Objects Specialty Group Postprints
Volume Twenty-Two, 2015

Proceedings of the Objects Specialty Group Session

AMERICAN INSTITUTE FOR CONSERVATION OF HISTORIC AND ARTISTIC WORKS

43rd Annual Meeting • Miami, Florida • May 13–16, 2015

A·I·C OBJECTS

AIC

Objects Specialty Group Postprints Volume Twenty-Two, 2015

Edited by Emily Hamilton and Kari Dodson,
with Sarah Barack and Kate Moomaw, Program Chairs

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OBJECTS

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This publication entitled Objects Specialty Group Postprints, Volume Twenty-Two, 2015 is produced by the Objects Specialty Group of the American Institute for Conservation of Historic & Artistic Works.

Cover photograph: Artist unknown, *Nargile*, mid-19th century, ceramic vessel ca. 1720, gilded silver and copper alloy, porcelain, enamels, rubies (spinels), emeralds (beryls), dimensions with lid: 66.5 × 17.5 × 16 cm. The Walters Art Museum, 49.2199 (Courtesy of the Walters Art Museum)

The articles presented in the Objects Specialty Group Postprints Volume Twenty-Two, 2015, have been edited for clarity and content. Each paper was peer-reviewed and the authors revised their papers based on these anonymous reviews. Responsibility for the methods and materials described herein, however, rests solely with the authors, whose articles should not be considered official statements of the OSG or the AIC.

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1156 15th Street, NW • Suite 320
Washington, DC 20005

http://www.conservation-us.org/

ISSN (print version) 2169-379X
ISSN (online version) 2169-1290

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Program Chair's Foreword

It is with great pleasure that I present the Postprints of the Object Specialty Group, from AIC's 43rd Annual Meeting in Miami, Florida, from May 13–16, 2015. The conference theme of "Practical Philosophy, or Making Conservation Work" provided a forum for the discussion of challenging projects, whereby colleagues might share unique approaches to work that straddles the fuzzy boundary between the ideal treatment and practical concerns. Along with colleagues and OSG board representatives Suzanne Davis and Lara Kaplan, I sought to select papers that not only addressed this dynamic theme but also those that discussed topics of current interest to the membership. Given the OSG's active dialogue through digital communications such as the list-serve, I felt confident that items of wide interest could be identified and selected. Our ultimate roster of speakers met these criteria and much more with thoughtful, well-delivered presentations, followed by active question-and-answer sessions.

These papers follow on the heels of those given at the conference and reflect an extensive amount of work on behalf of their authors. I am deeply indebted to these colleagues, as their contributions to this volume allow their work to carry on past the meeting and reach fellow conservators and scholars who could not travel to attend in person. In this volume, you will encounter discussion ranging from single case studies, such as Ariel O'Connor, Julie Lauffenburger, Meg Craft, and Glenn Gates' well-balanced consideration of a gilt nargile, and Paul Mardikian, Claudia Chemello, and Jerrad Alexander's extensive work on the *Saturn V* rocket engine parts following its underwater recovery, to questions of recently developed techniques, as with Cassy Cutulle and Seoyoung Kim's introduction to dry ice blasting on metals. Sharon Norquest, Amelia Kile, and David Peters bring our attention to safety concerns when handling radioactive objects, whereas Stephanie Hornbeck elucidates the legal and ethical ramifications of the new regulations as related to ivory.

To satisfy the needs of OSG members whose work focuses more on the bench, we arranged for a Tips Session lunch to complement the paper session. Such treatment-focused discussion is easily overlooked at conferences and yet can also be difficult to find in professional publications. I therefore felt that the inclusion of this session was of high priority, and our number of attendees suggested that others shared this view. I am very grateful to include several of these Tips as brief Postprints in this volume.

This conference also marked the first joint sessions held between the OSG and the EMG, and Miami's vibrant contemporary art scene provided a fantastic backdrop for the program. Organized in collaboration with EMG Program Chair Kate Moomaw, EMG Assistant Program Chair Kate Lewis, and with additional support from VoCA Executive Director Lauren Shadford, our stated focus was to invite abstracts that addressed collaborations with artists and artists' estates. As we felt that this topic would solicit a great number of comments and debate during the conference itself, we divided papers into two sessions, with discussion respectively led by Glenn Wharton and Jill Sterrett. I would also like to acknowledge their hard work and efforts at guiding our audience through a constructive dialogue.

Although certain papers were not able to be included in this volume, the majority of presenters have adapted their papers. Honoring both the general theme and our sub-theme, the Postprints here move from the realm of theory, such as Glenn Wharton's examination of the artists' intent, to its integration into actual practice, as in Gwynne Ryan and Steven O'Banion's introduction to the

Hirshhorn's artist interview program, or Céline Chrétien's comparison of ethnographic versus contemporary art conservation. Projects that focused on collaboration with living artists provided an effective contrast to those dealing mainly with estates, as represented by Crista Pack and Mina Thompson's work with artist Tasha Ostrander, or Donna Williams' encounters with artist Chris Burden, versus John Hogan and Carol Snow's discussion of the Sol LeWitt drawings at Yale University.

