was an entire fish trap, and that what we had saved was only the top half. It was a monumental archaeological find on the Northwest Coast (Olson 2005).

Ownership of the trap was complicated from the beginning. The area where the trap was found is the traditional fishing territory of the Auk Kwaan of the Tlingit people. (A kwaan is a region controlled by several clans.) Genealogical reckoning indicates these people arrived from the Stikine River area near modern Wrangell several hundred years ago. Montana Creek is a freshwater river, but also influenced by tidal action. It was therefore somewhat unclear if the location was today the property of the City of Juneau, or the State of Alaska. Non-navigable freshwater rivers are the jurisdiction of the City, while navigable freshwater rivers and intertidal



areas are the jurisdiction of the state. At the time of excavation, the City formally declined ownership, although the waterway has some tidal influence and is only navigable by a canoe or kayak. The Alaska State Museum (ASM) has not accessioned the trap into its permanent collection, and local Native groups including the Sealaska Corporation, Tlingit-Haida Central Council, and the Auk Kwaan continue to take an active interest in the trap.

The trap was originally cylindrical in form with straight sides and an interior funnel lashed to the front end. The trap was crushed in burial. Materials were identified as spruce (*Picea sitchensis*) by Mary Lou Florian of the Royal British Columbia Museum (Florian 1992) and hemlock (*Tsuga heterophylla*) by Bruce Hoadley (Hoadley 2005). For descriptive purposes, the trap remains may be divided into five sections: the entrance funnel, the main body, the detached “top” body fragment, and the deformed tail. The funnel is now a lenticular flattened oval. Long, straight pieces of hemlock (referred to as “staves” in the excavation report) intersect hoops of spruce branch where they are lashed together by spruce root. This root is wrapped around the hoop continuously until the intersection with the stave, where it loops around, forms a double or triple “X” with a cinch loop to keep it tight, then continues to wrap around the hoop to the next intersection. Overhand wrapping holds the funnel, which was constructed separately, within the body of the trap. The main body includes a section of shorter staves with tool-worked ends and fragments of cordage that suggest a possible door on a rope hinge. The far back end of the trap does not survive, but measurements of the hoops indicate that the trap did not taper. The tail of the trap includes only 18 staves of the full cylinder (40 staves total) and is bent upwards at an angle of approximately 45 degrees.

## 2. Excavation

Salvage archaeology began in 1991 (permit 49-JUN-453,) mainly undertaken by excavator Jon Loring, geomorphologist Greg Chaney, and archaeologist Robert Betts. The permit was issued for a time period when fish activity in the river was low, unfortunately corresponding to the rainy cold weather of fall and winter, and excavation took place between tides with sandbags and pumps to fight the water. The trap was taken by skiff and then truck to the Alaska State Museum (ASM) where it was treated with mixed low and high molecular weight polyethylene glycol (PEG) for approximately one year. The treatment was done by Jon Loring, who had some direction from the staff at the Canadian Conservation Institute and ASM conservator Helen Alten. The major funding for the excavation of the trap came from Sealaska Corporation, the Southeast Alaska Regional Native Corporation owned and run by Tlingit, Haida, and Tsimshian shareholders and formed as a result of the 1971 Alaska Native Claims Settlement Act. Since ownership of the trap was unclear, most of the excavation documentation was kept by Jon Loring (Loring, 1995.) This is the first basketry-style fish trap known to be recovered from an archaeological context on the Northwest Coast. Traps were usually removed from the streams after the runs of fish ended each year. They were stored near the fishing site or returned to camp for repair (Henrikson, 2005.) According to the excavators, high iron content in the soil along with quick burial of the trap by an advancing river bar and tidal action are thought to have contributed to the survival of this trap. Interviews with Tlingit elders about fish traps were conducted in 1992 and included in the excavation report (Loring 1995.) Radiocarbon dating of fragments from the 1989 discovery sent to Washington State University indicated the trap is

approximately 500 to 700 years old. Sample 1 (WSU-4140) gave a result of 500 +/- 70 and Sample 2 (WSU-4141) gave a result of 700 +/- 60 using the computer calibration program developed by geoscientist Minze Stuiver of the University of Washington and run by anthropologist Jon Erlandson from the University of Oregon (Erlandson 1990.) In 2004, the Juneau-Douglas City Museum (JDCM) was awarded a grant from the Alaska State Museum Grant-in-Aid program to conserve, mount, and exhibit the fish trap.

### 3. Condition when excavated and initial treatment

Approximately 80% of the trap still exists. The trap was crushed in burial and the back end of the trap did not survive, resulting in a mystery about how the trap terminates at that end. The top section is separate from the larger bottom section, and there are perhaps 10 staves missing. Most of the spruce root lashing on the top section of the trap did not survive, but perhaps 60-70% of the lashing on the main section was still present during excavation. The funnel end is quite well-preserved, although crushed into a lentoid shape with pointed corners at each side of the trap. The back end of the trap was found bent upwards with staves broken, yet still connected to the main section by a badly distorted spruce root branch hoop.

The top section of the trap exposed by erosion was removed first. Most of its spruce root lashing was lost in burial and/or erosion from the river bank and the plastic “zip ties” used to hold the elements together for transport and salvage caused some additional damage from abrasion. (“Zip ties” are plastic strips available from the hardware store with a self-ratcheting action that allows them to be pulled tighter but not looser.) Storage in a fresh water tank before treatment flattened this section somewhat, although it appears that attempts were made to correct this curvature during subsequent treatment. The bottom section was more carefully supported during excavation with a frame of aluminum conduit (custom shaped in the field with a pipe bender), 1” nylon webbing straps, 3” plastic mesh straps, and polyethylene foam inserts to form a hammock and help maintain its shape during transport and treatment at the Alaska State Museum.

During excavation, the fragile spruce root lashings were covered with cotton gauze in the roll form typically used for bandages. Areas that were particularly deteriorated were not wrapped with the gauze but encapsulated in fine polyester netting with loose stitches of white cotton thread. One area on the main section where twined cordage survived was wrapped in roller gauze and then sandwiched between large stiff pieces of plastic mesh that were stitched together to give the area rigidity. In the field, the funnel of the trap was supported with individual balloons inflated to give needed support. These were later replaced with blue polyethylene foam inserts carved to shape. Following treatment of the two main sections in PEG, the trap was allowed to slowly air dry on the support frame and put into storage. This hammock/frame unit was suspended from a wooden exterior to hang free like a baby cradle (Fig. 1). Additional pieces of polyethylene foam were inserted to hold the interior curvature of the trap with the aid of adjustable Plexiglas rectangles or “fingers” to follow the contour. These pieces of Plexiglas were individually adjusted (like a feeler gauge) and screwed firmly between a sandwich of narrow plywood boards. The ends of these plywood boards were lashed to the conduit with yellow nylon cord. (Medex, a medium density fiberboard bonded with polyurea-isocyanate resin, was originally used instead of Plexiglas, but it reportedly grew thick fuzzy mold quickly and was

replaced as per Loring 2005.) The cotton roller gauze was left covering the lashing throughout the PEG treatment and subsequent storage. While many additional detached fragments were treated, some were not treated but left wet and kept in plastic bags. Most of the notes from the field excavation and treatment could not be found in 2005, but the excavation report and many slides were available and Jon Loring (also on the mount making team for the 2005 project) was able to recount much of what happened (Loring 2005.) A label on the lid of the box where some cordage was stored reads: "PEG 20% u/v Reg 200 Start 6-9-97 12-11 to 26 Drying." The 1992 site overview plans indicated the proposed treatment as "25% solution of 10% PEG-200, 5% PEG-1000 and 10% Compound 20M in 500 gallons of water."



Figure 1. Fish trap in storage supports from initial treatment. Funnel at bottom and cylindrical main body are flattened, and the distorted tail section is visible at the top of the image.

#### 4. Condition and treatment before exhibition

Examination in 2005 indicated the PEG treatment worked well. The wood was a slightly darkened reddish or yellowish brown color from the paler excavation color (Loring 2005,) but still had the feel and look of wood, and the weight also seemed normal, if slightly lighter than expected. The wood seemed stable and reasonably sturdy, although there were breaks through several staves. It is unclear if these breaks happened during excavation or subsequent treatment, but most do not contain sand or debris at the splintered break edges. These areas might also have

been weakened in burial. Unwrapping a small test area indicated the roller gauze did not stick to the trap, but the spruce root lashings were very fragile, brittle, broken in many places, and were no longer providing any structural stability to the trap. There was significant dirt, sand, and small rocks between the lashings as well.

It was not possible to know exactly how difficult the treatment would be until work began. It was necessary to stabilize the spruce root lashing, stabilize the junctures, and make supportive mounts simultaneously, as each process facilitated access to the others. Working together, the conservator would stabilize the lashings enough to allow mount makers to support the trap and remove pieces of the cumbersome old support system, which in turn allowed the conservator access to additional areas to treat. Since the trap is basically a large cylindrical grid of staves and hoops attached at their junctures, maintaining attachment at these junctures was essential to the stability of the trap. The condition of the lashings did not allow them to perform this function. A combination of reinforcements for these individual points of connection, together with an externally supportive mount structure, would hold the trap in place without stressing the fragile lashings (Fig. 2).



Figure 2. Spring 2005 treatment in the lobby of the Alaska State Museum, with exhibit designer Robert Banghart (left) working on Mylar slings for the body of the trap. Dark strips below the body of the trap are plastic mesh and nylon webbing supports from the excavation. Ellen Carrlee (right) works on treatment of the lashings from the detached top section.





Figure 3. Corner of funnel before treatment, with cotton gauze wrapping from excavation covering spruce root lashings.



Figure 4. Corner of funnel during treatment, with spruce root lashings partially exposed, Japanese tissue repairs tucked under loose lashing fragments.

The support strategy utilized five main materials: Japanese Kozo paper, Tyvek (spun bonded polyolefin fiber in sheet form grade 1020 smooth texture), Mylar (polyester film), Plexiglas acrylic sheet, and brass. The Japanese paper was used to stabilize the lashings, whose condition could not be assessed until the unwrapping began. Luckily, the gauze wrapping did not stick to the spruce root lashings as a result of the PEG treatment, although splinters and dirt caused some snagging between the cotton and the artifact (Figs. 3-4). In each area, the top surface of the gauze wrapping would be cut open with a small scissors, partially peeled back and the surface cleaned with puffs of air and a soft paintbrush until the loose lashing pieces indicated mobility. Small torn pieces of Japanese paper approximately 1 cm square were saturated with a wheat



starch paste/PVA emulsion mixture and tucked into the interstices of the lashing wherever possible with a pointed tweezers. Saturated pieces of tissue could also be folded to serve as a gap-filler and adhesive for small detached fragments of the lashing. Points of good contact between the lashings and the hoops were sporadic, making a gap-filling measure necessary. The weakest adhesive possible was sought to ensure that any stress would cause the repair to fail instead of causing new damage to the artifact. Wheat starch paste alone was insufficient to support the weight of the fragments challenged by gravity. Methylcellulose was too weak as well, and not surprisingly, the two in combination were also too weak. The adhesive selected was wheat starch paste with a few drops of Jade 403 polyvinyl acetate (PVA) emulsion added to each batch. A batch size was the amount that conveniently fit into a large watch glass. Pieces of Japanese paper could be dragged through the adhesive and kept at the edge of the glass for application. Allowing them to dry slightly made them more tacky. These repairs reached full strength overnight, and the next day the underside of each lashing section could be unwrapped. More loss occurred as wrapping was removed since gravity pulled the exposed lashing fragments from the undersides of the hoops. To combat this problem, adhesive-soaked Japanese paper was tucked in before the fragments could fall. Cleaning these areas was not possible, and significant sand and dirt was consolidated into the paper. In some areas, there was no lashing under the gauze. In other areas, the lashings were badly crushed and could not be saved, or only partially saved. Approximately 30-40% of the main section of the trap had lashings that could be preserved to a degree that the wrapping technique could be studied. The Japanese paper could be tucked away out of view in many cases, but in others had the appearance of small white spitballs. The visibility of these was reduced by dotting acrylic emulsion paint on them with a tiny paintbrush to mimic the surround.

The trap was stabilized at junctures between the hoops and staves by narrow strips of Tyvek painted with acrylic paint in a brown, striated pattern on the top side only. One end of the Tyvek strip was attached underneath the juncture to either the hoop or the staff with Acryloid B-72 and allowed to dry. The strip was then pulled diagonally over the juncture to form a loop, snugged gently, and adhered to itself over the same area it was attached to the wood. Whenever possible, the Tyvek was slipped under the original lashing to help hide the Tyvek. Tyvek was chosen because it was lightweight, flexible, strong, and inert. All Tyvek strips were cut approximately the same width and painted a uniform color with acrylic emulsion paint (slightly distinct from the lashing color.) These strips were attached in the same diagonal direction as each other with the intent to have these stabilizing elements fully visible but camouflaged. They form a pattern with their regularity and can thus be easily distinguished from the real lashings by viewers studying the construction technique (Fig. 5). Determined viewers can also peek up from below and catch a glimpse of the unpainted white undersides of the Tyvek strips.

Mount making was designed and supervised by Robert Banghart of Banghart and Associates. The primary support for the main body of the trap was made from three 6" wide clear 10 mil Mylar straps used as a cradle (Fig. 6). Mylar was chosen because of its flexibility and strength. It was feared that flaws might cause the Mylar to split and quickly propagate a tear (stress razor) but testing of the material with heavy weights and punctures indicated the material would not fail in this manner. The Mylar slings were held with supports made from standard plumbing supplies. The end of each Mylar sling was rolled onto an uptake spool made from a tube of 1/2" rigid copper with mild steel reinforcement rod attached on the interior of the tube with Scotch-Weld

epoxy adhesive. The tube could be rolled like an axle where it entered a right-angle elbow-shaped street 90° pipe and held with a stainless steel set screw (hex drive with a national fine thread pitch of 8/32.) The right angle pipes were connected to legs of steel-reinforced copper tube by a silver solder joint, and set in a steel floor flange that was screwed to the deck. Strong gaffer's tape was initially used to hold the end of the Mylar to the uptake spool, but over time, the tape was not sufficient due to lack of compression strength on the uptake spool. To remedy the problem, clips were made from ¾" acrylonitrile butadiene styrene (ABS) plastic with a slot cut to create a "C" shape. In the future, use of these clips directly on the uptake spool to hold the end of the Mylar would be preferred. Curved sections of Plexiglas were added at the front and under the tail to prevent shifting of the trap. Additional 1/8" extruded Plexiglas rod stops were added to the tail support to prevent shifting of the slanted tail area. Extruded Plexiglas rod was used where possible to support the Plexiglas, with a brass pin holding the Plexiglas and rod together. Loctite cyanoacrylate adhesive with accelerant was used to adhere the pin and the rod.



Figure 5. Corner of funnel during treatment, with Tyvek strips attached. Tyvek gives physical support no longer provided by the original lashings. The Tyvek is painted a uniform color slightly distinct from the spruce root color to allow the viewer to distinguish repairs from the original lashing.



Figure 6. Mylar slings hang below the trap in preparation to replace the darker plastic mesh and nylon webbing straps supporting the underside of the trap. Mylar is temporarily clamped onto the uptake spool of metal supports made from basic plumbing supplies.

Padded brass mounts rising from the deck were added at various locations to provide individual support to detached or broken areas. Polyethylene felt with acrylic adhesive backing was used for padding. More than 30 detached pieces from the trap ranging in size from 10" to 55" were not reattached and exhibited with the trap. Most of these pieces were not attached to the trap when excavated and their exact placement cannot be determined easily because break edges were deteriorated. Some pieces whose locations were known were not reattached. Each piece would have required its own padded mount and the inner, empty cavity of the trap would then be filled with a forest of mounts, making the shape of the trap difficult for the viewer to read. The measurements of these pieces, however, helped confirm the original size of the trap. Janice Criswell (Tlingit-Haida basket maker and instructor, University of Alaska Southeast) and her husband Steve Henrikson (Curator of Collections, Alaska State Museum) were commissioned to construct a full-scale replica of the trap. The replica was completed in March of 2006 and suspended above the original artifact to help the viewer understand the archaeological remains (Fig. 7).



Figure 7. Montana Creek Fish Trap with repairs complete, undergoing final mount fittings. View looks into funnel of trap, with detached top section supported above the main body and bare sticks of distorted tail projecting upwards at the far end of the trap.

A 4 1/2" thick box truss was attached to the underside of the plywood that formed the original base of the trap support system. The surface of the plywood was covered with three coats of latex acrylic paint. The deck was covered with well-washed gray river rock to cover the mounting



hardware and mimic the river bed where the trap was found. The trap does not touch the deck or the rocks.

