Article: 48 pieces: Reassembly of an Ancient Greek marble lion using an internal armature with reversible mechanical components
Author(s): Joe Rogers and Dale Benson
Source: Objects Specialty Group Postprints, Volume Thirteen, 2006
Pages: 17-44
Compilers: Virginia Greene, Patricia Griffin, and Christine Del Re
www.conservation-us.org

Under a licensing agreement, individual authors retain copyright to their work and extend publications rights to the American Institute for Conservation.

Objects Specialty Group Postprints is published annually by the Objects Specialty Group (OSG) of the American Institute for Conservation of Historic & Artistic Works (AIC). A membership benefit of the Objects Specialty Group, Objects Specialty Group Postprints is mainly comprised of papers presented at OSG sessions at AIC Annual Meetings and is intended to inform and educate conservation-related disciplines.

Papers presented in Objects Specialty Group Postprints, Volume Thirteen, 2006 have been edited for clarity and content but have not undergone a formal process of peer review. This publication is primarily intended for the members of the Objects Specialty Group of the American Institute for Conservation of Historic & Artistic Works. Responsibility for the methods and materials described herein rests solely with the authors, whose articles should not be considered official statements of the OSG or the AIC. The OSG is an approved division of the AIC but does not necessarily represent the AIC policy or opinions.
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.
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.
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.
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.](image)

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 though 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 though 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 Pliacré 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.

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).
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 cramp” 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).
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.
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.
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.
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.
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.](image)

![Figure 30. Completed Ethafoam form of proper left rear leg prior to loss compensation.](image)

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-fill was used as a final layer for detailing the surface texture and features of the lion’s legs. The Poly-fill 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-fill, allowing for a better bond between layers. Areas were reconstructed detailing hair, veins, and surface imperfections as determined by the curator.

![Figure 31](image1.jpg) (left). Rear legs after loss compensation.

![Figure 32](image2.jpg) (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, 3rd 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 ketone 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.

Ethafom 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:

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_{10} 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.

Reference


Authors’ Addresses

Joe Rogers, Conservation Associate, Objects, The Nelson-Atkins Museum of Art, 4525 Oak Street, Kansas City, MO 64111, (816) 751-0442, (jrogers@nelson-atkins.org)

Dale Benson, Conservation Assistant, Objects and Mounts, The Nelson-Atkins Museum of Art, 4525 Oak Street, Kansas City, MO 64111, (816) 751-1251, (dbenson@nelson-atkins.org)