As with many undertakings, it takes not just a village but a machine to produce a volume of Postprints. I must take a moment to express my deep gratitude to both Kari Dodson and Emily Hamilton, the OSG Postprint Editors, without whose dedicated efforts this volume (and many others) would not exist. Their calm management of the process and highly prized organizational skills are an inspiration to us all. I would also like to acknowledge Suzanne Davis and her past efforts at establishing a peer review process for the OSG Postprints. This process was continued this year, and many colleagues served graciously as blind readers. Their patience and willingness to help their peers, without recognition, is greatly appreciated and helped to improve the content and readability of this volume. It also speaks to the congenial nature of our professional community—which is only strengthened by publications such as this.

Sarah Barack, Chair of the Objects Specialty Group

ARTIST INTENTION AND THE CONSERVATION OF CONTEMPORARY ART

GLENN WHARTON

This article addresses the use of the term *artist intention* in the conservation of contemporary art. The author draws from work with artists and from literature about intention, creativity, and the influence of social context to build a critical understanding of the term. The context for this research is the ongoing life of artworks in museums, where conservators, curators, and others decide how an artwork should be conserved and how the public should experience it.

Are artists the best source for articulating the intentions they had during the creation of their work? Some argue that artists' intentions during the creative process are not necessarily reflective of their artistic production, as they may not have achieved their intentions. Following this logic, it is best to rely on curators, art historians, conservators, and others to define an artwork's symbolic and aesthetic values based on analyzing the work itself, without interpreting expressions made by the artist. Other scholars argue that we need to go beyond the art object and study the social and material context of production to comprehend its meaning and aesthetic value. Examining conflicting debates in philosophy, literary criticism, art history, and the social sciences complicates using the term *artist intention* in the field of conservation. An argument is made for working with artists to arrive at conservation decisions, but to avoid mistaking artist opinions about problems at hand with expressions of their original intention.

KEYWORDS: Artist, Conservation, Contemporary Art, Intent, Intentions

1. INTRODUCTION

Art conservators strive to honor what they often refer to as artist intention in their work. Using scientific investigation, they identify materials and technologies of production to understand the original appearance and function of works in their care. They join forces with art historians and others to identify aesthetic and symbolic value inscribed in the work by the artist. Conservation is a pragmatic field. Conservators seek to understand artists' concerns to ensure that the public experience of the work is in keeping with the artist's vision. For generations, philosophers and scholars in the social sciences and humanities have debated whether it is possible to understand an artist's intent. Numerous publications address relationships between intention and the physical object of art, the creative process, and the social circumstances of production. The aim of this article is to question, from knowledge of this literature, how the term *artist intention* is used in the field of conservation.

My focus is on contemporary art, where many primary sources are available to conservators, including the artist as a spokesperson for their own ideas. Contemporary art offers a unique object of study for contemplating artist intent in conservation in part because the artist or those who knew the artist are available, but also because much of the art produced today no longer makes a claim of durability and fixity. I limit the scope of this article to variable forms of contemporary art in part for the sake of brevity. There is significant literature on artist intention in conservation[1] to which I do not refer, as my primary interest is in examining how the term is debated in other fields, including philosophy, art criticism, literary criticism, and sociology. Much of this literature is contradictory and virtually impenetrable without a background in the disciplinary theory on which it is built. Just the same, a basic understanding of how this highly contested term is discussed in adjacent fields is helpful in reflecting on its use in conservation.

Before discussing this literature, the use of *artist intention* in conservation needs to be considered. Conservators often employ the term broadly, from reference to ideas in the design and execution of an artwork to thoughts that artists have years later in response to a conservation problem. In this article, I begin with ideas in the artist's mind during the creative process; however, in the end, I come back to use of the term in reference to practical conservation problems.

It is helpful to recognize that attempts to identify the true or authentic nature of an artwork for purposes of conservation have been dismissed in recent conservation literature in recognition that authenticity is subjectively perceived and shifts over time with changes in both the art object itself and the cultural values of people who experience it (Clavir 2002; Laurenson 2006). I embrace these mutable conceptions of authenticity without launching a full defense of their use.

Debates over authenticity and defining what is and is not art are relevant to a larger discussion of artist intention, but I choose to limit the scope of this article and focus on how conservators use the term in reference to their research. I am not attempting to build a coherent argument about artist intention or a philosophical understanding of intentionality.[2] Instead, my aim is to provide an understanding of various lines of thought that complicate attempts to understand intention in relation to artistic works. My goal is to lay the groundwork for reconsidering, if not replacing, the term *artist intention* in the conservation of contemporary art.

Contemporary art conservators have a growing arsenal of methods through which they can learn from the artist. Hummelen and Scholte (2012) chronicle the development of artist questionnaires and other forms of knowledge transmission from artists to conservators. They reference a rapidly growing literature that provides conservators with models for developing questionnaires, interviewing artists, and archiving data from their investigations. The not-for-profit organization Voices in Contemporary Art (VoCA) trains conservators and other professionals in artist interview workshops. Through their programming, VoCA and other organizations, such as the International Network for the Conservation of Contemporary Art (INCCA), advocate collaborative approaches among professionals to learn from artists.

In my own practice as Media Conservator at the Museum of Modern Art in New York (MoMA), I spent much of my time building institutional knowledge about artist preferences that will inform future staff in their exhibition of works by these artists and in conservation research. I frequently used the term *artist intent* to characterize the ideas that artists expressed, but always with some trepidation. Considerable time had often passed since they created the work, which meant that I was asking them to recall past intentions to address a current situation. The technical problems at hand were often unanticipated when they created the works, such as digitizing analog media or emulating software-based works. I came to see the term as charged and ambiguous, and any chance of retrieving or articulating intention as an improbable task.