Wallace Olson described the finished exhibit:

As an anthropologist and archaeologist, I was happy that at least we were able to salvage some remains. I never expected, or hoped that the entire trap would be preserved...I was convinced that there was no way that a six-hundred year old fish trap, partially exposed to the air, crushed in its burial, could ever be displayed or replicated. My hope was that at least we might save a few pieces and carbon-date them. In spite of my doubts, the staff at the Juneau-Douglas City Museum was able to design and build a beautiful non-obtrusive support system to display the trap. When one looks at the display model, it is exactly the same as what I, and the archaeologists found. Today, as someone who was “on the scene,” from the beginning, I can walk into the Juneau-Douglas City Museum and honestly tell people, “Yes, that’s the way it was found and recovered” (Olson 2005).



Figure 8 Trap in exhibit case with replica by Janice Criswell and Steve Henrikson suspended above. The archaeological trap remains are crushed but the replica suggests its original shape.

## Suppliers

ABS plastic pipe, set screws, steel floor flange, street 90° pipe,  
Plumbing supply stores or local hardware stores.

Acryloid-B72® ethyl methacrylate (70%) methyl acrylate (30) co-polymer in acetone and ethanol:

Conservation Resources International LLC. ([www.conservationresources.com](http://www.conservationresources.com))

Jade 403 polyvinyl acetate emulsion, Kozo Japanese paper, Tyvek spun-bonded polyolefin fabric in grade 1020 smooth texture:

TALAS ([www.talasonline.com](http://www.talasonline.com))

Liquitex acrylic paint in burnt umber, red oxide, and yellow oxide:

Art supply stores such as Dick Blick ([www.dickblick.com](http://www.dickblick.com)).

Loctite cyanoacrylate adhesive with accelerant, Maylar polyester film (10 mil), Scotch-Weld DP-100 Quick Set Epoxy:

McMaster Carr ([www.mcmaster.com](http://www.mcmaster.com)).

Padding of polyethylene felt with acrylic adhesive backing:

Benchmark ([www.benchmarkcatalog.com](http://www.benchmarkcatalog.com)).

Permacel Professional Grade Gaffer's Tape:

Theater or sound equipment supply stores, or at Uline ([www.uline.com](http://www.uline.com)).

Wheat Starch Paste. Commercially available product made in Japan, from the supply at the Alaska State Museum conservation laboratory. Label in Japanese. Comparable product sold at TALAS as Zen Shofu Wheat Starch Paste ([www.talasonline.com](http://www.talasonline.com)).

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## **DON'T ROCK THE BOAT: RECONSTRUCTION AND MOUNTING OF A WATERLOGGED DUGOUT CANOE**

Howard Wellman

### **Abstract**

A 19<sup>th</sup> century dugout canoe was excavated from the banks of LaTrappe Creek on Maryland's Eastern Shore in 1993. In the following years it was treated by the standard process of impregnation with polyethylene glycol, and dried in a vacuum freeze-drier at the Maryland Archaeological Conservation Laboratory (MAC). The canoe was recovered in several pieces, continued to break during treatment, and the treated yellow pine now has the approximate strength of hard cheese. Knowing that the canoe would go out on loan to a local museum, the MAC Lab conservator had to devise a reconstruction method and supporting mount that would serve for both transport and display, and could be done with limited resources. The canoe was reassembled by pinning the pieces together with fiberglass rods, with additional adhesion provided by Butvar B-98. The conservator relied heavily on the expertise of a volunteer boat restorer during the pinning and reconstruction. Of equal value was the help of a volunteer blacksmith who built the base frame on which the boat was reconstructed, and then custom fit curved ribs that supported the fragments. The reconstruction and support were intended to work as a permanent unit – once the canoe is in place, its own weight will hold it together and hold it in place on the mount. The museum borrowing the canoe has incorporated the frame into a custom display case, and is providing the case with environmental controls to minimize the natural dimensional movements of the wood. The process used proven techniques adapted from much larger shipwreck conservation projects, but could not have been carried out without the expertise of the MAC Lab's volunteer corps.

### **1. Introduction**

In 1993, a hiker discovered an almost intact 19<sup>th</sup> century dugout canoe eroding out of the bank of LaTrappe Creek, a tributary of Chesapeake Bay on Maryland's Eastern Shore (Site No.18TA303). The subsequent history of this canoe's treatment and re-treatment contains valuable lessons for conservators: the benefits and problems of volunteer involvement in conservation, and how to complete a project with extremely limited resources.

It was decided to conserve this particular canoe since local watercraft from this period are rarely preserved. Interesting technological details were immediately apparent, such as the technique for gauging hull thickness during construction: Dowels of a fixed length were inserted into the hull from the exterior, so that when they were exposed during the carving of the interior, a uniform hull thickness was ensured. Other features are comparable to canoes of similar age and contexts in the Chesapeake and surrounding Mid-Atlantic area (Thompson 2006; Lavish and Surgent n.d.).

A hastily assembled crew of more than 30 volunteers excavated the canoe during a winter storm

under the direction of Bruce Thompson, Assistant State Underwater Archaeologist from the Maryland Historical Trust (MHT), who volunteered his own time (Fig. 1). The canoe was recovered in approximately fourteen pieces ranging in size from 1.5m long to palm-sized fragments. The pieces of the canoe were transported to the Chesapeake Bay Maritime Museum (CBMM) in St. Michaels, Maryland, which had expressed an interest in preserving and displaying the boat. The staff and curator of the CBMM undertook the conservation of the canoe with volunteer labor, following a treatment plan drafted by Betty Seifert, the Chief Conservator of the MHT. Ms Seifert could not directly assess the condition of the boat, or treat it herself, since this was a private project and State resources could not be used. Treatment recommendations were based on deterioration assessments and species ID from the archaeologists, photographs and video of the excavation, and guided by Ms Seifert's personal experience of treating similar waterlogged wood. The treatment followed a standard outline: mechanical cleaning with water and brushes to remove mud, sand, and plant roots, continued washing to remove salt water, followed by polyethylene glycol (PEG) immersion, and de-watering by slow air-drying. The molecular weights of PEG used (400, 1430, and 3350) were based on donated materials, since there was no funding available for materials. Where vacuum freeze-drying is not available, or not possible due to the size of the object, controlled slow drying is an acceptable alternative, but often requires a higher concentration of PEG.



Figure 1. The canoe being excavated. Photo by B. Thompson.

All work, including the slow-drying, was to be done at CBMM by the volunteers under the control of Museum staff without the direct supervision of an experienced conservator. No records were kept of desalination time, cleaning procedures, or the PEG impregnation schedule. Ms Seifert was contacted again in 1995 for the loan of a circulating pump to filter the PEG solution, but was not asked to inspect the progress of the treatment. She was assured that everything was proceeding “according to the plan” (Seifert 2000).

The canoe had to be moved in 1999 because of renovations in the non-climate controlled barn at CBMM where treatment was underway. The MAC Lab had opened in 1998, so CBMM turned the project over to State control, the canoe was formally donated to the MHT, and delivered to the MAC Lab with little warning in the middle of a hot summer. The volunteers at CBMM had allowed the solution to evaporate to a greasy sludge to reduce the volume of PEG waste for disposal and to make transport easier. They also thought the more concentrated the PEG, the better the treatment would be (Seifert 2000). The PEG concentration was in excess of 80%, and the blend of molecular weights was uncertain. Parts of the canoe were exposed to the air. The failure to follow the treatment recommendations may be attributed to a misunderstanding of conservation methods, opposing ideas of proper treatment, and false economies on the part of the Museum. The number of pieces now totaled approximately 30, as many of the pieces (particularly long side pieces) had fractured badly during treatment and handling.

When the canoe fragments were delivered, the MAC Lab was newly opened with limited staff. The PEG had active bacterial slime, and the wood was very weak. There was no conservation staff to finish treatment and no funding for the work, though State officials were now willing to claim the project. The Chief Conservator decided that freezing the canoe in the newly installed vacuum freeze drier was the best option to save it from further deterioration. MAC Lab archaeologists, technicians, and volunteers helped remove excess PEG from the surface, together with a large amount of mud and sand that had not been removed before PEG impregnation.

Freeze-drying was done in two batches between July and December 1999, using the Virtis 48”x144” vacuum freeze-drier. The hull fragments were pre-frozen at -40°C for 24 hours in the specimen chamber of the freeze-drier. During freeze-drying, chamber pressure was at approximately 20 millitorr, condenser temperature was at -57°C, and the specimen chamber was brought up from -20°C to 0°C in stages as the wood lost weight. Progress was monitored by measuring weight changes of six pieces and with temperature probes in the wood.

After freeze-drying, the surface of the wood was still covered by a thick waxy layer of PEG, there was a lot of sand and mud still adhering to the surface and cemented into the many cracks, wormholes, and root holes. Lab volunteer efforts to remove sand and roots with picks and vacuums proved frustrating because of the excess PEG. While sitting in the lab, it was noted that pre-existing cracks and checks were still unstable, changing with the ambient relative humidity.

## **2. Re-treatment (2000-2001)**

In order to stabilize the canoe and prepare for exhibition at CBMM (who were now being very



vague about when and if they wanted to exhibit it), it was necessary to find an efficient and economical procedure to remove the excess PEG and mud. Perhaps because PEG remains water soluble after impregnation, the conservation literature has few references to reversing a PEG treatment, particularly for large objects (Cooke et al. 1993; Smith 1998). There was no funding available for extensive post-treatment work, so tests were limited to materials on hand at the MAC Lab. The wood was identified by microscopic examination of thin-sections as one of the species of southern pine (e.g. *Pinus taeda* or *Pinus palustris*), which cannot generally be distinguished on the basis of wood structure (Panshin and de Zeeuw 1980; 446). It was assumed that removal of excess PEG would be relatively easy due to the regular and open microstructure of pine. The wood itself was soft and liable to break under its own weight along existing cracks. There was minimal resistance to probing with a pin.

PEG removal by poultice and immersion washing was tested. Considerable success was achieved by immersion washing and gentle brushing. The surface color lightened considerably, and weight losses up to 50% were noted. Dimensional changes were measured across the tangential dimension between stainless steel pins. The weight loss could be attributed to the removal of large volumes of sand, especially with the most worm-eaten wood. At extreme washing times (up to 72 hours for small fragments), significant shrinkage and distortion of the wood on drying was noted, but brief washing times (ca. 1 hour for small fragments) provided good results with minor shrinkage. Because no additional PEG was introduced, the pieces were not to freeze-dried again, but allowed to dry slowly in closed polyethylene containers. Weight and pin dimensions were recorded after drying for 72 hours. The washing and cleaning was reported in greater detail at the Stockholm meeting of the ICOM-CC WOAM working group (Wellman 2001).

Ultimately, it was decided to immerse the canoe pieces in a solution of 70% v/v ethanol/water. Ethanol improved the wetting of fine pore structures, and also speeded the drying while minimizing wood/water interactions. During immersion, surfaces were brushed to remove excess PEG and loose deposits of sand and mud. Where possible, washing was done under a fume extraction hood for safety (Fig. 2). For the largest pieces, the wash tank was placed in the MAC Lab's Solvent Workroom, which is equipped with spark-proof fixtures and separate air-extraction. Lab staff wore respirators and other personal protection as required by health and safety regulations. Washing time for the individual pieces was variable, but based on the tests the time was kept to a minimum. Larger and denser pieces were allowed a longer immersion time to get maximum penetration into deep crevices. Some pieces were re-washed and brushed more frequently if excess PEG was not removed from the surface. The bow and stern sections of the canoe (about 2m and 1m long respectively and up to 10cm thick) were immersed for three days over the weekend, and this still did not remove deep deposits, or all the surface coating. Slow-drying was done in the Solvent Workroom, with the objects initially tightly bagged and wrapped in polyethylene sheet. Drying was monitored by measuring weight changes. The bags were opened slowly over the course of two weeks, and the final weights stabilized in two to six weeks depending on the size of the piece. The used wash solution was recycled in the MAC Lab's solvent still to reclaim the ethanol.



Figure 2. Immersion washing of hull fragments in a fume hood. Photo by H. Wellman.

The wood was then cleaned with brushes and a vacuum cleaner (Nilfisk with HEPA filter and rheostatic control), using a modified nozzle to remove sand from deep crevices. The final weight loss in the large pieces ranged from 8.6% to 54%, with an average of about 20%. The most dense and solid pieces had the least loss, and the most worm-eaten had the highest. This is probably due mostly to removal of sand and mud. All the pieces had a considerable improvement in color, surface feel, and the adherent sand was easily removed. Details such as wood grain and dowel holes that had been obscured became visible. However, some sand remains in the crevices and trickles out when the pieces are shifted. The variability in surface color probably reflects the incomplete removal of the excess PEG in some areas, probably due to the difference in degradation of the wood in different parts of the hull. The upper sections which were more exposed during excavation and impregnation have more fine root penetration and tend to be darker after re-treatment. Micro-cracks have formed, suggesting very small scale collapse of the wood structures. Dimensional changes were visible in the small scale but pre-existing checks and cracks were stabilized. This discrepancy is considered to be the result of localized ethanol drying causing micro-fissures while the removal of excess PEG caused the larger cracks to react less rapidly to environmental changes. The overall fit of the broken pieces is good.

Since re-treatment, there has been no evidence of PEG migration to the surface, so the canoe appears to be stable under the relative humidity and temperature that can be expected from ambient laboratory environments.

### 3. Reconstruction

In order to reconstruct the fragile hull, a combination display/transport mount consisting of a steel frame with form-fitted ribs was designed with the assistance of Pat Fulcher, a blacksmith and MAC Lab volunteer. The design of the frame is intended to make the entire canoe moveable in one piece by forklift, pallet jack, or human-power with appropriate holds for any of these modes. It is cushioned against shock during transportation, and the undercarriage can be dressed in the museum for an appropriate display. The base frame incorporates a slight curvature that is compressed by the weight of the canoe, creating a stiffer foundation.

The canoe was pre-fitted in sections, and Mr. Fulcher shaped support ribs to individual sections with a home-made contour gauge and his portable forge (Fig. 3a-d). Ethafoam padding protected the wood while fitting continued.



Figure 3. Blacksmith Pat Fulcher shaping support ribs. Upper Left: Measuring hull curve. Upper Right: Shaping the rib. Lower Left: Checking the curve. Lower Right: Installing the rib on the armature. Photos by H. Wellman.

With the ribs clamped temporarily in place, the canoe could be reassembled. A new team including the author, the original excavator Bruce Thompson, and volunteers Chris Martin and Steve Pratt (a professional boat restorer) gathered to examine and fit the pieces together (Fig. 4).



Figure 4. Assembling the hull fragments. Photo by B. Seifert.

The canoe fragments were laid out on the padded frame, and fitted to the ribs with plastic clamps while the sequence of joins was mapped out. The assembly technique was adapted by the author from a procedure used at Texas A&M University by Peter Fix on the hull of *LaBelle*, a French colonial ship recovered in Matagorda Bay by the Texas Historical Commission (Fix 2000). Hull fragments are prefitted, dowel holes are drilled, and the sections are pinned together with fiberglass rods. In this case, 1/8" or 1/4" rods were used. The experience of Steve Pratt was invaluable, bringing together interpretive needs, the requirements of the fragile wood, and best possible boat restoration techniques. Where possible, the drill holes and rods were concealed inside the joins, but a few had to be inserted through the exterior surface (Fig. 5). Where possible, these pins were located inside existing root or worm holes. Butvar B-98 (polyvinyl butyral, 50% in ethanol) was used as an adhesive in the joins and inside the dowel holes to provide additional support. The rods were also used to bridge gaps and provide support where wood was missing.





Figure 5. Pinning the hull fragments together. Left: Pre-drilling the pin hole. Right: Inserting a fiberglass pin. Photos by H. Wellman.

Reconstructions of similar sized vessels (e.g., Moore 2001) have usually avoided the problems of pinning fragments together. An internal bolted armature is used, or it may be possible to take advantage of plank and rib structures and existing fastener holes. The vessel's strength comes from the interlocking elements, whereas a dugout's essential structural strength cannot be recovered once fractured.

Once the entire hull was pinned and held rigidly, the ribs were removed one by one and given a final trimming and shaping, then painted with commercial epoxy sealant and enamel paint (Rustoleum flat black). The ribs were then bolted to the frame, and padded with black Volara (closed-cell polyethylene foam). While the frame was painted black to minimize the visual effect, the borrowing institution requested that the visible pins and bridges be left white for educational purposes (Fig. 6).





Figure 6. Canoe, completed. Photo by H. Wellman.

#### 4. Transport and installation

The CBMM finally determined they did not want to display the canoe, but by good fortune a new marine museum in Baltimore, the Frederick Douglas – Isaac Myers Maritime Park (FDIMMP), saw it, fell in love, and decided to craft their new central display of African-American maritime history around it. A professional art moving company was contracted to crate the canoe on its mount, truck it to Baltimore, and load it into the second floor gallery through an external cargo door via a crane (Figs 7-9). The support frame worked extremely well during the whole packing, transport and installation phases, and saved the moving company significant time and effort.



Figure 7. Moving the canoe on its frame. Photo by R. Morehouse.



Figure 8. The canoe in its shipping case. Photo by H. Wellman.