I also realized that although I was generally interested in their original intention for the artwork, my real concerns were about practical problems. I sought their opinions on current options for treatment and display. Sometimes I realized that their responses reflected other concerns in their mind, including their present career advancement and their future reputation. As described by van Saaze (2009), the knowledge produced during our interviews was “co-produced,” in that my framing of topics and guiding the conversation influenced what they said. These recognitions of additional agendas and my own impact on what was said further complicated my references to their comments as expressions of original intent.

Should the term *artist intention* in the conservation of contemporary art be replaced? In the following four sections, I discuss issues that complicate its use before returning to consider its replacement in the conclusion.

2. THE INTENTIONAL FALLACY

Are artists the best sources for understanding meaning embedded in their work? Arguments against asking artists include the concern that they are haunted by original ideas that they tried to express rather than what they actually did express. Critics may argue that they did not achieve their intentions. If this is the case, fabricators, collaborators, art historians, scientists, conservators, and social scientists may be better equipped to discuss what the work should look like and how it should be presented.

Scholars in many fields write about the relationship between intention and creative objects. By far, the most influential publication of relevance is Wimsatt and Beardsley's 1946 essay *The Intentional Fallacy*. Their concern is whether critical assessment of literary works should be judged by how well the author achieved their intentions. They believe that "the intention of the author is neither available nor desirable as a standard for judging the success of a work of literary art" (Wimsatt and Beardsley 1946, 468). They argue that a work should be judged by itself and that looking beyond it shifts attention from the text itself, which is the best source of information. The implication of this argument for conservation is that we should use the physical work of art as our sole source for understanding it rather than artist statements about its meaning. This argument squares well with positivist approaches in scientific conservation research that derive all needed information from material analysis.

The Intentional Fallacy spawned a generation of literary and art criticism that lasted well into the 1960s, known as New Criticism. These critical theorists advocate close reading of texts and artworks, and reject interpretation based on outside influences, such as statements from authors and artists. Many of these scholars develop nuanced arguments about the role of intention in the creative process. Wimsatt, Beardsley, and their followers became known as *anti-intentionalists*, whereas those who argued that artists' mental states and behavioral dispositions should be considered in interpreting artworks were labeled *intentionalists*.

Steve Dykstra is one of the few conservators who addresses *The Intentional Fallacy* in his writing (Dykstra 1996). He takes on the task of breaking down its implications for paintings conservation practice. Dykstra expands on different variations of artist intent and attempts to make sense of them for conservators. Using the cleaning controversies of the 20th century as a backdrop, he divides the opposing sides into camps: *scientific conservators*, who believe in knowing a work through scientific means, and *aesthetic conservators*, who use aesthetics and social science to understand an artwork. He further examines the agency of the artwork itself to function independently from artist intention by creating emotional, psychological, and social effects. He also references the artwork's intention when we perceive its need to be displayed one way or another.

In the end, Dykstra (1996) stakes a claim by supporting all sides and concluding that interpreting artist intent in conservation is an interdisciplinary task, potentially involving historians, critics, connoisseurs, philosophers, scientists, and conservators. It requires scientific analysis, philosophical and psychological understanding of the artist, as well as sociological and art historical contextualization to identify artist intention for the purpose of conservation. Although his focus is on historical art, he recognizes the importance of engaging the artist in contemporary art research.

Paul Eggert might agree with Dykstra. As a scholar and practicing editor, Eggert writes about parallels between the work of editors and conservators. He engages in various contemporary debates about authorship and artist intention in an analysis that leads to a deeply nuanced understanding of the role that artists' stated intention plays in conservation research and decision making (Eggert 2009, 105–108). He suggests that statements of intention by artists should influence the conservator's understanding and contextualization of an artwork but that they need redefinition to become applicable. This redefinition that conservators must undertake inevitably deprives the artist statements of their capacity to encompass the wholeness or integrity of the work. Following this declaration that conservators must redefine artists' stated intentions, Eggert leads his reader back to the artwork itself and its agency as a source for conservation research. Yet inevitably there are competing agencies that have to be balanced even within the artwork that complicate conservation research. In the end, he suggests that conservators should not forget that most viewers are interested in the artist's agency, or statements of intention. This brief distillation of Eggert's writing does not capture his remarkable intelligence and sophistication, but it serves our purpose of further communicating the complexity of contemporary writing about interpreting artist intentions in adjacent fields.

3. INTENTION AND THE CREATIVE PROCESS

Creation is often described as a process of translating a mental image into form. There are many variations on this theme, and discussion about the relationship between the idea in an artist's mind and the physical manifestation of their creative work is highly contested. For instance, scholars debate whether images of an artwork in an artist's mind exist apart from the act of creation. Artists describe the creative process in many ways, no doubt reflecting the diversity of artistic practices. Michelangelo famously evoked an image of sculpting as releasing a sculpture from a block of stone. Artists with whom I have worked deny a total prefiguring of an artwork in their minds. They describe having an initial idea or image that evolves in tandem with production. In a seminal lecture titled "The Creative Act," Duchamp describes the creative process in these terms:

> In the creative act, the artist goes from intention to realization through a chain of totally subjective reactions. His struggle toward the realization is a series of efforts, pains, satisfactions, refusals, decisions, which also cannot and must not be fully self-conscious, at least on the esthetic plane.
>
> The result of this struggle is a difference between the intention and its realization, a difference that the artist is not aware of.
>
> Consequently, in the chain of reactions accompanying the creative act, a link is missing. This gap which represents the inability of the artist to express fully his intention; this difference between what he intended to realize and did realize, is the personal "art coefficient" contained in the work. (Duchamp 1957, 139)

Christian Scheidemann, a conservator who frequently works with artists to research methods and materials in their art production, evokes a similar process. He suggests that many artists describe their ideas as evolving from materials and processes, and that they rarely have preconceived images of the final product. He expands on Graham Wallas's four stages of creativity: from preparation to incubation, illumination, and verification (Scheidemann 2010). During preparation, the artist may research a particular subject, but the subject matter is internalized into the unconscious mind during the incubation phase. The idea emerges from preconscious to awareness during the illumination phase. It is transformed into visual being during the final process of completion, or verification. These four phases may be criticized as being too linear, and they certainly vary from artist to artist, but they provide another model that further complicates the notion of fixed intention prior to creating a work of art.

Artist ideas continue to evolve even after a work is first exhibited. This is especially true for installations and performances that are inherently variable. An example of this is the case of Marianne Vierø's installation, *Indoor Gardening* (fig. 1). Students in my 2012 seminar, "The Museum Life of Contemporary Art," interviewed Vierø about the four times the work had been installed in the past. She changed the materials and their spatial relationships for each installation. She commented that she was working out problems in her mind with each iteration. By the fourth installation, she had resolved her questions and decided that it could now be re-presented with less variability. In fact, she mentioned that after working through these problems, she was less engaged with the work and had moved on to solving new artistic problems.

This change in Vierø's engagement with concerns about the materials and their display signals a shift in her relationship with the work. It has not yet been acquired by a collector or an institution; however, if it is acquired in the future, it may be difficult for her to immerse herself back into these concerns if she is interviewed about its display. This example directs our thinking toward the creative process as problem solving, along with artist relationships to these problems over time.

Fig. 1. Four installation images. Marianne Vierø, *Indoor Gardening*, 2009–2011, painted wood, book, ceramic, glass, plastic, dimensions variable (Courtesy of Marianne Vierø)

4. INTENTION AND CHANGES OVER TIME

It is helpful to consider change over time in framing a discussion of artist intention in conservation. For this, I borrow the model of object biography that is used in the fields of anthropology and sociology. This model recognizes physical change as well as an accumulation of meaning as an object travels through time and to new physical locations (Kopytoff 1986; Gosden and Marshall 1999). The model of object biography has already been applied to the conservation of contemporary art to help us understand how meanings attributed to artworks change throughout their lives due to changes in their physical state, their use, and their social, cultural, and historical context (van de Vall et al. 2011). As depicted in figure 2, artworks can experience different life stages from creation and initial display to acquisition, documentation, storage, exhibition, loan, and conservation intervention. The point of this diagram is to highlight various moments in an artwork's life when conservation research and decision making takes place. These are moments when artists are contacted for their opinions. Any of these stages present opportunities for working with artists to understand their concerns about representation and to revisit questions of meaning and materiality. Stages such as exhibition and loan are often repeated in variations that benefit from new information. As conservators well know, conservation intervention may take place at any life stage.

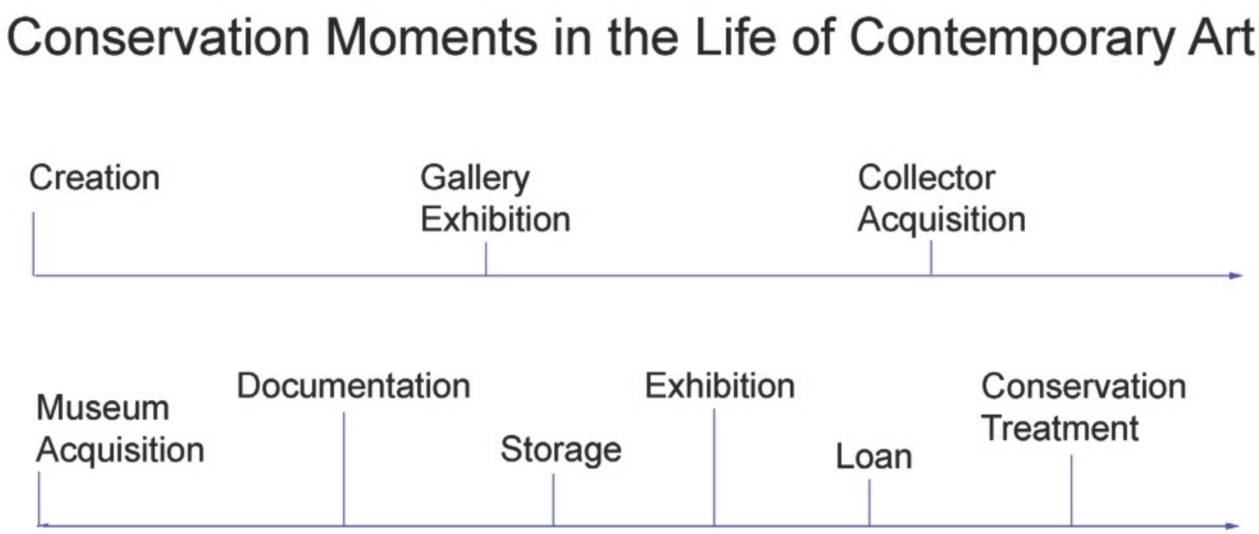

Fig. 2. Life stages of an artwork when conservators contact artists for their opinions about conservation and display (Courtesy of Glenn Wharton)