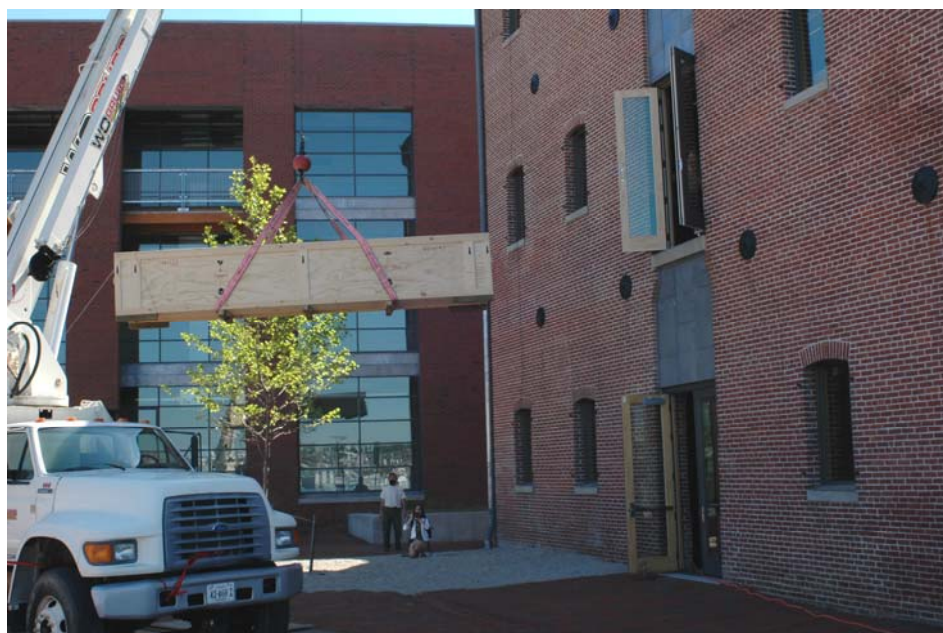


Figure 9. Lifting the canoe to the museum gallery. Photo by H. Wellman.

FDIMMP also contracted for the construction of a custom display case incorporating a micro-climate generator (AirSafe from NoUVIR) to provide constant environmental conditions (Fig. 10). The canoe has not been installed in the case at this time.



Figure 10. Design sketch of the climate-controlled display case for the canoe.

## 5. Conclusion

The MAC Lab conservators learned a number of valuable lessons from this experience. First and foremost were the different experiences gained working with volunteers. Every stage of recovery and conservation involved volunteer labor, some good and some bad. The unwillingness of project managers (or their misunderstanding of the complexities of conservation) at CBMM to provide qualified conservator oversight led to the poor initial treatment of the canoe, and led to a much greater investment in time and labor to ameliorate the damage. By contrast, skilled craftsmen, working in concert with trained conservators, were able to prepare the canoe for display with a minimum of resources. The care put into the canoe paid off in the long run, as it became an object of desire for interpretive uses.

## Acknowledgements

- The Maryland Historical Trust
- Bruce Thompson and his corps of archaeology volunteers
- Betty Seifert & the MAC Lab staff
- MAC Lab volunteers Pat Fulcher, Celia Daniel, Fred & Karen Dellinger, and Steve Pratt.
- Chesapeake Bay Maritime Museum
- Historic St. Mary's City

- Living Classrooms Foundation and the Frederick Douglas – Isaac Myers Maritime Park

## Suppliers

Butvar B-98, Volara:

Conservation Support Systems, (800) 482-6299, (CSS@SILCOM.COM)

Epoxy coating (INSL-X Checkrust, INSLI-Tile II, EP-53BG):

INSL-X Products Corp., Stony Point, NY, 10980.

Rustoleum flat black enamel paint:

Ace Hardware.

Fiberglass rods:

GE Polymer shapes-Jessup, 8255 Patuxent Range Road, Jessup, MD 20794-9600, (301) 604-3623.

AirSafe air control system:

NoUVIR Research, 20915 Sussex Highway 13, Seaford, Delaware 19973, (302) 628-9933.

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## **CONSERVATION OF ASSYRIAN RELIEFS AT THE BROOKLYN MUSEUM**

Tina March, Lisa Bruno, Hiroko Kariya, Won Ng, Ellen Pearlstein, and Helen Stockman

### **Abstract**

Conservation of six monumental alabaster reliefs, four broken and two intact, weighing up to 3500 lbs. each, was carried out at the Brooklyn Museum after previous repairs and installation methods failed while they were being moved. The surfaces of all six reliefs were steam cleaned, followed by drying with acetone and ethanol. Cement from a former repair was removed mechanically from the surface with scalpels. The four broken reliefs were disassembled, cleaned of plaster repairs, and reassembled using epoxy. To stabilize the four broken reliefs during movement and reinstallation, a steel mount was attached to the back using bolts. The reliefs were installed in the galleries using a wall cleat with bolts or a turnbuckle system. Small chips of stone were reattached using B-72 in acetone. Ghosting from fill materials remaining on the surface and disfiguring scratches were toned with Liquitex acrylic emulsion paints. The joins were left unfilled.

### **1. Introduction**

Twelve Assyrian reliefs in the Brooklyn Museum collection were installed in the galleries in 1956. Following standard masonry construction methods, they were installed in-situ, section-by-section, secured to each other and the wall with copper alloy pins and plaster. They remained in this location until 1990 when six of the reliefs were deinstalled so that construction in that area could be carried out. During the deinstallation, the joins of four fragmentary reliefs began to give way. It became clear that the previous restoration was not strong enough to remain stable during movement, and that the repairs would have to be redone. It was not until 2001 that treatment was carried out on the six deinstalled reliefs. In addition to surface cleaning, the goal of the treatment for the 4 broken reliefs was to structurally unify the fragments as a whole so they can be safely transported in the future without the joins failing. This treatment would include attachment to a backing/frame for support. While the treatment was fairly straight forward, the logistics of maneuvering, mounting and installing these objects became quite involved.

#### **1.1 History**

The monumental stone reliefs were part of the walls of the Northwest Palace of Ashurnasirpal II (883-859 B.C.), of the ancient royal city Kalhu, now Nimrud, in modern day Iraq. Other reliefs from this palace reside in collections that include the British Museum, the Louvre, the MMA, and the Oriental Institute at the University of Chicago (Paley 1976). British archaeologist Henry Layard found the site in 1840, and excavations began in 1845. The first shipment of material from this site was to the British Museum in 1846 (Layard 1849). Interest in this material had peaked, and in 1853 associates of Layard shipped a set of 13 reliefs to London for sale. These reliefs would eventually make their way to the Brooklyn Museum. The earliest documentation

refers to 13 reliefs, however one relief (BM 55.146) consists of joined separate upper and lower halves, now counted as a single object. Soon after their arrival in London, these reliefs were purchased by an American dealer named Henry Stevens. In 1855, he had them shipped to Boston, where they remained for several years until purchased in 1858 by James Lenox for the New York Historical Society. They were installed between 1858-9 on the ground floor of the NYHS building on 2<sup>nd</sup> Avenue and 11<sup>th</sup> Street (Dyson 1957). In 1912, the reliefs were moved from the Second Avenue building to the new location of the NYHS on Central Park West. Minutes from a meeting dated 1911 indicate that this move was to include “resetting the frames and fastening the broken pieces with bronze dowels” (NYHS 1911). Transparencies in the BM archives show the reliefs enclosed in frame units that overlap the relief edges (Fig. 1). Brown paint stripes on the surface parallel to the relief edges were noted prior to the most recent treatment, and are thought to derive from repainting these frames.



Figure 1. Archive image from the New York Historical Society showing frames overlapping the edges.

In 1937, as a result of a changing collecting mission at the New York Historical Society, the reliefs were placed on long-term loan at the Brooklyn Museum and installed in galleries on the third floor, dedicated to ancient cultures (Fig. 2). Note in this installation photograph, that there are no wooden frames surrounding the reliefs. It is unclear when these were removed, but presumably at the NYHS before their loan to BM (NYHS 1937). The museum was obligated to periodically update the Historical Society about the care of objects on loan to Brooklyn. Reports were made by then Curator of Egyptian Art at the Museum, John Cooney. The 1937/38 report referred to the stones being “washed with plain water, no solvents of any kind nor soap being



Figure 2. Installation at the Brooklyn Museum around 1937.

used” (Cooney 1937/1938; Fig. 3). The reliefs remained on view until 1949, when due to a changing mission in the gallery, the reliefs were boarded up in situ. The gallery was to become a space used for public lectures, and the Museum could not afford to hire a guard to be stationed in the space to protect the reliefs. Cooney’s 1949 report to the NYHS discussed the possibility of mounting the reliefs onto movable steel frames for display in another gallery space, however this was not done. They remained covered from 1949-54 until 1955, when the BM was able to purchase the reliefs, due to the generosity of Hagop Kevorkian (Nagel 1955). In 1956, the reliefs were installed in a gallery dedicated to Mr. Kevorkian, where they remained until 1990. It is noteworthy that photos of the installed reliefs published in 1957 (Fig. 4) show them without any fills in the losses, indicating plaster fills present prior to the recent treatment were applied some time after that date. These images also show residual material, likely cement, surrounding loss edges on the relief surface, which appears to relate to even earlier undocumented fills. Letters from 1858 in the NYHS Archives indicate that there was discussion of restoration and it is possible that this material relates to this time period (Stevens, B.F. 1858).



Figure 3. During treatment photograph at the Brooklyn Museum, around 1937. The left side has been washed with water.



Figure 4. Installation at the Brooklyn Museum around 1957. There are no fills in the break edges.



In 1966, a proposal was made to clean and coat the reliefs with a “permanent coating”; however no record of that treatment can be found in the Conservation, Curatorial, or BM Archives records (Bothmer 1966). Subsequent analysis of surface deposits by FTIR did not clearly support an applied coating. However, FTIR of brown resinous drips on the surface were identified as gutta percha (Martin 2001). This was also described by Prof. Sam Paley, an Ancient Near East specialist who published detailed information about the Museum’s Assyrian reliefs, as the material used to take impressions of the inscriptions (Paley 1976).

In 1990-91, Museum construction necessitated the deinstallation of six of the twelve reliefs. Contract riggers from More Specialized worked with museum conservators to transfer these reliefs to padded wooden A-frames that had been constructed so that they could be moved, with the reliefs on them, using a pallet jack (Fig. 5). This deinstallation provided insight into the 1956 installation methods. Following standard masonry construction techniques, the relief fragments were assembled on top of marble-clad I-beams in the gallery, using copper alloy dowels installed into oversized holes in join surfaces, and between the fragments and the wall. The approximately 6” gap between the relief backs and the wall was maintained by these pins embedded in plaster at the wall surface, and by filling the gaps between the side edges and the wall with a 2” thick layer of plaster. Newspaper had been used behind the reliefs to contain the inner edges of the plaster (Fig. 6).



Figure 5.  
Deinstalled  
reliefs resting on  
A-frames, 1990.





Figure 6. Deinstallation of reliefs in 1990 showing 1957 installation techniques where the reliefs were pinned to the wall and secured using plaster.

## 2. Condition

The reliefs remained in storage in a closed gallery space on the A-frames until treatment could be carried out in 2001-2002 (Fig 7). The surfaces were grimy and had sustained graffiti and minor scratching and abrasion from years of open display in the BM galleries. The concrete around the break edges and the yellowed gutta percha residue were visually disturbing. Old installation paint was present on many of the edges. The plaster fills were cracked from deinstallation and were both unstable and unsightly, as they had discolored significantly over the years (Figs. 8,9).

## 3. Treatment

While surface cleaning was one of the goals of the current treatment, the primary goal was to reverse the old joins and structurally unify the fragments as a whole so they can be safely transported in the future without the joins failing. The six reliefs had remained leaning on their custom designed wooden A frames since deinstallation. The faces of the reliefs were visible, to allow for determining the cleaning methods first. The treatment was carried out in a closed

gallery without climate control or a ventilation system. Condition and treatment of each relief were recorded with photographic documentation.



Figure 7. Relief on A-frame in storage, 2001.



Figure 8. Detail of gutta percha residue.



Figure 9. Detail of cement along break edge.

### 3.1 Cleaning Tests

Although all stone samples were identified as alabaster using FTIR, the slabs have some visual differences that could divide them into two categories (Martin 2001). The first is a relatively uniform and fine-grained stone with a gray-brown appearance. The second type is an uneven

coarse-grained stone with a mottled, translucent appearance, containing large inclusions. Cleaning tests were carried out and differences between test results on both of these stone types were minimal. The following materials and methods were tested to remove surface dirt, grime and possible coating material.

### **3.1.1 Solvents**

The following solvents on cotton swabs were rolled over the stone surface: deionized water, ethanol, acetone, petroleum benzine, xylene, toluene, deionized water with Orvus, a deionized water and ethanol mixture (1:1), a deionized water and acetone mixture (1:1), and 2% dibasic ammonium citrate (pH 8.4-8.6). Also rolled over the surface on swabs were the Keck mixtures, where Shellsol has been substituted for petroleum benzine: Keck I (acetone 10%, diacetone alcohol 5%, Shellsol 85%), Keck II (acetone 20%, diacetone alcohol 10%, Shellsol 70%), Keck III (acetone 30%, diacetone alcohol 30%, Shellsol 40%), Keck IV (acetone 30%, diacetone alcohol 20%, ethanol 10%, Shellsol 40%) (Kushel 2006). All the above solvents removed loose surface dirt to varying degrees while acetone and ethanol appeared to be best for removing embedded grime. Cleaning with deionized water followed by acetone was most efficient and effective. However, visually, the overall stone surfaces appeared only slightly cleaner.

### **3.1.2 Poultices**

Two compositions of solvent gels, acetone gel (60 ml acetone, 12.5ml water, 2.5 ml Ethomeen and .75g Carbopol 934) and acetone/ethanol gel (100 ml ethanol, 100ml acetone, 13.6ml Ethomeen C25, 4g Carbopol 934), were applied to the surfaces with a Mylar cover. After 15-20 minutes, the gel was cleaned with Shellsol and iso-octane alternating with deionized water. It was difficult to completely remove residual gel (Wolbers 2000). Various Attapulgit clay mixtures were tested. Attapulgit with deionized water only, deionized water and Orvus, deionized water/ethanol (1:1), and deionized water/acetone (1:1) were applied to the surfaces with a tissue paper barrier. After drying completely, the poultice was removed and the areas were rinsed with the same solvents used in the poultice. Commercially available paint stripper containing methylene chloride (Zip Strip) was tested as well. The poultice cleaning was no more effective at removing surface dirt and grime as simple swabbing.

### **3.1.3 Steam cleaning**

Steam-cleaning tests were conducted using the Robby VS3000 vapor cleaning system which can supply up to 40 psi of pressurized steam. The nozzle held at about 2-3" from the stone surface. Excess water on the surface was dried with cotton wadding. The surface was further cleaned with cotton wadding saturated with acetone and ethanol (1:1). This removed both dirt and grime better and more quickly than swabbing and poultice methods. However, care was required, especially when cleaning the coarse type stone, because its matrices and veins are vulnerable to loss. This was resolved by controlling the pressure and the distance between the steamer and the stone.

### 3.1.4 Removal of fill materials

Plaster fills in the joins were easily softened with deionized water. The cementacious material on the surface of the reliefs was unfortunately harder than the stone and was only minimally affected by water, organic solvents and dilute acid (pH around 2.5-3). Mechanical cleaning using an electric engraving pen/tool, fitted with a stainless steel point was found to be effective in reducing thick areas. A scalpel was also useful in reducing the material close to the stone surface.

## 3.2 Surface Cleaning

Based on the above tests, steam cleaning followed by acetone/ethanol (1:1) in cotton wadding was found to be most efficient and effective in removing surface dirt and grime. This method also minimized exposing the stone to excess water and exposing conservators to excess solvents in an unventilated workspace. The decorated surfaces of all six reliefs were cleaned as follows. An area to be cleaned (approximately 1 foot square) was steam cleaned, followed immediately by wiping the surface with cotton wadding and/or Webril cotton lintless sheets saturated with an acetone/ethanol mixture (1:1). The use of acetone and ethanol not only removed additional grime and old paint residue, but also hastened drying of the water. The distance of the steamer nozzle from the surface of the reliefs was modified as required to provide the best results. This process was repeated until the surface was cleaned to the desired degree. Some areas of overpaint from the previous treatments were reversed with water. The cementacious fill materials were removed mechanically using a scalpel blade and electric engraving tool.

## 3.3 Reversal of Previous Structural Treatment

Upon completion of the surface cleaning, the reversal of the previous joins was the next step in the treatment of the reliefs. Engineers and riggers were consulted regarding the possible methods and techniques of join reversal, including vertical disassembly. Although unstable due to the weight of each broken section of a relief, the joins remained firmly in place. The decision was made that in order to keep within the budget and time frame of the project, the joins of the reliefs would best be reversed when flat and face down. The riggers were especially helpful with suggestions regarding the tools and equipment necessary for separating the fragments. Before rigging the reliefs flat, the museum's architect, working with consulting structural engineers from Robert Silman Associates, P.C., confirmed that the load capacity of the workspace floor was adequate to accommodate all four of the fragmentary reliefs.