In her writing about conservation and materiality in conceptual art, Sanneke Stigter provides examples of artists' views that evolve along with their changing artistic interests over the life of the work. In one case that she analyzed, the Dutch artist Ger van Elk rearticulated his thoughts about an artwork as he responded to replacing altered photographic material and adapting a site-specific work to another site, 35 years after fabrication (Stigter 2009). She points out that artists' ideas about how a past work should be conserved are influenced by artistic problems that they are currently working out. Artists not only change their minds and their interests, they respond differently to new circumstances. Years later, they may not even remember the ideas they had during the design and execution of their work. In fact, can we really expect anyone to articulate the same idea decades later?

Artworks that are meant to be reinterpreted for each iteration are considered variable. For these works, museums and other owners develop the capacity to make their own interpretive decisions as they gain an understanding of the variability inscribed by the artist. Yet many artists maintain creative relationships with their prior works even after the moment of sale. Some savvy artists specify in contracts that they or their designees must be present and have decision-making authority at each installation. Given the labor and per diem costs involved in such an arrangement, museums and collectors may elect to negotiate these terms. In some cases, a "weaning" process evolves. Artists and their agents may be brought in during the first few installations, but over time the interpretive capacity of the owner grows as knowledge is transferred from the artist.

Reactive Books by John Maeda poses another challenge regarding artist ideas over time (fig. 3). Originally conceived as interactive computational "books" that the public could purchase on CD-ROMs and interact with on their home computers, Maeda worked with MoMA staff to reconceive them for exhibition when they were acquired by the museum. They are currently exhibited with interactive devices that respond to input from keyboards, microphones, and video cameras. Museum visitors witness changing graphic compositions on monitors that respond to their interaction.

I worked with students from the 2010 Handling Complex Media class in the Moving Image Archiving and Preservation Program at New York University to interview Maeda about original, current, and future technologies associated with the works. When we discussed future changes in exhibition technology, Maeda said that the exhibition equipment was not important to him. He suggested that we make a video recording of people interacting with the works and exhibit the video in the future rather than keep the software and hardware operational.

Fig. 3. John Maeda, *The Reactive Square*, 1994, 10-key numeric keypad, microphone, software, LCD monitor, flat screen monitor, 460.2006.1-2; *Flying Letters*, 1995, track pad, software, LCD monitor, flat screen monitor, 461.2006.1-2; *12 o'clocks*, 1996, software, LCD monitor, flat screen monitor, 462.2006.1-2; *Tap, Type, Write*, 1998, alpha-numeric keyboard, software, LCD monitor, flat screen monitor, 463.2006.1-2; *Mirror, Mirror*, 2006, 10-key numeric keypad, video camera, software, LCD monitor, flat screen monitor, 71.2007. Dimensions variable. Museum of Modern Art, gift of the designer with additional support from Samsung. (Courtesy of Glenn Wharton)

I was initially surprised by this remark. How could an artist suggest such a radical alteration? On later reflection, I realized that if the thrill of discovery through interaction is key to appreciating the work, and future generations do not experience a thrill in interacting with old technologies, then perhaps watching people experiencing this thrill better communicates the essence of the work. Exhibiting video documentation may better transmit the authenticity of experience. By exhibiting the work with original equipment, MoMA might risk becoming a museum of archaic technology and miss communicating the core concept of experience. An argument could be made that exhibiting a video of people interacting with the *Reactive Books* is a more authentic conservation act, but my point here is to illustrate the complex relationships between artist ideas and their works through the passage of time.

5. INTENTION AND THE EXTERNAL CONTEXT OF CREATION

While scholars referenced in the prior sections are concerned with relationships between ideas in the artist's mind and the work they produce, others focus on how external forces such as social environment, available materials, and current technologies influence the creative process. This realm of research makes it clear that artist intention cannot be disentangled from the social and material circumstances of production. A few examples of scholarship on these external agents follow.

Martin Heidegger extends Aristotle's doctrine on causality in his analysis of objects coming into being (Heidegger 1993). Through the example of a silver chalice, the silversmith is seen as bringing together the potentialities of the silver in the form of a chalice through a process in which the material, the form, the context, and the thought all give themselves up to the existence of the chalice. Although his analysis leads the reader into deeper philosophical territory, for our somewhat reductive purposes we can point to Heidegger as carrying forward Aristotle's focus on the material itself as one of the four causes or explanations of object creation. Silver has physical qualities that influence the artist's ideas, design, and fabrication.

Just as materials influence the creative process, technical innovations also impact artists' ideas. An example of this can be seen in the evolution of moving image and media technologies. Early in the 20th century, film artists began to experiment with depicting movement, and they added color and audio as new technologies emerged. Today, media artists create born digital multichannel works based on source code and digitally produced imagery. These quickly changing technologies influence the creative impulse of artists by allowing new avenues of exploration.