Contract riggers from More Specialized placed the reliefs flat, face down on padded wood palettes that were elevated to a comfortable working height with timber blocks. Before moving, the front surface of the reliefs were covered for protection with a layer of heavy gauge Mylar, followed by a layer of 1" thick polyethylene foam. Sheets of ultra high molecular weight polyethylene (UHMW) were placed on top of the foam. The UHMW polyethylene provides a slick, friction-reduced surface to assist in sliding the fragments of stone once separated. A second layer of Mylar was attached to the top surface of the wooden palette with staples (Fig. 10). The palette was then positioned against the padded face of the relief and secured with nylon straps.

The riggers winched this stone/palette package up off the A-frame using chain hoists hung on a mobile gantry positioned over each relief. The blocks of timber were strategically positioned to support the palette, as it was lower to the horizontal position. The backs of the reliefs were now exposed and accessible for treatment (Fig. 11).

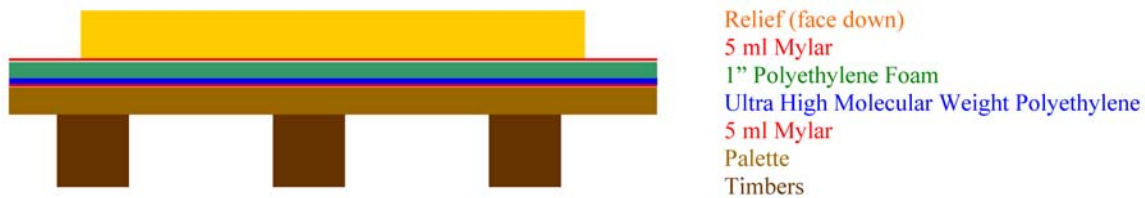


Figure 10. Relief package.



Figure 11. Reliefs are rigged, face down.

The minimal plaster fills present on the back edge of the break lines were removed mechanically using various small tools. High-density nylon and acetyl wedges were cut and shaped from bars of each type of plastic. Each wedge was approximately 11" long, 1 3/4" wide, with a thickness of 3/4" tapering to less than 1/16". These wedges were used with dead blow hammers to separate the stone fragments once the bulk of the fill plaster was removed. Hard plastic was chosen over wood or metal on the advice of the various riggers consulted. The plastic was less likely to damage the surface of the stone than a metal wedge, and the plastic being a harder surface was less likely to compress than wood, which could also abrade the soft stone surface. While working with these plastic wedges, nylon was the preferred material. Acetyl was often too brittle and would chip at the thin end. The various gaps and losses along the break edges allowed for insertion of the thin wedges. The force of repeated hammering alternating between multiple



wedges in sequence was sufficient to separate the joins. This indicated that no structural adhesive had been used in the assembly of these fragmentary reliefs. As the joins parted, short metal copper alloy pins were found in drilled holes along the joins. These were also secured only with plaster and they were removed after mechanically reducing the plaster. Simple wooden benches, made in the museum's carpentry shop, the same height as the palettes, were used as extra working space onto which the now separated fragments could be slip so that the break edges could be accessible for cleaning. Also, a hydraulic lift allowed us to move small relief sections out of the way completely when necessary. Sheets of the UHMW polyethylene were used to assist in the movement of the fragments.

The backs and edges of the fragments were cleaned of dust and grime, plaster, and gallery paint. Vacuuming was done overall. Typically, the plaster was softened with water and mechanically picked off using a scalpel blade. Brushing was sometimes necessary to access plaster imbedded in the recesses. Paint residue from previous gallery painting was removed with various organic solvents. When the backs and edges were cleaned, the riggers returned to flip the fragments face up. Many of the separated fragments, due to their relatively small size could be turned over by hand. The gantry was used to turn the largest fragments. The fragments were now ready for re-joining and mounting.

#### **4. Introduction to the Remounting**

Structural engineers were consulted on a preliminary basis to advise on a mounting system for the reliefs. In general, the discussions centered around the belief that only pinning and adhering the fragments together with adhesive would not achieve structural stability. A backing or a custom frame attached to the object would be necessary to achieve structural stability.

##### **4.1 Considerations for Reinstallation**

Because the other six reliefs had not been removed from the galleries in 1990/91, there was a desire to have continuity in the presentation of all twelve reliefs. The six reliefs remaining in the galleries are essentially flush against the wall, with the sides of each relief exposed. The space between the back of each relief and the wall had been filled with plaster and painted the wall color. This meant that for the six re-installed reliefs, the structural backing could not be visible at the sides. The reinstalled reliefs should also be relatively the same distance from the wall as the existing installed reliefs. Finally, the newly conserved reliefs should be the same height as the reliefs in the gallery. The reliefs that remained in the gallery had been placed on I-beams, set into a bedding material, so that the reliefs could be leveled and the top edges were in alignment.

Initially, the use of aluminum honeycomb panels as backing support for the reliefs was investigated primarily because it is a strong, lightweight, rigid material that had been successfully used to remount large heavy mosaics (Blackshaw and Cheetham 1982; Sweek et al. 2000), and by the Museum of London to back their Assyrian reliefs (Stockman-Todd 2002). According to the preliminary discussions with engineers, if aluminum honeycomb was used as a backing, the reliefs would need to be completely backed, however, the reliefs are larger than the largest honeycomb panel manufactured at the time. The panels for our reliefs would need to be

made by joining separate panels together at the factory. They would then need to be attached to the backs of the reliefs, either with an adhesive or by means of a mechanical attachment. As using an adhesive would completely obscure the backs of the reliefs, mechanical attachment by drilling into the stone was investigated. Because the thickness of each relief is not uniform and the surface of the backs are uneven, the mechanical attachment had to be adjustable to enable leveling of the honeycomb panel. The honeycomb panel needed a certain minimum number of attachment points, uniformly distributed across the surface, and not at a join of two honeycomb panels, to insure that there would not be a point of weakness in the panel itself. On the relief, the attachment points could not fall at or along a break line. These points of attachment would have to be pre-determined so that holes for the hardware could be drilled in the honeycomb by the manufacturer, as they did not recommend self drilling into the panels. A cleat would need to be attached to the back of the honeycomb panel to secure the relief to the gallery wall during installation. With all of these factors to consider, mechanically attaching the panel to the relief had become quite complex. Additionally, the thickness of the relief and backing package would exceed the current installation parameters of the six reliefs that remained on display.

The use of a steel mount or framing system was then researched. According to the preliminary discussions with engineers, the simplest method to structurally mount these reliefs would be to construct a metal frame around the reliefs, holding all of the fragments in place. This would have been ideal, in that no mechanical attachment or drilling was required, and likely was the reason for the frame around the reliefs when they were at the NYHS. Unfortunately, this did not fit our design parameters, as the frame would be visible around all sides. However, a metal mount could be mechanically attached to the back of each relief, designed to span the breaks only. Most of the back of the relief would remain visible. The profile could be designed to be minimal to mimic the current installation, yet provide the needed structural support for each relief. The specifics of the mounting will be further discussed in the treatment section.

#### **4.2 Consideration of Methods of Reassembly**

Various options for reassembly of the fragmentary reliefs were considered. Ultimately, it was decided to reassemble the fragments horizontally, face up on the wood palettes. Had we chosen to assemble the fragments vertically, we would have needed outside riggers for an extended period of time. This would have proven to be both time consuming and expensive. By assembling the fragments horizontally, the work could be performed in-house, on the already existing palettes, and time could be taken to ensure that adjoining fragments aligned well. It would keep the cost of the project within budget, while taking advantage of equipment on hand.

Test-fitting the fragments was conducted before the actual reassembly. All of the fragments were moved manually by the objects conservation staff, greatly aided by the slick surfaces of the Mylar and UHMW Polyethylene sheeting. Due to the uneven backs of the reliefs, the face of each fragment was usually not level and would rest at a slightly different height creating steps at the join line. Wood and plastic wedges were used to level out individual sections to ensure proper alignment, and wedges were secured to the back of the relief with microcrystalline wax where necessary to prevent them from becoming dislodged while moving the fragments into position. Their positions were mapped out on the pallet.

## 5. Structural Treatment

Since the support backing was designed to attach to the back once the reliefs were vertical, the goal of the structural treatment was to stabilize the joins so that they could withstand the force of being rigged from horizontal to vertical.

### 5.1 Adhesive and Pins

As the previous joins using plaster and copper alloy pins were clearly not structurally strong enough to withstand any movement, structural epoxy was considered. Desirable qualities in this adhesive were: a record of acceptance for conservation use, a pot life with a long enough working time to get all fragments aligned and leveled at once, a neutral color, to be of sufficient viscosity to remain in the location applied and also serve as a gap filler where there are significant gaps between the fragments, to be easy to mix with a simple epoxy:hardener ratio, and finally, be financially feasible and available in large quantities. The following four epoxies were explored and tested after a literature search: Sikadur 32, Hi-Mod LPL (high-modulus long pot life) by Sika, Sikadur 35, Hi-Mod LV LPL (high-modulus, low-viscosity, long pot life) by Sika, Araldite AY103 with HY991 by Vantico, Araldite 2011 by Vantico.

The Araldite 2011 by Vantico was selected because it met most of our requirements. This epoxy has a medium viscosity, golden honey color, a 2-hour pot life, 50/50 volume-mixing ratio, and is available in a variety of sizes with no minimum order. It is composed of a bisphenol A epoxy with an amine hardener.

Although the engineer suggested that the use of pins between pieces would contribute little to strengthening of the joins, we selected to use pins in strategic positions as an added precaution. Our goal was to use the extant dowel holes and not drill new ones. Ease of removal of the pins we applied now was important in the event they need to be removed in the future. Therefore, instead of securing the pins in place with an adhesive, we used pressure fit epoxy and bulked B-72 sleeves (Krumrine and Kronthal 1995). The holes identified to be used for pins were coated with two coats of 10% Acryloid B-72 in acetone, lined with a paste composed of 60 ml 20% B-72 in acetone, 40g cellulose powder slightly dampened with acetone, and 3g fumed silica. The lining was lightly sanded to a smooth finish when dry. Preparation of the selected holes proceeded with inserting Pliacre epoxy putty into the hole on one side of the break edge at a time. While the putty was still soft, a pre-measured 1/4" diameter stainless steel pin, covered with Vaseline, a petroleum jelly, then plastic wrap, was inserted into the Pliacre. The two sides of the adjoining fragments were pushed together and the Pliacre was allowed to set. Once set, the pin was removed, and the corresponding hole on the adjoining fragment was prepared with the Pliacre in the same manner. When the second side was set, the pin was removed and cleaned of the barrier layers, and then repositioned in the hole to await assembly. This procedure was followed for all pins used in the four reliefs requiring assembly.

## 5.2 Assembly

The edges to be joined were coated with 2 coats of 10% B-72 in acetone and allowed to dry for 2 weeks. A recently published study had shown that the B-72 layer was unlikely to significantly undermine the strength of the epoxy in a structural join, and would aid in its reversal when necessary (Podany et al. 2001). One relief was assembled at a time. The epoxy was mixed in plastic containers using wood tongue depressors and applied with a brush onto one section at a time, to both sides of the adjoining break edge. Mylar strips had been placed under each edge of the stone to catch dripping epoxy. Just before pushing the two adjoining sections together, the Mylar was removed. Extra care was taken when fragments with pins were being joined to ensure good alignment. This process continued until each fragment was in place. Wedges were added as necessary to level or hold pieces in the desired position. This process was used for all four fragmented reliefs. Even with the multiple test assemblies performed prior the actual adhering together of the fragments, additional adjustments were necessary in the final assembly since not all activities could be precisely replicated (Fig. 12).

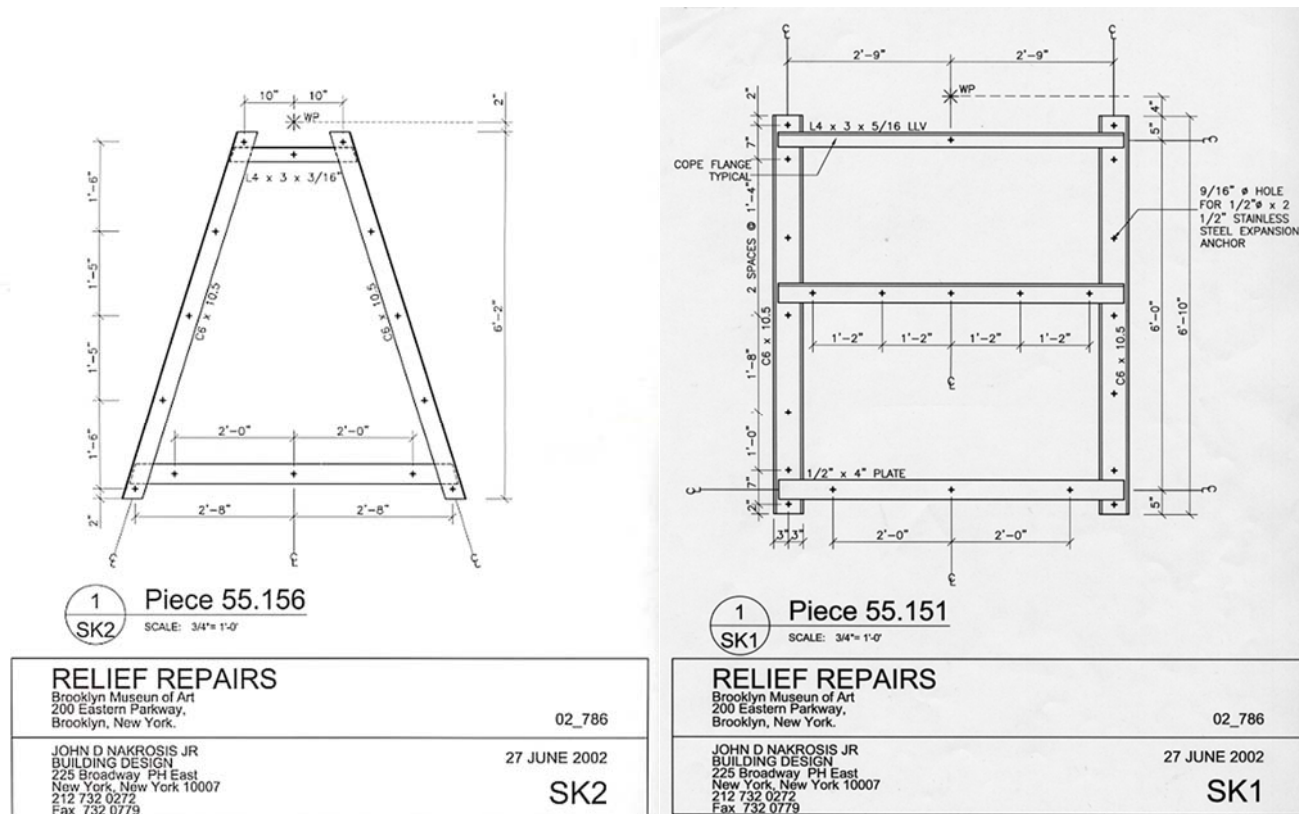


Figure 12. Horizontal assembly of reliefs.

## 6. Backing Support

The final design chosen for a support was a steel structural backing, which was secured mechanically to each fragment of the four broken reliefs. The backings, designed by John Nakrosis of Nakrosis Building Design, were customized for each of the reliefs, the shape determined by the configuration of the breaks (Figs. 13,14). As determined by the engineer, the steel backing was attached to each fragment with at least two bolts. The backing members were made out of a combination of C6 x 10.5 or C4 x 7.25 steel channel, and L4 x 3 x 5/16 LLV. The steel backings were fabricated by D.V.S. Iron works. Holes were predrilled for the bolts used to attach the backing to the relief. The horizontal top section of each backing was used as the

connecting piece to a steel wall bracket that secured the reliefs to the wall. Since the backings were attached to the reliefs while vertical, steel hooks were welded to the top of the backings so that they could hang from the reliefs while we were working. The backings were coated with a neutral grey paint by the manufacturer to inhibit rusting. The two unbroken reliefs did not require a backing.



Figures 13 (left and 14 (right). Backing designs by John Nakrosis.

## 7. Rigging the Repaired Reliefs Upright

Two of the repaired reliefs were rigged and returned to the A-frames without incident. These reliefs were strapped to the palette with nylon straps padded with Ethafoam. This package was winched up by chain hoists hung on a mobile gantry and placed on the A-frame, face in, in preparation to attach the backing. A third relief, 55.156, presented more of a problem. As the package was lifted, the adhesive joins failed instantly. The package was immediately placed back on the timber blocks. Neither injuries nor new breaks occurred, but this relief would have to be reassembled. The lifting method for the final fragmentary relief was adjusted to avoid more joint failure. In order to counter the inward pressure of the straps on the relief as it was winched, the face of the relief was sandwiched by covering with 1" Ethafoam followed by a large plywood board (Fig. 15). The lifting of this more rigid package was successful.



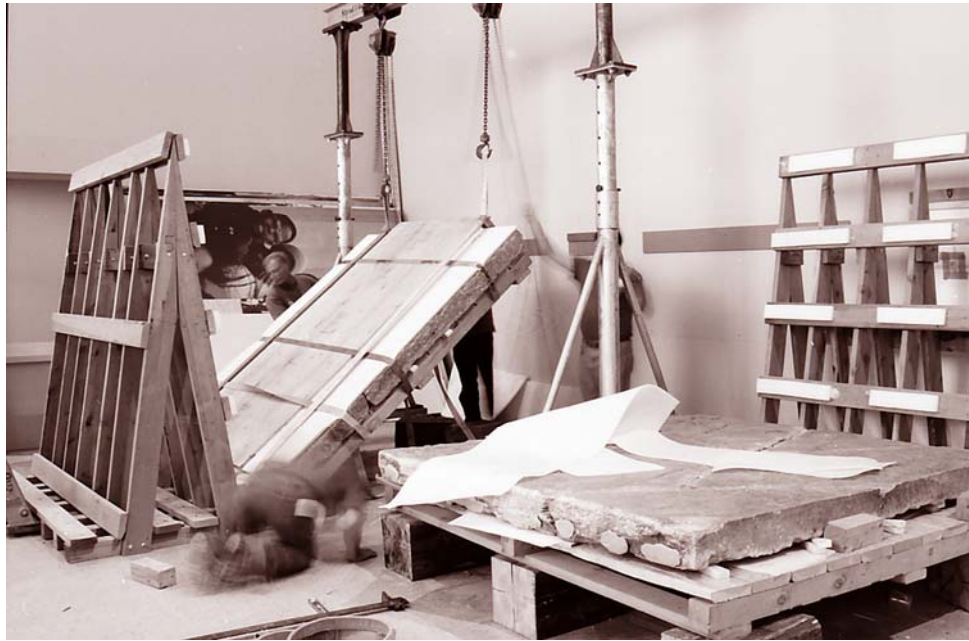


Figure 15. After assembly, reliefs get rigged upright onto A-frames.

### 7.1 Re-Treatment of 55.156

The cause of the joins failing was a very simple one. As we took the sections apart, we realized there were very few points of actual contact between these pieces. The epoxy we used did not have enough bulk to fill the gaps between the stone. In areas where there was contact, the epoxy sheared off the break edge with very little stone being pulled off. The break edges were prepared by mechanically removing the little epoxy that was in contact with the stone surface with scalpels and small chisels. Acetone was selectively used on the epoxy to assist in the mechanical removal.

Although various options for repair were discussed, it became clear that we would need to reassemble the relief the same way, horizontally, but using a more highly bulked epoxy. After investigating more viscous Araldite epoxies, Araldite 2013 was chosen for the re-treatment. This is a paste epoxy, grey in color, 1-hour pot life, 50/50 volume mixing ratio.

After assembling as before with this new epoxy, the relief was strapped around its perimeter to hold the sections together while the epoxy cured. Straps had also been placed around the relief in a grid pattern, and these were cinched to hold the fragments in place.

When the riggers returned to flip the relief, the straps conservation put on remained in place. The rigid sandwich was reconstructed as before using plywood and Ethafoam and the relief was successfully raised and placed on its A frame.

When viewing the reliefs from the back, it was apparent that there were large gaps in the break edges. Additional filling with the Araldite 2011 epoxy heavily bulked with fumed silica

(approximately 1:2 epoxy: silica) was conducted to reinforce the joins where edges are thin (Nagy 1998). The bulked epoxy could be rolled into coils and pushed into the voids by hand or with small tools. Occasionally, additional fumed silica was added while working to maintain this dough-like consistency.

## 8. Attachment of Backing

Various fasteners were investigated for attaching the steel backings. Working with our structural engineer for the project, John Nakrosis, we chose the Wedge-Bolt by Powers Fasteners. The wedge bolt is a one-piece anchoring device with a dual lead thread. It is easy to install, removable, has good load performance and is vibration resistant. The fact that this was a one-piece system and removable was very appealing. With the other anchoring systems, the bolt itself could be removed, but the sleeve would remain imbedded in the relief unless drilled out.

Before attachment, the backings were padded with 2-3 layers of ¼" Volara foam adhered with PVA-AYAC in toluene. With the aid of several art handlers, the backings were placed on the backs of the reliefs, being held in position by the hanging hooks at the top. Wooden blocks, used as shims, were placed under the hooks in order to raise and level the backing to the appropriate location for each relief. Once the correct position was achieved, straps were placed around the backings and reliefs to help hold them in place. The predrilled holes in the steel members were used as guides for drilling the holes into the stone. Conservation drilled ½" diameter holes into the stone using a special Wedge-bit fitted in a hammer drill. Teams of two conservators were used for this process. While one person drilled, a second would gauge the drill insuring the desired angle of entry was maintained. The engineer advised that a minimum of 1 ½" was necessary for the drilled holes to provide sufficient depth for secure anchoring of the bolts. The bolt length used in any one location was determined by the thickness of the stone in that area and the distance of the back surface of the stone to the backing. Depending on the length of a bolt used in a given area, the drilled hole depth in the stone was a minimum of 1 ½" but deeper at times depending on the thickness of the stone. The holes were vacuumed of the stone dust, and the bolts inserted. (Fig. 16)

At the recommendation of the engineer, once all bolts were inserted, Pliacre epoxy putty discs, approximately 4" in diameter, were placed around the bolts between the backing and the stone, to make up for gaps and to help support and distribute the weight of the backing and the tension on the bolts. Mylar (1 ml.) squares were used as separators between the Pliacre and left in place. Once the Pliacre hardened, the bolts were tightened. The hanging hooks on the top of the backings were then removed by cutting with a small angle grinder.



Figure 16. Backing in place with hanging hooks at top.

## 9. Installation Considerations

As previously mentioned, the height of all the newly backed reliefs had to be consistent with the installation of the six reliefs that had remained on display. W-beams (wide-flange beams) were used to raise the reliefs off the ground to bring them to single height uniformity. W-beams were used over I-beams because their extra wide flange provided more surface area for the reliefs to rest upon. Once in place, the W-beams would then be clad in granite to disguise them and visually match the existing installation. As all the reliefs are a unique height, the height difference between each relief in the previous installation had been compensated for with plaster applied to the I-beams. Rather than using plaster, we made up the height difference with Medex boards, a brand of fiberboard, which sat on top of the W-beams. These boards were made up of layers of  $\frac{1}{2}$ " –  $\frac{3}{4}$ " thick Medex laminated together with a piece of 1" thick, 9 lb. high density Ethafoam hot glued to the top of the Medex stack. Although this is a very dense piece of foam, we hope it will provide some cushioning for the bottom edge of the stone. The amount of Medex layers varied to achieve our target height for each relief. The beams and boards were done in sections with gaps left in between, not as a single long piece, to allow the riggers to get straps or a forklift underneath the stone during installation.

### 9.1 Anchoring to the Wall

The designs for attaching the reliefs to the wall were also discussed with the structural engineer. They were designed in such a way to allow for adjustment during installation, thus ensuring the

faces of the reliefs were plumb to the wall. For the four reliefs that required the backing attachment, an L-shaped steel wall bracket was made. The long leg would be attached to the wall and the short leg would meet the short leg of the L-shaped angle on the top of the backing. Pre-drilled holes on both short legs would be lined up, and a bolt inserted to hold them together. For the two reliefs without a backing, a different system was devised. We did not want to drill unnecessary new holes into the backs of these reliefs, therefore we chose to use the existing holes along the top edge of each relief. An L-shaped rod, attached to the wall, would pivot downward into the holes once the relief was in place between the backing and the wall attachment. The excess space in the holes around the rods would be filled with Pliacre epoxy putty. Both the brackets and L-shaped rods were installed into the wall with Hilti brand fasteners (Hilti HIT Adhesive Anchoring System). These fasteners are compatible with the wall structure, which is a hollow, concrete masonry block. This system consists of bolts screwed into an internally threaded insert placed in the wall and secured with an epoxy system formulated for concrete.

## 9.2 Installation

The riggers returned to install the reliefs, which involved the use of 2 gantries, a forklift, a palette jack and a J-bar. Each relief was strapped with loops at the top. The arms of the forklift slipped through the loops of the straps overhead. The relief was lifted straight up, and moved into place, over the W-beams, with the assistance of riggers guiding it into place. Conservation staff adjusted the placement of the W-beams as needed. Once everything was in place, the bolts were simply slid into place. Fine adjustments could then be made. If one side needed to move slightly forwards or backwards, it was adjusted using a J-bar, while holding the other side in place (Fig. 17).



Figure 17. Installation, 2002.

Medex shims were added or removed from the W-beams to level while lifting an edge with the J-bar. Also, further adjustments were made to bring the face of the relief into plumb. For almost all of the reliefs, they were leaning slightly backwards at the top. To compensate, the screws in the threaded inserts were loosened, resulting in the wall plate moving forward with the relief. The resulting gap between the wall plate and the wall was filled with finger shims cut from Medex (Fig. 18). This basic process of installation was carried out for all four reliefs with backings.

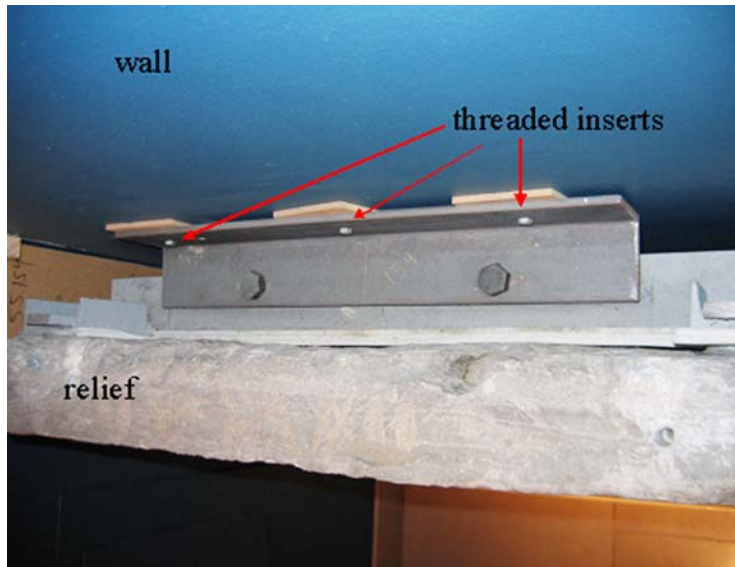


Figure 18. Installation, attachment to wall.

The two reliefs without backings followed the same basic adjustment routine; the only difference being how they attached to the wall. For these, a turnbuckle system was used. On one end is a straight rod which screws into the threaded wall insert. On the other end is a left hand threaded L-shaped rod. The L-shape rod fits into existing holes along the top of the relief. The excess space in the hole was lined with Mylar and filled with Pliacre. Once the Pliacre cured, the turnbuckle was turned to make additional adjustments to the plumb. Although this was a somewhat tedious process, the concept is very straightforward, easily reusable, and most importantly, it enabled us to use pre-existing holes in the relief for installation.

## 10. Compensation

Granite kick plates were fabricated and installed by an outside contractor. The reliefs had approximately 6" gaps on the left and right sides between the back edge and the wall, and of varying height along the bottom edge, which needed to be filled. As discussed before, in the 1950's installation this was done with plaster. We shaped ¼" Medex to fit into this void. After a rough cut was made to get a basic shape, the edges were further shaped with a Dremel tool for a snug pressure fit (Fig. 19). The boards on the side were painted the color of the gallery walls, as specified by the Design Department, and the area between the relief and granite, also filled with the shaped Medex, was painted a neutral beige.





Figure 19. Medex “fills” between relief and wall.

After installation was complete, the surfaces of the reliefs were vacuumed with a soft brush and lightly wiped with acetone and ethanol on Webril wipes to remove any dust and grime that resulted from installation. After discussion with the Curator, Jim Romano, it was decided not to fill the break edges or compensate for losses. However, it was decided to tone out any remaining concrete and plaster ghosting along the break edges. Also toned out were any major disfiguring scratches. Liquitex acrylic emulsion paints were used (Fig. 20).

## 11. Conclusion

The process of working closely with a structural engineer and art riggers during the treatment phases of such large objects proved invaluable, especially when dealing with budget and time constraints. The expertise of these two groups greatly assisted in the creative problem solving processes that conservators often undertake when facing less than ideal working circumstances. Our goal of stabilizing the reliefs was carried out with a relatively simple and inexpensive backing and installation design that can be easily removed and reused in the future, should the reliefs be deinstalled again.



Figure 20. After Treatment, 2002.

## Acknowledgments

The authors wish to thank all of the current and former BM conservators and interns who participated on this project, including Sara Moy, Katrina Posner, Sara Caspi, Karl Knauer, Sara Creange, Christina Krumrine, and Ken Moser, as well as all of the support departments including the Carpentry and Paint Shops, Collections Management, Archives and the Digital Lab. Additionally, we would like to thank the rigging company More Specialized, and outside experts including Bob Eberheim, Mike Aurin at Sillman and Associates, John Nakrosis, Dave Geiger, DVS Iron works. Finally, the Curators for this collection, Richard Fazzini, and most especially Jim Romano.

## **Consultants**

Preliminary designs for backing system and general mounting advice provided by Dave Geiger, Geiger Mountmaking and Design, Inc., 2407-2413 Third Ave. 1R, Bronx, NY 10451.

Advice on separating and moving fragments provided by Bob Eberheim, Eastern Rigging Supply Company, Inc. Box 39, Cos Cob, CT 06807-0039

Engineering Consultant for mounting and installation provided by John D. Nakrosis Jr., Building Design, 225 Broadway PH, NY, NY 10007

Engineering Consulting for Brooklyn Museum provided by Robert Silman Associates, P.C., 88 University Place, NY, NY 10003-4542, [www.rsapc.com](http://www.rsapc.com)

## **Suppliers**

Iron Frames:

DVS Iron Works, Inc. 117 14<sup>th</sup> Street, Brooklyn, NY 11215

Ultra High Molecular Weight Polyethylene, nylon and acetyl bars and stainless steel rods, dead blow hammers:

McMaster-Carr, P.O. Box 440, New Brunswick, NJ 08903-0440, [www.mcmaster.com](http://www.mcmaster.com)

Pliacre (Phillyseal R – Rat Seal):

ITW Philadelphia Resins, 130 Commerce Drive, Montgomeryville, PA 18936

Rigging:

Eddie McAveney of More Specialized Transport, 145-147 Myer Street @ R. R. Avenue, Hackensack, NJ 07601

Araldite 2011, 2013 epoxy resins:

Vantico, 4917 Dawn Avenue, East Lansing MN 48823-5691

Engraving tool/pen:

Sears Craftsman or Dremel brand. Dremel tools available at hardware stores.

Robby VS 3000 Chemical free steam cleaning machine:

Robby Vapor Systems, Inc., 8930 State Road 84 #323, Davis, FL, 33324

Powers Fasteners:

Tanner Bolt and Nut Corp., 4302 Glenwood Road, Brooklyn, NY 11210, ([www.tannerbolt.com](http://www.tannerbolt.com))

Fasteners:

Hilti Inc., 5400 South 122<sup>nd</sup> East Ave., Tulsa, OK, 74146, (www.hilti.com)

Orvus WA Paste, Webril Wipes, PVA, Volara foam:

Talas, 20 West 20<sup>th</sup> Street, 5<sup>th</sup> Floor, NY, NY, 10011, (212) 219-0770

Zip Strip:

manufactured by Star Bronze, PO Box 2206, 803 S Mahoning Ave, Alliance, OH, 44601, (800) 321-9870, available at local hardware stores

Ethafoam (Polyethylene closed cell foam planks, 9lb.):

Atlas Material Inc., 116 King Street, Brooklyn NY, 11231, (718) 875-1162

Hydraulic Scissor Lift, GL168076:

Global Industries Equipment, 22 Harbor Park Drive, Port Washington, NY, 11050, (800) 645-2986

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## **CONSERVATION OF BIG STUFF AT THE HENRY FORD – PAST, PRESENT AND FUTURE**

Clara Deck

### **Abstract**

Henry Ford's acute personal interest in restoring his "treasures" inspired astonishing exhibits that have attracted visitors for 75 years. His museum, including the 80 historic sites in the Greenfield Village "history park", was Ford's obsession from the 1920s until his death in 1947. He acquired enormous collections of Americana but it was in collecting and restoring technological and transportation artifacts that he was a pioneer. His resources for acquiring huge collections seem to have been almost limitless. His drive to restore objects demanded his individual attention even while he was at the helm of one of the world's largest automobile manufacturing companies. His approach to restoration was sometimes idiosyncratic since he mistrusted intellectuals.