Some scholars focus on the influence of political and cultural climate on creativity and art production. For example, as post-modern theory, relativism, and the politics of multiculturalism became dominant in cultural discourse during the late 20th century, many artists questioned social structures of power in their creative work. Questioning authority also led to participatory forms of art that give voice to normally disenfranchised populations. This distribution of creative authority through introducing multiple voices further complicates attempts to articulate the artist's intention.

In *Patterns of Intention*, art historian Michael Baxandall (1985) investigates ways in which we attempt to understand the minds or intentions of artists from other cultures and historical periods. He analyzes statements that critics make about paintings through their use of language and asks what actually goes on when we think about the intentions of an artist from another time. He steers away from the intentionalist debate about authorship referenced earlier this article, as well as any sociological analysis of art production, such as those mentioned in the following. Yet in his nuanced argument for "inferential criticism," Baxandall repeatedly references cultural influence and the difficulty that later critics have in understanding it:

> [P]ainters cannot be social idiots: they are not somehow insulated from the conceptual structures of the cultures in which they live. (Baxandall 1985, 71)
>
> It is usual, when discussing the "understanding" of other cultures and actors in them . . . to start from a distinction between *participants*' understanding and *observers*' understanding. The participant understands and knows his culture with immediacy and spontaneity the observer does not share. He can act within the culture's standards and norms without rational self-consciousness. . . . He moves with ease and delicacy and creative flexibility within the rules of his culture. . . . The observer does not have this kind of knowledge of the culture. (Baxandall 1985, 109)

Sociologists often take a more structural approach that provides other complications to identifying artist intention. In his classic book *Art Worlds*, Howard Becker (1984) describes the creative process as inextricably linked to social networks such as art supply manufacturers, fabricators, dealers, critics, collectors, and at times, conservators. Becker argues that art making is an inherently collective enterprise that is not guided by a single actor's intent. Social scientist Bruno Latour (2005) further claims that any work is the result of an "assemblage," not in the art world sense of putting things together, but in the sociological sense of everything being a result of diverse actors operating with what can be very diverse purposes.

For instance, many media artists today work with teams of people with diverse technical skills, such as videographers, editors, programmers, and producers. Sometimes these artists claim single authorship over all of this input, and other times they recognize co-authorship in this team approach to art making. In either case, artist intention is not only influenced by emerging media technologies but also by the creative minds of many contributors.

Yet another concern about external influences on creativity is the conventions that exist in any society. Common assumptions can remain unspoken—for instance, about display and conservation strategies. Philosopher Sherri Irvin (2005) writes about the social context of an artwork in terms of "implicit sanctions" or "tacit assumptions" that may not be expressed but should be considered when researching artist intention. She provides an example of an artist creating a painting in an environment in which the norm is to hang it against a wall. In our culture, paintings are not normally exhibited on the floor or hung upside down. When asked about how to display the work, artists do not think of providing an explicit directive to hang it right side up on a wall, nor does anyone think to ask. These unspoken intentions are socially constructed and "black boxed" in the artist's culture, and they add another dimension to any quest to understand an individual artist's intention, especially for those living in another time or place.

6. CONCLUSION

Thus far, I have questioned the broad use of the term *artist intention* in the conservation of contemporary art by providing multiple and often conflicting examples of how it is debated and understood in various scholarly fields. Philosophers since Aristotle have attempted to clarify relationships between ideas in artists' minds and the products of their work. Critical theorists argue that it is a mistake to interpret art through artist-expressed intentions, and that one should not look for sources outside of the object to understand its meaning. Social scientists, on the other hand, suggest that understanding the cultural context of production is essential to understanding intention embedded in a work of art. Others focus on how art materials and technologies influence artists' ideas and their creative processes.

Adding changes in artist interests over time and the problem of reducing mental pictures into language further complicates the task of defining intention. In addition, people say things according to the situation at hand. Depending on the context of an interview, artists may describe their work in ways that appeal to curators, collectors, or the media rather than respond honestly about what they were trying to achieve in the studio. For instance, they may prefer speaking about ideas associated with their current work in the presence of a curator who may acquire or exhibit their new work in the future. Additionally, they may say things to disguise the fact that they simply do not remember what they were thinking when they made the artwork.

Given all of these complications, seeking to define artist intention for the purpose of conservation can easily be seen as naïve and ill advised. At minimum, *artist intention* is an ambiguous term that conservators should use with caution. Yet conservation is a field in which actions must be taken based on best available information, and artists are a very good resource for information leading to conservation decisions. They will no doubt continue to be a primary source in research for conservation and display of their work.

Should conservators replace the term *artist intention*? It is a matter of clearly defining how the term is used, as well as the objectives of specific research projects. If conservators use the term in reference to artists' "opinions," "directives," "guidelines," or perhaps "sanctions" (Irvin 2005) regarding conservation interventions or exhibition procedures, then it takes on an applied definition that is particular to the field of conservation. In this case, artists respond to artworks in their present condition, given problems at hand or anticipated problems in the future. As a profession, we may agree that conservation has its own, legitimate use of the term that differs from how scholars in other fields use it. On the other hand, if the research aim is to investigate symbolic value attributed to the artwork by the artist during creation, then the using the term is in line with how it is used by scholars across many disciplines.