Today Ford's legacy is an institution (now called The Henry Ford) with a consciously maverick approach to public program development. It is a dynamic "history attraction" with huge unique artifacts and vast numbers of collections. We actively use hundreds of antique collections every day. This paper explores the stewardship of key industrial artifacts at The Henry Ford, especially steam engines, from the days of our foundation to the present. It shows how Ford's involvement has had a lasting effect on our current approach to stewardship. Conservators at THF recognize the rewards and drawbacks inherent in the conflict between using and preserving collections and in so doing we embrace the complex challenges of caring for large industrial collections. Our approach to this dichotomy has been built on Ford's legacy with the goal of creating successful preservation strategies that champion the ethical stewardship and responsible use of the collections.

### **Henry Ford and his collections**

"These relics of days that are gone by tell only truthful tales. They can not lie."

Henry A. Haigh, friend of Ford, 1929 (Greenleaf 1964, 100).

"Henry Ford never does things by halves." H.B. Morton (1934).

The collections of Henry Ford's Edison Institute are huge in number and many are massive in size. The institution stewards one of the world's greatest accumulations of important large technological artifacts. Yet it is also burdened by Ford's reputation for over-restoration that calls into question the value of these collections as authentic historical records. Conservators and curators at The Henry Ford are constantly assessing and judging Ford's original approach. He rescued and revived the objects, and he was a pioneer in the field of Industrial Archaeology. But he had an insatiable appetite for slick cast iron and shiny nickel finishes and he wanted everything to operate. He used his company's skilled craftsmen and took advantage of his

immense industrial complex that provided resources for restorations of industrial artifacts. He also had absolutely no patience for scholarship. So contemporary keepers of these collections will always wonder which of his philosophies should be embraced and which should be discarded as they try to work within professional codes of ethics to fashion a reasonable conservation strategy in a consciously maverick institution.

Research into Ford's choices and methods has led to some insights into the conservation decision-making processes of the past and it has allowed conservators to question in particular some assumptions about the proper handling, maintenance, operation and storage of all the artifacts but especially the large technological collections. The "Big Stuff" at The Henry Ford today presents unusual conservation challenges not simply due to the scale and complexity of the objects themselves but also because of the collector's own priorities and peculiar approach to exhibiting them in the first place. Solutions to these challenges in a growing and ever evolving "history attraction" must be as innovative and bold as our founder's vision yet must also be rooted in an ethical framework that sustains the objects themselves.

During the nineteen twenties, by the time his Model T was a worldwide success that made him a household name, Henry Ford was already in his fifties and a multi millionaire. Although he indulged in a number of philanthropic activities, collecting old stuff was his major pastime. Well before he had anywhere to put it all, he had been happily amassing historical artifacts. He worked with agents who found relics and supervised their transformations to his own idea of beauty. He commonly delighted every visiting dignitary who came to pay homage to the celebrity industrialist at his Dearborn headquarters by showing them roomfuls of treasures in his Engineering building. He filled up his office, and used an area behind a new Ford Motor Company engineering laboratory, called Building 13, to sort his objects and prioritize restoration projects (Upward 1979, 21). He eventually acquired millions of artifacts. Dozens of men, collectors and restorers, were employed by Ford to support his obsession. He traveled to Britain on frequent antique shopping sprees where he collected almost everything his heart fancied, including some of the most ancient relics of the Industrial Revolution. Soon he developed an interest in restoring historic buildings, starting with a couple of inns out east and his own childhood home. He accumulated buildings and furniture, as well as all description of technological antiques from clocks to sewing machines. Ford also amassed roomfuls of rather small stuff: Edisoniana, phonographs, music boxes, firearms and fiddles. One of the objects he scoured the country for early on was the very agricultural traction engine he had operated as a young man (Lacey 1987). His interest in farm machinery, industrial production and electrical equipment soon outpaced the room he had to keep it in. Many objects that Ford did not want or that he considered duplicates were simply scrapped from Building 13 (Ford Motor Company Archives 1956, Peter York). There is no record of how many were scrapped, but estimates suggest about one third of the machinery shipped to the site survived. Before he had even conceived of the museum, he had a sizeable crew employed in the restoration of the relics. For restoring each of these treasures, Ford had access to a talented pool of his own Ford Motor Company employees. He took personal responsibility for the restoration of each of his treasures, guiding the process with meticulous attention to detail. The idea for the Institute grew out of his interest in bringing back his collections to their original appearance.

All this effort eventually led to the idea of a new kind of museum: a twelve-acre museum

building and an historic Village containing houses and businesses, but especially structures that could exhibit working machines showing his favorite industrial processes. It was to be a vast illustration of Man's Great Technological Progress that he called The Edison Institute. (The complex eventually became known as Henry Ford Museum & Greenfield Village but more recently adopted the name "The Henry Ford" to encompass the entire facility, which now includes a recently revived Rouge factory tour.) Starting in 1927 and throughout the 1930s, in the midst of a worldwide depression, Ford spent millions building his museum and historic village, "America's first theme park" (Lacey 1987). He bought out entire manufacturing machine shops and furniture stores. But nothing is a better measure of his collecting passion than the Big Stuff: hundreds of British and American steam engines (stationary, locomotive and agricultural), and enough machine tools to outfit three working machine shops in Greenfield Village and then some. Ford also acquired about a dozen airplanes and a considerable number of railroad rolling stock, not to mention fire engines and horse drawn vehicles. He shipped countless tons of cast iron machinery to restore and power his living history project, having boilers and even whole engines re-fabricated if none were in reach to buy. Workers once reported unloading five carloads of artifacts in one day...five train carloads, that is (Ford Motor Company Archives 1951, Roy Schumann).

Henry Ford spent his time and seemingly endless resources to indulge in a hobby that eventually grew to epic proportions. By the mid 1930s, after production at Ford Motor Company moved from Detroit to the enormous Rouge complex in Dearborn, Michigan, Ford "held the reins of control tightly in his hands" but was actually less and less involved with the car manufacturing business (Nevins and Hill 1962, 71). Instead Ford pursued his other interests, chief among them being his obsession with antiques. His manufacturing lieutenant Charles Sorenson made the observation that: "After Ford started Greenfield Village and the Museum at Dearborn he was seldom at the Rouge Plant. In his later years he actually put more hard work into the Museum than into the Ford Motor Company" (Sorensen 1956, 19). It could be said that Ford became more deeply involved with the old stuff than the new and by the 1940s his erratic control of both the company and the Village meant trouble for both. His ambitions were almost megalomaniacal and he ran out of time to do everything he wanted to do. Although he did not write nor record anything directly about his major collecting passion, anecdotal stories of Henry Ford's personal interaction with his historical collection offer a view of his restoration philosophy and his idiosyncratic notions of history.

For almost three decades, Henry Ford spent the better part of every day when he was home in Dearborn guiding the work at the Museum and Village. He called every shot: "The old man told everybody what to do" said one hand who had worked for Ford for many years (Ford Motor Company Archives 1953, LeoRugg, 23). Ford would come around every day, after visiting the schoolchildren saying their prayers in his Greenfield Village chapel, to check on works in progress and give orders to the foreman. Many anecdotes of his visits to restoration projects under way in the Village attest to the acute interest he had in works in progress. A born tinkerer, according to his own favorite personal legend, he needed to be present as his men worked to fulfill his dream of elevating technological contrivances to their proper glory. "The details of practically everything were taken up with Mr. Ford. It was learned that if something were done in the Village or the Museum that he didn't like it would soon have to be done over again. It was much easier to have a complete understanding with him originally, than to tear something down

and re-do it, though that did occur in some instances” (Ford Motor Company Archives 1951, Fred L. Black, 40). It is well established that he supervised restorations personally. Evidence of Ford’s own approach to restoration can be seen in the remainders of these gigantic collections still at The Henry Ford.

A series of oral histories with former employees and acquaintances of Henry Ford conducted by the Ford Motor Company archives in the 1950s reveal some of Ford’s approach to the preservation of his collections. Ford hired carpenters, cabinetmakers, machinists, die makers and laborers to work on his antiques. They remembered working on antiques before the museum was created. Ford singled out factory workers he liked and showed them antiques he wanted to have them work on. The oral history project interviewed men like Roy Schumann, who was a steam shovel operator before he started working on Ford’s antiques. He was foreman of the “bull gang” of men who rigged up all the huge British and American steam engines for Ford’s museum. Schumann’s crowning achievement was the installation in the museum of an enormous gas/steam engine weighing 750 tons, one of nine massive engines that powered the famous Highland Park plant where the assembly line was born. He was proud to do it all “by hand” using men’s muscle power, winches and cribbing. He recounted that Ford would check on his work daily: “If he was really interested he’d drop back and look the job over maybe half a dozen times a day” (Ford Motor Company Archives 1951, Schumann, 5).

Schumann was one of the handpicked elite that Ford put to work on restoration and installation. Some of them thought they had been hired to work on experimental engines only to find that they were instead spending all their time perfecting old antique engines (Ford Motor Company Archives 1956, William Mielke, 154). They first set up shop in the huge new Ford Engineering building in proximity to where the antiques were flooding in. But there they were liable to be caught by the hardnosed Superintendent of Production at the Rouge nicknamed “Cast Iron Charlie” Sorensen who, one day, summarily ordered twenty men back to work at the Factory. Ford got wind of it and they were back in the workshop the next day. Apparently the scenario was repeated more than once. “Mr. Sorensen would abruptly order them all back to work, and Henry would bring them back the next day.” (Ford Motor Company Archives 1952, Harold M. Cordell, 16). Much of the work on the wooden antiques, smaller domestic arts devices and machine tools was done in the recreated Village buildings after construction began there in 1927. As much as possible was done at the Village where Ford could keep an eye on progress and the men could work in peace away from the bustling manufacturing complex. Anything that was too large or specialized, like casting, re-machining of steam engine crank shafts or plating could be sent to the Rouge shops, where they also had a locomotive maintenance department. There was also a team working on automobiles throughout the 1930s and 1940s who had only to “send to the Rouge” for parts, plating and bodywork whenever necessary. They restored about one or two cars per year. The largest steam engines were restored in the Locomotive shop at the Rouge complex under a man named Bill Miller (Ford Motor Company Archives 1954, Ernest Foster). Any part they needed, no matter how large, could be designed, cast, machined and finished right on the premises. About one hundred agricultural engines were restored on museum property. Eventually at least a dozen stationary steam engines operated in Greenfield Village. (Fig 1).



Fig. 1. View toward the High Park Engine, Henry Ford Museum, 1941.

Ford's apparent mistrust of intellectuals affected how he ran things at his private park (Morton 1934). A report defending the Edison Institute from government questions under the new Fair Labor Standards Act of 1938, when Ford was decidedly at the helm, listed all the jobs at the Edison Institute and it is clear from this record that Ford's emphasis was squarely on the machinery restorations. The report lists 81 janitors, 11 millers (wood & grist), 8 men each for foundry work and antique car repair, 4 men in the boiler shop, 4 blacksmiths, 1 shoe repairer and no fewer than 20 machinists. They were *all* restoring other machines. Yet there were only 4 office workers and one librarian (Edison Institute Archives 1938). Stories still circulated decades later that Ford's son Edsel (who with Henry and his wife Clara represented the board of the Edison Institute) tried to professionalize the place during this period. As Ablewhite recalled, "...Edsel would get somebody out here whom he thought might become interested in the place and maybe become a curator or director. Mr. Ford would take him out, and if he couldn't talk intelligently about a piece of machinery, he was out; that was his criterion" (Ford Motor Company Archives 1956, H. Ablewhite, 76).



**Ford's attention to detail but his lack of research: a belief in "horse-sense"**

The craftsmen and machinists working for Ford had fond memories of all the attention they received from the Great Man as he began spending more and more time directing their restorations. Said Peter York, a craftsman who worked on Ford's antiques from the earliest days, "Mr. Ford took a lot of interest in what we were doing with these things. He was right with me every day" (Ford Motor Company Archives 1956, Peter York, 31). Henry Noppe was a Dutch die maker who came from the Highland Park plant to work on Ford's antiques in Building 13. He hand-picked his crew of up to 25 men from the tool room at the plant and began restoring anything Ford asked him to, starting with the guns. "When I first came over here in '29, Mr. Ford ran the village himself. He was always in charge; nobody had anything to say. Mr. Ford would get there in the morning and be waiting for me when I showed up....He was very much interested in what went on here in the Village. That was his hobby, even though he didn't do it himself; it was his hobby to see things done the way he wanted it" (Ford Motor Company Archives 1953, Henry Noppe, 10).

Edward Cutler was Ford's self-taught architect in charge of reconstructing buildings brought to Greenfield Village. Referring to the restoration in the early 1930s of the Sir John Bennett jewelry shop that contains a tower clock, bells and bell-striking "Jack" figures [1] of Gog and Magog from London, England, Cutler said:

You know Ford was the kind of man, if he singled you out to go to Chicago to sell some cars, you would go and do it, whatever he told you to do you did. I would do things around here that I would have to cart home a bunch of books every night, and my wife would laugh at me, because they were so new to me, but I had to find out. You were told to do it and you did it, you never said you couldn't do it. You always went ahead and made a stab at it, and tried to do it and did it (Ford Motor Company Archives 1956, Edward J. Cutler, 53).

Ernest Foster also worked on the wooden figures of Gog and Magog. He worked on everything from guns to furniture to tractor parts. As far as he was concerned,

Mr. Ford run it himself. In other words, when Mr. Ford wanted anything done, that's what was done. He was the boss. I think Mr. Ford had plenty of people down at the Rouge to run the automobile end of the business. Mr. Ford was here in the Village every day when he was home. It was his hobby (Ford Motor Company Archives 1954, Ernest Foster, 8).

**Ford's "better than new" restoration philosophy**

Although Ford was conscious of his role in preserving technological history, he did not have much patience for exhaustive research on authentic details. As for Ford's restoration philosophy, if it can be called that, "very shiny" might be the operative words. Many of his restorers saw nothing wrong with this approach. Foster mentions this specifically: "We didn't do any research on any antiques at all. We just reconstructed it according to the lines of the object itself" (Ford Motor Company Archives 1954, Ernest Foster). "I rebored cylinders, remachined crankshafts

and everything that come along for the steam engines” remembered William Reinhart. “Ford never brought in blueprints or sketches for us to work from. He just told us what he wanted done.” He would just say, ‘Fix it up’...” “We had to put more finish work on them than was originally on them because Mr. Ford liked it.” Rinehart was proud to declare that, “He always wanted a draw file finish. That was his finish. A lot of those engines are better now than they were originally.” (Ford Motor Company Archives 1954, William Rinehart, 19). Rinehart was the only interviewee who remembered keeping notes. He recalled keeping a little book in his tool box for his own interest, but this book was not retained by the institution.

Ford often imposed his vision of beauty onto these artifacts, transforming too many into not altogether accurate representations of a type. Little restraint was shown and the term “minimal intervention” would have been a foreign concept to the men restoring Ford’s treasures. Many machines and engines had their bright work nickel- or even chrome-plated, and too many were painted with shiny black lacquer paint. Today, the stewards of the collections refer to artifacts having been “Fordized” when they exhibit plating where none would have been originally, when inappropriately elaborate parts are added and when all the castings are rendered perfect by applications of thick, shiny black paint. It is clear that the restorers working in the Village and at the Rouge had free rein to show off their design and machining prowess. On the one hand historians can lament liberties taken in the restoration of some of these relics. Yet at a time when few men had the means, much less the will, to acquire such significant collections of technological artifacts, Ford’s liberties can also be interpreted as a mark of his intense respect for the engines and their makers. Who could appreciate the art in derelict machinery? Bright and shiny, just like a gleaming black Model T, the objects would get notice and esteem.

The story of the Dotterer steam engine tells of a classic “Fordization” treatment to “one of the very earliest American steam engines in existence” (Bowditch 1993). Built in 1835, the engine was “badly compromised” by Ford once he acquired it. The most obvious change made during the Ford-era restoration was the replacement of the original wooden base frame. Instead of finding proper southern yellow pine to recreate the frame timbers clearly visible in photographs taken of the engine in-situ, Ford made massive steel members, carefully tapped and drilled to hold the cast iron bedplate of the engine.

The Dotterer engine is now destined for loan to a restored pre-civil-war iron foundry museum in Tannehill Ironworks State Historical Park near Birmingham, Alabama. The current restoration scheme was carried out by Robert Johnson who worked on many engines for the Smithsonian’s centennial exhibit in the Castle on the Mall in 1976 and has many years of familiarity with the Ford collections. Johnson was eager to be a part of the resurrection of a significant American icon. And he knew where to acquire the massive southern yellow pine timbers required for the bed. So a decision was made to restore the engine to an era closer to its original use and undo the “Fordization” as far as possible. Johnson discovered numerous interesting incongruities. Every bit of bright work on the engine was nickel-plated by Ford’s men at the Rouge. Johnson drew the conclusion that virtually all parts except for the castings are replacements. He expected the link-rods and beams to be wrought iron, but they are all, in his view, homogenous modern steel. John Bowditch, the Institute’s former Curator of Industry thinks on the other hand that the parts are original but simply machined down to a smooth finish and then plated. Perhaps metallurgical testing can improve our understanding of this conundrum. However the Dotterer

was treated, Ford might have realized it would be rarely used once it was set up in the Rice Mill in the Village (now re-purposed). The “bright work” of rarely used machinery soon rusts without regular oiling, so Ford plated the bright work to keep it shiny. The same restoration problems that might have plagued Henry Ford plague conservators today. How to keep previously over-restored, recently re-polished metal from corroding overnight in humid environments? Today the answer is often lacquer or wax coating but nickel-plating seemed a great solution at the time.