Whether the term *artist intention* is replaced or not, conservators should avoid using it naïvely. Any quest for understanding artist intention, whether by asking the artist, their collaborators, scientists, critics, historians, or social scientists, should be based on an understanding of the complex relationships between ideas in artists' minds, diverse influences on their work, and the art that they create.

ACKNOWLEDGMENTS

I thank artists Marianne Vierø and John Maeda for providing their thoughts about their work and for their openness to classroom interviews. I also express my gratitude to the students who interviewed them, Elizabeth Barbeau, Joe Galluci, and Kristen Hudson, along with Mona Jimenez, whose Moving Image Archiving and Preservation class at New York University (NYU) led the interview with John Maeda. The content of this article developed over time in tandem with my work at MoMA and my teaching at NYU, and it reflects the many conversations I have had with artists, colleagues, and students. I am also indebted to friends, colleagues, and editors who read drafts of this manuscript and provided invaluable critique, including Sarah Barack, Jim Coddington, Kari Dodson, Emily Hamilton, Hanna Hölling, Michele Marincola, Harvey Molotch, Matt Skopek, and Cybele Tom.

NOTES

1. Historical examples of writing on artist intention in conservation literature can be found in "Part II: The Original Intent of the Artist" (Stanley-Price et. al. 1996) and in more recent writing by Gordon and Hermens (2013).

2. Readers who want to explore philosophical treatment of intention and intentionality may choose to start with the influential book *Intention* (Anscombe 1963).

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FROM THEORY TO PRACTICE: INSTITUTING THE HIRSHHORN ARTIST INTERVIEW PROGRAM

GWYNNE RYAN AND STEVEN O'BANION

It is becoming widely recognized among conservation professionals that artist interviews play an essential role in the conservation of modern and contemporary artworks. Artists continue to push boundaries by exploring unconventional materials and fabrication techniques. Further considerations have arisen with the advent of installation and conceptual art. Communication with the artist is often necessary to elucidate not just how a work was made but also which components or qualities are central to its meaning, thus requiring preservation. In 2012, the Hirshhorn Museum and Sculpture Garden was awarded a Smithsonian Postgraduate Fellowship in conservation to develop an artist interview program for the institution. Although primarily driven from a preservation perspective, the Hirshhorn Artist Interview Program was a museum-wide initiative with the goal of generating systematic face-to-face dialogues with artists. This article explains the motivations behind the creation of the interview program, the challenges that arose during its development, and the future of the program as it becomes integrated into the daily workflows of the conservation lab and the museum as a whole. As a practical example of the ways in which artist interviews can play into treatment choices, the conservation of an installation by Ann Hamilton is presented.

KEYWORDS: Ann Hamilton, Artist interview, Hirshhorn Museum and Sculpture Garden

1. ARTIST INTERVIEWS AT THE HIRSHHORN

Among conservation professionals, there is a growing consensus that information obtained through collaboration with artists and their studios can be essential in addressing the long-term care of contemporary artworks. Involving the artist's voice in the care of his or her work is not a new concept at the Hirshhorn Museum and Sculpture Garden, where the conservation files are populated with notes and correspondence from artists that date back to the opening of the museum in 1974. Today, these types of collaborations play a significant role in the overall approach to the conservation of the collection.

Artist-conservator collaborations can range significantly in duration from short interactions to lengthier ones lasting several years. However, in most cases, these collaborations are considered to be ongoing in the sense that relationships are being established over time, through multiple and widely varied formats of interaction that are as individual as the artists themselves.

In tandem with the growing practice of engaging with artists comes the responsibility to capture and manage this information in a meaningful way. Providing future caretakers with access to this content along with an appropriate degree of context to allow for informed decisions regarding an artwork's preservation is also important. Unlike the many informal means of communication that occur when collaborating, an artist interview, when structured as a formal dialogue, lends itself to being recorded and archived in a systemized way.

2. WHY DEVELOP A PROGRAM?

Increased emphasis on artist collaborations in the everyday activities in the conservation lab at the Hirshhorn required a shift from the ad hoc manner in which interviews were being carried out. It was recognized that a more organized and thoughtful process for conducting and capturing these important dialogues needed to be developed in a manner that would be more congruent with documentation standards for routine lab practices. Consequently, the logistical considerations required to conduct these interviews were examined with an emphasis on funding, staff, equipment, and time. It became clear that the necessary planning and coordination among a variety of people, maintenance of equipment, and management of post-interview data generated would require significant resources.

As a result of this realization, the goal became the development of an interview program within the conservation laboratory that would enable interviews to be conducted as a normal part of the acquisition, exhibition, and treatment processes. The establishment of new protocols would also be developed to make these discussions available to future caretakers of the collection in a format that could be easily accessed. The challenge was to build a sustainable program in a cost-effective manner that would satisfy the needs of the museum. In 2012, Steven O'Banion joined the Hirshhorn through a Smithsonian Postgraduate Fellowship in conservation to address this challenge.

3. INITIAL PLANNING

The first step in conceiving how to shape an artist interview program at the Hirshhorn was to examine other successful interview programs. Whenever possible, conversations were set up with the individuals who founded or managed these interview programs. The aim was to hear the thought processes and considerations that were taken into account when structuring a program to fit a particular institution's needs. Through these discussions, two significant commonalities emerged. First, the programs were designed to fit the existing workflows of the institutions; second, they utilized existing resources.