Another story of a steam engine relates a Fordization that may have resulted in a treatment more in keeping with current conservation practice. Herbert Morton, the Engineer in Charge of Plant at the Ford Motor Company, England, was commissioned by Henry Ford in the late nineteen twenties and thirties to acquire old engines and other objects in Britain. Morton traveled far and wide gathering “suitable specimens” that could “only be found in Europe” (Morton 1934). He looked after their restorations and shipped them to Dearborn. He collected many objects that struck Ford’s fancy, whatever he could convince the owners to part with. He set them all in their places of honor in Ford’s Edison Institute museum.

The earliest Newcomen and Watt engines that Ford so desired were icons of the Industrial Revolution and well known to British engineering societies. Morton warned Ford that the “cost of obtaining them, and their dismantling, shipping and re-erection in America might be enormous”. Ford declared, “Well, I’ll tell you – I’ll spend Ten Million Dollars” (Morton 1934). Morton’s most important find was a rocking beam steam engine from about 1760 that John Bowditch has declared “quite possibly the oldest extant steam engine in the world” (Bowditch 1993). Morton recounts a delightful story of his attempts to reproduce authentic replacement parts for this great Newcomen engine, known as “Fairbottom Bobs.” Yet even this venerable acquisition barely escaped Ford’s penchant for making things “better than new”. Ford himself visited the site of the derelict engine in Fairbottom Valley of the English mining county Lancashire. After having actually jumped up on poor Morton’s shoulders to peer into the vertical cylinder and tumbling down in a fit of laughter, Ford made up his mind that he had to have it. Great obstacles were overcome to dismantle the relic. The foundations and many parts were unearthed and the well shaft dredged in hopes of recovering the pump chain and bucket. Back at the museum, Morton worked with Roy Schumann and his gang to reproduce the foundation pits and reassemble the carefully documented stone columns. At last, after the engine was completely reassembled, Morton found that he had disappointed Ford on one detail. He had replicated the badly rotted rocking beam with a massive oak timber that had been adzed to replicate what Morton was certain must have been the authentic finish. “Ford came along and said ‘I don’t like that, let’s have it planed and made nice and straight’”. Feeling certain that he would be criticized by aficionados for such a decision, Morton risked “decapitation, which everybody assured me would happen”, but took a risky compromise and had it straightened but then covered it with thick tar. Ford’s reaction was, “My, that looks fine”. So Morton had his “rough appearance” and “Mr. Ford had his straight lines” (Ford Motor Company Archives 1956, Hayward Ablewhite). This solution, which is actually well in keeping with current philosophies that call for replica parts to be distinguishable from originals, offers some insight into the approach Ford’s agents took to make him happy.

It is clear that the intent of Ford’s restorations was first, to render the machines operable whenever possible, and second, to make them look attractive. Today the practice of conservation

for large industrial artifacts employs a more systematic approach to rigorous methodological standards. Justification for decisions like replacing parts and finishes and even sometimes merely polishing surfaces must be duly recorded. Retreatability – a goal difficult to achieve with big stuff, especially if it has been left to deteriorate in aggressive environments – must also be considered. Treatment decisions and methods must be documented and photographed.

But for Ford these notions would likely have been met with impatience if not disdain. In rare cases restraint was shown in the replacement of only missing elements or badly worn parts. Many agricultural wagons and processing equipment exhibit their original finishes as do some machine tools and a few engines. Agricultural implements like plows and harrows have been documented recently with very few wooden elements replaced. In many instances new repairs are beautifully applied with obvious restraint, leaving worn parts that bear the character of their original use in the farmer's field. More often machines were "improved upon" by the restorers under Ford's direct supervision, with some highly questionable results. For instance, if one were to study the history of steam engines solely from the collections of the Henry Ford, one might draw wildly inaccurate conclusions about the prevalence of nickel plating on machined engine parts.

An example of an artifact that was not Fordized is the beautiful horizontal steam engine made by Franklin Machine Works in 1848. Considered to be emblematic of its type, the engine has gracefully curved spokes on its flywheel/belt wheel, and two pairs of fluted columns to hold the valve motion transfer shafts. Clearly, it was never left to deteriorate outdoors. As a contract conservator of large objects on the Made in America exhibit project in 1991, the author was asked to conserve the original paint surfaces on this remarkable survivor. Under dozens of layers of over-paint, staff laboriously uncovered one of the earliest layers: a deep rich green. The flywheel spokes were red, and the original paint still in remarkable condition. An area of original paint was left as found on the cast frame and one side of the flywheel. This was due to time constraints, but also as a form of visual documentation of its restoration history.

### **Loss of focus on "Big Stuff" after Ford's death**

After Henry Ford's death in 1947, some restoration projects were left unfinished, and the institute's resources shifted away from the industrial collections. Things were left pretty much untouched in the museum where Ford had left them, and in the Village his handpicked restorers eventually left or retired. Rather than build on this particularly resource-intensive aspect of Ford's legacy, most of the industrial collections were kept fairly stagnant. Slowly the engines stopped whirring. Rather than maintain everything in working condition, many of the big machines and engines in the Village were allowed to lie fallow. The machine shops closed. There is evidence that employees of the Detroit Edison electric company still sent employees to the museum to study power generating equipment for hands-on demonstrations as late as 1952 (Detroit Edison Company Newsletter 1952). But very little "Big Stuff" was collected or restored during the 1950s and 1960s.

Clara Ford was left with the daunting task of running the Edison Institute after her husband's death (three years after his son Edsel had passed away). She hired H.B. Ablewhite, a former

Episcopal Bishop and Supervisor, Ford Motor Company Sociological Department, to run the museum for her. Ablewhite knew he was walking into a hornet's nest. In 1949 he found "the files in deplorable condition" and no one who could actually be said to be running the operation. He knew this was because Ford had "guarded the place so carefully and refused to let anybody come in who would interfere with him" (Ford Motor Company Archives 1956, H. Ablewhite). The exhibits remained almost stagnant for years thereafter. Very little mass collecting of industrial collections took place throughout these years, but a few significant large pieces were acquired. One of these was a 600-ton Allegheny locomotive that was squeezed into the museum in 1956. Visitors to the Museum in the mid 1970s could still climb to the mezzanine of the Highland Park engine and look out over the tractors and agricultural engines which held a place of prominence in the central axis aisle of the great hall of the museum.

### **The coming of museum professionals**

Professional curators hired during the 1970s saw the potential of the collections to fulfill the newly refined educational goals of the institute. Efforts were made to save some of the industrial relics that had been left outdoors in the Village once Ford's twelve-acre Hall of Technology had filled up. Two huge steam engines, a beautiful circa 1855 Gothic beam engine, and an 1895 Triple-expansion steam engine and generator set, were brought inside. Due to the extensive deterioration sustained by these behemoths after many decades of exposure, a conscious decision was made by then curator John Bowditch to restore rather than conserve both engines. Bowditch also reinstated tours of some of the engines in the museum that could be run at very slow speeds on compressed air. He revived the Armington and Sons machine shop in the Village, which is a recreation of a typical 19<sup>th</sup> century "small jobs" metal forming facility, complete with clerestory windows and two line shafts. Ford had placed it prominently near the front of Greenfield Village to educate the public about the importance of American precision manufacturing but over the years it had become inaccessible to the public because it was crammed with unrelated machinery. He cleared out decades of accumulated junk and installed a remade boiler so the steam engine could work again. Although setbacks occurred such as the death of a steam engine attendant in the early 1980s, progress in dealing with the industrial collections as valuable and non-renewable resources was steady.

Since Clara Ford's tenure, curators, facilities maintenance and administration staff had been required to cope with all aspects of collections management and care. Eventually, however, the museum eventually saw the need for a separate department of Conservation. After a devastating fire in the museum in 1970, curators began to make formal requests for a full conservation department (Upward 1979). This step was taken and a new laboratory wing was built onto the museum in 1972. It took some years for conservation staff trained in fine art conservation and horology to turn their attention from the fascinating decorative arts collections to the industrial collections. The transition was truly underway when work began on the Made in America project in 1989. That large museum exhibit employed a range of approaches to present industrial artifacts to the visitor. The conservation strategies kept these approaches in mind, dedicating a large specially-hired crew to completely disassemble, repaint and rebuild into operational condition the Triple Expansion steam engine and Westinghouse generator that until then had become eyesores in Greenfield Village. Other rare survivors, such as a stationary steam engine



made by the Franklin Works in 1848 and a small metal planing machine from 1868 were discovered to have original paint surfaces under years and years of over-paint. Because these objects did not need to operate, a much more conservative treatment of selective and careful over-paint removal was applied to them. Since the Made in America project there have been rare instances of new operational collections; the majority of these are small crafts working machinery and historic automobiles.

Today a new generation of conservators and curators embraces the challenges of caring for the industrial and transportation collections of The Henry Ford. Conservation of “Big Stuff” at The Henry Ford now endeavors to adhere to the basic tenets of professional standards. These standards are applied to every possible use of industrial artifacts, whether that use is educational demonstration or the presentation of a non-operational historic relic. Individual treatments may involve replacement of badly deteriorated parts, while within the same artifact other elements may be treated in a much more conservative fashion. Rare original paint on industrial objects is highly valued. Treatment reports are complicated and lengthy, sometimes best presented as a treatment log where essential decisions and methodology are carefully recorded. Stated policy is still “to conserve rather than replace, to repair rather than restore”, and great effort is often spent in the retention of original parts and finishes.

The Dymaxion House project illustrates the collaborative nature of large-scale conservation projects. This three-year project hired contract professionals and technical staff to prepare Buckminster Fuller’s prototype round aluminum “Dwelling Machine” for an exhibit that opened in October 2001. The conservation task was carefully planned and well funded. It was designed according to the principles of well established Building Conservation practice, applying architectural methodologies to an artifact that is more Industrial Prototype than Historic Structure. The unusual structure of the Dymaxion House posed unique problems. It hangs from tensioned rings and cables off a central mast. It was a prototype and not designed to withstand the traffic of about a half-million visitors a year. So the restoration required an engineering study and some shoring up of the structure. The project was directed by a professional architectural conservator and included structural engineers, metallurgists, chemists, museum conservators, the U. S. Forestry Service and numerous volunteers and paid staff to accomplish the job over a three year period. It applied the tenets of the Venice Charter (International Charter for the Conservation and Restoration of Monuments and Sites 1964) and began with a well reasoned Historic Structures Report that identified the history of the physical structure and established clear priorities for the million-dollar project. Progress was recorded in many ways; the most accessible to the public was a Conservators Journal on the Museum’s website. It culminated in a set of “as built” drawings [2] of the restored Dymaxion House produced by an intern from an International Council for Monuments and Sites (ICCOMOS) program. The drawings conform to standards established by the Department of the Interior’s Historic American Building Survey/Engineering Record. The Dymaxion project shows how large scale treatments can be organized.

Although large scale projects are exciting and garner the most attention, conservators at The Henry Ford maintain an interest in all aspects of collections preservation. An equal amount of time is spent departmentally on recognizing the most pressing conservation needs of the whole institution and addressing these preservation issues globally and across the whole Institution. A Conservation Assessment Program through the Institute of Museum and Library Services in the

1980s helped focus attention on systematic policies to preserve all the museums collections. Thus efforts are spent improving daily use and repair of the hard-working operational collections as well as improving exhibit and storage conditions for all collections. Conservators engage in collections care from new acquisitions to exhibit planning by focusing on a holistic approach to collections management with an emphasis on preservation planning. The institution has a long history of using historical collections “as originally intended”. Yet conservators regularly advocate for the responsible utilization of these collections. Efforts to counteract a culture of consumption sometimes appear to be uphill battles. Conservators emphasize the need for comprehensive maintenance plans, not only for collections in use or on static exhibit, but also in storage.

In terms of the actual work entailed in preparing “Big Stuff” for exhibit, contemporary stewards probably deal with many of the very same kinds of treatment issues that Henry Ford’s men did. It is only the philosophical approach that differs. In most cases the museum no longer has the same access to men who personally remember operating the machinery. Access to highly skilled industrial craftsmen for restoration work can be more difficult today than it was in Ford’s time. But just like the men at the Rouge Locomotive shop and Mr. Schumann’s “bull gang” of museum riggers, present-day restorers must consider many of the same issues: How is the huge stuff best moved without risk to the staff or the collections? How can the machinery be used and operated responsibly? Where can it be stored safely? Where is there space to restore and reassemble it? Is there good evidence for the treatment choices?

The millions of industrial artifacts at The Henry Ford still pose huge management challenges today. Merely storing and handling “Big Stuff” that is measured by the ton can be a particularly daunting task. Another useful tool in this endeavor is the recently adopted ranking policy. The ranking policy classifies objects based on the historical rarity of each artifact and its relative importance to the collections. It is used as a guideline to help set preservation priorities for individual collection items. It also serves as a framework to assist in the critical decision to operate a collection artifact. The ranking may also influence the level of funding and effort that will be spent improving the physical access and mitigating environmental agents of deterioration in storage. In a fast-moving organization with collections so vast that major cataloging initiatives are still ongoing, ranking collections based on their relative value helps conservators prioritize work. The ranking policy helps conservators accept that not every collection item is rare or even valuable and that conservation efforts must be reasonable and focused to be effective. It is an approach that allows preservation to keep pace with program expectations for responsible use of the collections.

There is a proposition that the operation and preservation of historical artifacts are mutually exclusive concepts. This is doubtless true, but not altogether tenable as the only guiding conservation principle in a public institution. Making a costly decision to maintain an artifact in operating condition may be justified after rigorously weighing a range of issues. After considering each artifact’s restoration history, its past use, the detrimental potential of wear and the artifact’s potential for creating memorable learning experiences, running artifacts in controlled circumstances and at reduced loads can sometimes be justified. Today, there is a whole department of skilled professionals dedicated to the maintenance of the Greenfield Village Railroad. Other full time staff (although nowhere near the numbers Henry Ford employed for

the same jobs) maintain the Historic Operating Machinery and Antique Vehicles. Their primary job is to inspect and maintain over two hundred working artifacts in the museum and Village. Conservators developed these positions, and have coached the staff members ever since the positions were created starting in the 1980s. Conservators established training and maintenance protocols throughout the 1990s, guiding skilled men who were interested in machinery and restoration but did not have formal conservation training in the philosophy and practice of museum conservation. Conservators also supervised these departments until early in 2006 when conservation's role in the daily operation of artifacts was relegated to that of adviser. There is an official Preservation Policy for the collections that includes conservation oversight of all the collections. Any new operational artifact would theoretically require a conservation treatment and a maintenance plan. But this process has not yet been tested in the new management structure.

## **Conclusion**

Henry Ford put a great deal of time, effort and money into finding and restoring antiques. He amassed a huge number of collections, some of them artifacts of very large proportions: hundreds of steam engines, agricultural machinery, electrical production, machine tools and Edison's entire Menlo Park complex were dismantled, transported by ship and train car-load to Dearborn Michigan for re-erection. Although he "Fordized" many things, his collecting vision was impressive. His "concrete and inductive approach to history" was very different from an intellectual's aesthetic, reasoned analysis (Greenleaf 1964, 95). Unlike other wealthy collectors who wanted fine art and high-end antiques to show off their superior aesthetic understanding, Ford assembled his own version of history where agricultural, industrial and domestic arts objects prevailed. Yet Ford's ultimate vision for the collections themselves was so personal and eccentric that after he died it became difficult to sustain or augment this dream on the scale he must have envisioned. After his death, the institute he founded had serious challenges maintaining his collections without his financial resources. Slowly, inexorably, the machinery he fired up went dormant.

Today, teams of curators, conservators and living history professionals recognize the great advantage that access to this great collection grants them to tell powerful history. Programs that extol the value of the "Big Stuff" also advocate for its responsible use. Since the 1970s curators have been refining plans to add to the collections in specific areas. Real strides have been made in bringing machines that had been left outdoors into the museum. Conservators, registrars and collections managers meanwhile have been struggling to establish preservation priorities in a rapidly expanding, dynamic institution. Ongoing efforts continue to document, survey and care for these collections. Treatment decisions need to be based on diligent research and careful artifact analysis. Preservation plans and strategies that align themselves with the greater institutional vision contribute to an ever more responsible approach to the utilization of the collections. Documentation, especially recording the justification for major compromises, is a crucial legacy that this generation of caretakers can give to the future stewards of the "Big Stuff".

In Ford's day it seems that no expense was ever spared for restorations. The fact that The Henry

Ford is now a non-profit institution means that there is no longer carte blanche for funding any initiative, conservation work included. The conservators of today would have been able to talk a lot of great shop with Ford's restoration gangs. The men were skilled workers but they were not guided nor governed by anyone else's scholarship. Yet many of the actual techniques of treatment for large industrial artifacts that are employed today would not be unfamiliar to Ford's men. The real difference lies in basic methodology. Ford's faith in the "good old horse sense" of his men probably stood him in good stead when it came to the machine tools, motors and engines that he himself knew so much about. Unfortunately, Ford's way of learning by doing allowed some collections to lose their original finishes. Ford expected virtually every piece in his collections to operate and his taste for the aesthetics of shiny surfaces sometimes outweighed historical veracity. Yet Ford's unique vision saved many significant artifacts from destruction. The technological and industrial artifacts that he retained from the truck- and train-car-loads that arrived for years at his property were in some cases better cared for than the decorative arts such as furniture. Ford employed all the men necessary to polish up old lathes, motors and massive steam engines almost as fast as he could collect them. There is no intention of undoing every "Fordization" in the Ford collections. But the artifacts will continue to be studied and recorded. Contemporary stewards must be humbled by the great trouble and expense Ford took in restoring his treasures, to his great pleasure.

### Acknowledgments

The author would like to acknowledge the support of colleagues past and present at The Henry Ford, especially John Bowditch and Marc Greuther, Curator of Industry.

### Endnotes

1. The large wooden figures with moveable arms which strike the bells are called "Jaquemart", or in Britain, "Jacks".
2. "As built" drawings are measured architectural drawings of the structure as it was actually constructed, as opposed to the architect's original renderings or construction drawings. [Editor's note: Many building projects now require the submission of "as built". Renovations to older buildings are often complicated by the lack of this documentation.]

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## HAIR CONSOLIDATION AND TREATMENT OF AN INSECT-DAMAGED DANCING HAT FROM SIERRA LEONE

Anya McDavis-Conway, Jakki Godfrey, Bruno P. Pouliot and Richard Wolbers

### Abstract

This paper was presented in the form of a poster at both the AIC's 34<sup>th</sup> Annual Meeting in Providence, RI and the 2006 Association of North American Graduate Programs in Art Conservation (ANAGPIC) conference at Winterthur Museum. The poster discussed the consolidation and overall treatment of an insect damaged dancing hat from Sierra Leone. The object is part of the collection at the University of Pennsylvania Museum of Archaeology and Anthropology (UPMAA). The hat was treated as a practical component of the second year studies for the Winterthur/University of Delaware Program in Art Conservation. The dancing hat is primarily composed of goatskin/hair and raffia, and is decorated with cloth, cowrie shells, wooden elements, and mirrors. In the early 1980's, the object became severely infested by clothes moths, which resulted in extensive damage to the goat hair. Before treatment, much of the hair remained, but was lying unattached to the skin. A novel method for consolidating the hair in situ was developed for the hat after both consultations with other conservators and testing. Different consolidants were tested using a nebulizer (mist application). Among the consolidants tested, a mixture of hydroxypropyl methylcellulose and Aquazol 500 produced the best results. This solution along with this method of application served to consolidate the loose hair in place while leaving it somewhat flexible and unchanged in appearance.

### 1. Introduction

The Sierra Leone dancing hat is a complex construction made of goatskin, cowrie shells, fabric, wood, plant fiber thread, and mirrors. The object is a large hat consisting of a drum-shaped crown with a raffia brim. There are added elements at the front of the hat that imitate a face with two eyes and a nose. The crown is decorated with panels wrapped in coral, black, white, blue, and red fabrics, cowries, and white goat hair fringe. Twelve tongue-shaped goatskin ornaments lay atop the raffia brim. These ornaments are decorated with cowries, white goat hair fringe, mirrors, and elements wrapped in colored cloth. Three separate goatskin ornaments, decorated with white hair fringe and red fabric, hang further down along the sides when the hat is worn (Figs. 1, 2).

This object is part of the collection at the University of Pennsylvania Museum of Archaeology and Anthropology (UPMAA #29-61-1e-h), and has been at the museum since at least 1929. Catalogue records from the University describe the hat as part of an "abon" or costume of a medicine man. The culture is listed as Timne from the Bumpe Chiefdom of Sierra Leone. A similar hat is part of costumes made by the Mende people, who also live in southern Sierra Leone. Assuming that the closely related cultural groups share some traditions, this type of hat and costume may be common to both the Mende and Timne. The hat may also have been used by members of the Poro secret men's society. This is a powerful society into which all young

Mende men were initiated before they were considered adults (Hommel 1974). The hat is most likely part of a *goboi* or *gbini* masquerade costume. These masquerades manifest the spirit of Poro and emphasize the secret society's role in supporting political authority. *Goboi* appears for leaders and initiation ceremonies, while *Gbini* is used at numerous Poro events. These masks accompany raffia costumes, and their ornaments are meant to swing out and shake while a dancer performs (Visonà 2001).



Figure 1. Hat before treatment, front.



Figure 2. Hat before treatment, back.



Figure 3. Insect damage. The surface of the skin can be seen where the black hair is missing.

Although the hat was structurally stable before treatment, the hair and plant fibers would actively fall out, particularly when handled. This is due in part to the inherent deterioration of the skin and embrittlement of the cellulosic component of the plant fibers. However the major cause for the loose hair was a severe clothes moth infestation that occurred in the early 1980's. Insect wings, frass, and webbing were present everywhere, particularly in the more hidden sections of the goat hair. The insects, attracted to keratin, grazed primarily on the oily part of the hairs nearest to the skin. This resulted both in extensive hair loss and instability of the remaining hair (Fig. 3). Related condition details included widespread surface grime, dust, and deformation / detachment of some of the skin ornaments.

This hat was treated by Anya McDavis Conway and Jakki Godfrey as a practical component of second year studies for the Winterthur/University of Delaware Program in Art Conservation (WUDPAC) under the supervision of Winterthur objects conservator Bruno P. Pouliot, and with the assistance of Professor Richard Wolbers. The WUDPAC students who major in objects conservation are given the opportunity to treat, among other materials, one ethnographic object and the UPMAA has for many years allowed students to work on objects from their extensive ethnographic collection.

## 2. Methodology and Rationale

Treatment began with vacuuming and removal of the insect frass, webbing, and other debris from the surface of the hat. Both a Nilfisk vacuum with HEPA filter and a dental vacuum with a water filter were used. During this process, it became clear that the insect debris was often interwoven with the hair and could not be completely removed from the ornaments without further disturbing, and in many cases entirely removing, the remaining goat hair. Therefore, it was determined that many areas of the goat hair would need to be consolidated in situ as part of this treatment.

Varied past experiences from the project supervisors, as well as other conservators, helped determine that an effective method of stabilizing the loose hair *in situ* could be through mist consolidation. This method was chosen due to its gentle nature, since the pressure of the mist results in only minimal movement of the loose hair. Additionally, any movement quickly subsides once the hair becomes somewhat damp. Misting also provides small consolidant particles that do not significantly change the hair's appearance, yet form small bridges at the points where two hairs touch or where they are in contact with the skin. In order to produce an effective and fine mist, it was important that the consolidants be soluble in water, due to its high surface tension. The high surface tension of polar solvents promotes the formation of stable droplets in the air when nebulized. Additionally, low viscosity solutions, typically those between ½ % - 2%, are necessary for effective misting.

Aquazol (poly(2-ethyl-2-oxazoline)) and several cellulose ethers including methyl cellulose, ethyl cellulose and hydroxypropylmethyl cellulose were chosen as test consolidants because they are all water soluble and typically have good aging characteristics. Organic consolidants such as the cellulose ethers and materials such as gelatin are often used in treatments of organic objects. The cellulose ethers differ from each other by their functional group substitutions and molecular weights. The specific cellulose ethers were chosen because of their different molecular weights and corresponding strengths. Methyl cellulose has a methyl functional group and the lowest molecular weight of the chosen cellulose ethers. Hydroxypropylmethyl cellulose is a cellulose ether with both methyl and hydroxypropyl functional group substitutions. It also has a relatively high molecular weight, which translates into increased strength. The lower surface tension and lower polarity of hydroxypropylmethyl cellulose will also allow it to wet better onto the goat hair substrate. Our testing confirmed that the hydroxypropylmethyl cellulose was a stronger consolidant in this application compared to other cellulose ethers. According to Feller and Wilt, water soluble cellulose ethers were found to have good aging properties (Feller and Wilt 1990).

Aquazol 500 was chosen to test because as a synthetic consolidant it is less attractive to insects. Its solubility in water allows it to form a mist; and its lower polarity, relative to the cellulose ethers, allows it to wet onto the goat hair. Aquazol 500 was chosen because it is the highest molecular weight Aquazol compound, and is therefore relatively strong. According to testing performed by Richard Wolbers, Aquazol maintains a neutral pH and good solubility after aging (Wolbers, McGinn and Durbeck 1994). Aquazol 500 has a Tg of 55 °C and an elongation at break of 380%. During testing, it was found that Aquazol 500 increased the flexibility of a consolidant solution and allowed for a less viscous solution at higher concentrations.

Tests were performed on samples of zebra hair, which closely resembles goat hair in texture, thickness and length. Small strips of zebra skin were cut for testing (approximately 2 1/8" x 7/16"). The hair on half of each strip was cut just above the skin with a razor and left to lie as is, mimicking the loose goat hair on the hat. Consolidation tests were performed on these samples using the cellulose ethers and Aquazol 500 individually and in combination. Consolidant solutions of varying viscosity, ranging from ½% - 2%, were tested. The consolidants were applied to the zebra hair samples with a nebulizer (Sunrise De Vilbiss Pulmo-Aide LT Compressor, see Fig. 4) until the hair appeared saturated (approximately 12-14 passes). Once dry, the samples were examined, and in many cases a few more applications of the consolidants



were necessary to impart enough stability to the hair. Respirators were worn during this treatment to prevent inhalation of the mist.



Figure 4. Mist consolidation of the hair.

### 3. Results and Observations

After preliminary testing, it was determined that hydroxypropylmethyl cellulose, and a mix of this adhesive with Aquazol 500, provided the best results. This was due to the Aquazol not providing enough strength on its own and the hydroxypropylmethyl cellulose being slightly too strong and viscous. Compared to the cellulose ethers, a large amount of Aquazol can be added to a solution while maintaining a low viscosity and therefore allowing it pass through a nebulizer. Ethyl cellulose, methyl cellulose, and plain Aquazol 500 were not strong enough to successfully consolidate the zebra hair samples.

Photomicrographs were taken of two zebra hair samples before consolidation, and respectively after one and two applications of a consolidant (Fig. 5). Sample #1 was consolidated with 1% hydroxypropylmethyl cellulose in deionized water while sample #2 was consolidated with a 1.5% solution of 2:1 Aquazol 500: hydroxypropylmethyl cellulose in deionized water. After two consolidation campaigns, no visual change could be seen in the samples when viewed normally, and only minimal accumulation of adhesive could be seen under magnification with a stereobinocular microscope.





Sample 2. 1:1 HMC : Aquazol 500 BT 7.5x



Sample 2. 1:1 HMC: Aquazol 500 BT 20x



Sample 2. 1:1 HMC: Aquazol 500 After 1st Consolidation 7.5 x



Sample 2. 1:1 HMC: Aquazol 500 After 1st Consolidation 20x



Sample 2. 1:1 HMC: Aquazol 500 After 2nd Consolidation 7.5x



Sample 2. 1:1 HMC: Aquazol 500 After 2nd Consolidation 20x

Figure 5. Photomicrographs of hair.

After testing, it was determined that a 1.5% solution of 2:1 Aquazol 500: hydroxypropyl methylcellulose best consolidated the zebra hair samples. Therefore, this mixture was applied with a nebulizer to a discrete area of goat hair on the hat. Since this test also proved successful, the consolidation method chosen was used on the remaining areas of loose goat hair. This method effectively consolidated the hair in place while leaving it flexible and not affecting its appearance (Figs. 6, 7).



Figure 6. Detail before consolidation of hair.



Figure 7. Detail after consolidation of hair.

In a few areas where the goat skin hangs down vertically, mist application consolidated the hair into a mat, but did not sufficiently re-adhere the mat to the skin surface. In these instances, a drop of 5% Butvar B-98 (polyvinyl butyral) in ethanol was inserted underneath the mat with a syringe and gently patted down. The Butvars are colorless, flexible, and tough thermoplastic resins. They are soluble in alcohols, acetone, and aromatic hydrocarbons, but are insoluble in water. Butvar B-98 has a Tg of 72-78 °C, a tensile strength of 5.6-6.6 x 10<sup>3</sup> psi, and an elongation at break of 110%. It was chosen because of these properties, but especially due to its flexibility, ability to dissolve in ethanol, and its compatibility with skin.

Additionally, consolidation did facilitate the process of frass removal. Once consolidated, the moth frass and webbing could be more easily picked out from the surface with minimal disruption of the goat hair.

#### 4. Conclusion

Our tests determined that a 1.5%, 2:1 mixture of Aquazol 500: hydroxypropyl methylcellulose: in de-ionized water worked best to consolidate the insect-damaged goatskin hair. Application of this mixture with a nebulizer permitted thorough consolidation of the hair, while retaining its



flexibility and maintaining its visual appearance. The consolidant solution was applied until the hair appeared saturated. In some areas, depending on the amount of damage, repeated applications were necessary. After consolidation, a drop of 5% Butvar B-98 in ethanol was applied with a syringe to the few mats of hair that required extra stabilization. A small amount of pressure was applied to secure these sections of hair to the skin. Some practical information gained during this project regarding effective mist consolidation includes using low viscosity solutions and only filling the nebulizer container approximately 1/5 full.

In addition to overall vacuuming of the hat and consolidation of the hair, other aspects of the treatment of this hat included local humidification and re-shaping of the bent goatskin ornaments. The cloth components were cleaned with polyurethane cosmetic sponges (see Suppliers list) and the detached ornaments were re-attached with Japanese tissue toned with acrylic paints using wheat starch paste. A storage mount was also created to properly support the hat. The mount was designed to alleviate stress on the object and prevent further damage from occurring once it is returned to storage at the UPMAA (Figs. 8, 9).

Recommendations for additional study include further investigations of the ageing qualities of the chosen consolidants when used with similar materials, as well as the long-term effectiveness of the stability of the consolidated hair. Results of preliminary tensile tests show that the 1.5%, 2:1 mixture of adhesives used as a consolidant has a breaking strength of 24.29 MPa and is actually stronger than hydroxypropyl methylcellulose alone with a breaking strength of 18.42 MPa. However, the high modulus, suggesting brittleness of the adhesive mixture, is unclear. Past research has found that adhesive mixtures containing Aquazol have only one Tg, signifying that in adhesive mixtures Aquazol acts as a solvent or plasticizer. Following this, the tensile modulus in the tensile testing of the adhesive mixture should have been less steep (Wolbers 2006). Due to the unclear significance of the results of our tensile tests, further physical testing of these materials should be performed in the future.

## Acknowledgements

The poster and paper were published with the permission of the University of Pennsylvania Museum of Archaeology and Anthropology (UPMAA).

The authors would like to thank the following for their useful treatment suggestions: Julie Ream (conservator in private practice), Jessica Johnson, Susan Heald, and Marian Kaminitz from the NMAI, as well as Ruth Norton from the Field Museum. We would also like to thank Connee McKinney and Don Shenkle from UD Publications for their assistance in the design and printing of the poster that was presented at the 34th AIC annual meeting and the 2006 ANAGPIC conference. We would like to acknowledge Debbie Hess Norris, WUDPAC chair, for her constant support and encouragement. Finally, we would like to thank Virginia Greene, Dwaune Latimer, and the UPMAA for their input and for allowing us to treat this fabulous object.



Figure 8. Hat, after treatment, on new storage mount. Front view.



Figure 9. Hat, after treatment, on new storage mount. Back view.

## Suppliers

Pulmo-Aide LT Compressor/Nebulizer:

DeVilbiss, P. O. Box 2069, Tri-Cities, WA 99302, (509) 374-9530

([www.dmeonline.com/nebulizers.html](http://www.dmeonline.com/nebulizers.html))

Hydroxypropylmethyl cellulose:

Sigma, 6950 Ambassador Drive, Allentown, PA 18106, (800) 325-3010

([www.sigma-aldrich.com](http://www.sigma-aldrich.com))

Aquazol 500, Butvar B-98:

Talas, 20 W. 20th St., 5th Floor, New York, NY 10011, (212) 219-0770

([www.talasonline.com](http://www.talasonline.com))

Cosmetic sponges (24 Piece Wedge Sponge Block, Latex Free Polyurethane Foam):

Qosmedix.com, also available from local drug stores/pharmacies

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