Although the Hirshhorn Artist Interview Program is preservation oriented and driven by the conservation department, it began as a museum-wide initiative. It was clear that if an interview program were to be successful, it would need internal museum support and thus also benefit other departments. As such, a committee was established consisting of members from several museum departments to steer the program.

Among the committee members, it was decided that the Hirshhorn's goal was to build relationships with artists over time rather than framing artist interviews as a one-time opportunity to nail down an artist's response to a list of questions. The committee also defined the scope of the program and established criteria for prioritizing interviewees. There was consensus that the program should focus on artists who are either represented in the Hirshhorn's collection or those whose work is in the process of being acquired. In addition to the artists themselves, individuals associated with the artists were also identified as potential interviewees. Studio assistants, family members, and gallerists may have different perspectives or specific information.

Prioritization of which artists to interview was based on a range of criteria. The committee acknowledged the importance of reaching out to artists who are advancing in age. Curators on the steering committee pointed out that many institutions tend to overlook Washington, DC–based artists, and therefore local artists were targeted as well. Further, Jill Sterrett, the Director of Collections at the San Francisco Museum of Modern Art, noted that a work of art receives the most attention when it is acquired, goes on loan, or is installed (Sterrett, pers. comm.). Thus, it was agreed that the Hirshhorn would take advantage of the momentum of these moments. Finally, considering that there was only a modest budget to pay for travel and lodging expenses for interviewees to come to the Hirshhorn, noting when artists represented within the collection were visiting the Washington, DC area was important.

Numerous interdepartmental collaborations contributed to the success of the Hirshhorn Artist Interview Program. For example, the programs department had already established a "Meet the Artist" lecture series, which regularly brings artists to the museum. On many occasions, the curatorial department worked in tandem with conservation when planning and conducting these interviews. The communications department helped to brand the program and, when appropriate, incorporated clips from the interviews into the museum's webpage and social media platforms. Portions of many of the interviews were then shared with the education department to augment the training of the Hirshhorn's interpretive guides.

4. LOGISTICAL CONSIDERATIONS

Once the goals and scope of the Hirshhorn Artist Interview Program were defined, there were workflows to develop and numerous logistical considerations to resolve. To address these considerations, once an interview subject had been identified, a preparatory meeting would be set up among museum staff members who had an interest in the interview. The meetings often would start with brainstorming the types of information that the group hoped to gather from the interview. The aims of the interview then guided subsequent decisions.

The format of each interview would be selected based on the desired outcomes. It was important first to consider whether a written communication, phone call, or informal or formal interview would best achieve these goals. Selection of the interviewer depended largely on identifying those most familiar with the artist and his or her work. In some instances, having two interviewers was deemed beneficial, as both interviewers could bring their expertise to the discussion. When picking the venue for an interview, having the artworks in question on hand or installed whenever possible was prioritized. This ability to look at and examine the artwork together with the artist often facilitated discussion about specific elements relating to its manufacture or its condition, as the presence of the artwork would often serve to jog the artist's memory. In addition to hosting interviews at the Hirshhorn, interviews were also conducted in artists' homes and studios, as these familiar environments often assisted in making the artists feel more comfortable than they might in the foreign environment of a conservation lab or conference room.

Amassing all of the equipment necessary to record interviews that varied greatly in their format, number of participants, and locations was particularly challenging, especially on a tight budget. One of the first pieces of equipment purchased was a small, easy-to-use audio/video recorder, as its portability was well suited to an informal interview. The video camera can capture non-verbal situations, such as when an artist points to a specific location on a work or image in a book. Further, the discrete device is less intimidating than the cameras and lights needed for a production-quality video.

When higher-quality video recording was required, two digital single-lens reflex cameras and lights were used, which the Hirshhorn already owned for photo documentation. The cameras recorded fairly high definition video and were user friendly. These qualities were helpful, as often it was essential to delegate the filming and operation of equipment to interns or assistants less familiar with camera technologies. In addition, having two cameras was found to be an asset, in terms of covering multiple angles of a complicated recording environment, such as a gallery or studio. Even in arranged interview settings, it was advantageous to have two angles to cut between during the editing process (fig. 1).

The ability to capture clear audio during an interview was prioritized. Although ambient audio recorders work well in controlled environments, like an empty auditorium, they can pick up a lot of background noise in less controlled settings, such as a gallery with an echo or a public space. As a result, a wireless microphone system was purchased that greatly expanded the types of locations where the interview could be recorded successfully.

Prior to every interview, test recordings were made with the designated equipment. Based on the quality of the recordings, adjustments would be made if necessary. After each interview, the equipment used was recorded in a log along with comments about what worked well and what did not. This log could then be referred to when planning what equipment to select for future interviews.

When requesting an interview, one person would be designated as the point of contact. That person would extend the initial invitation, concisely stating the purpose and intended use of the interview. Also at this time, permission would be requested to record the interview. Several days prior to the interview, the interviewee would be contacted with specific details. On occasion, a list of topics that the interviewer hoped to discuss or, in a few instances, specific questions would be sent ahead of the interview. This was especially important if there were technical questions that needed clarification, thus giving the interviewee a chance to prepare.

Fig. 1. Example of an interview setup with one camera directed at the artist and a second capturing the interviewers as well. (Courtesy of Steven O'Banion)

Post-interview considerations were equally as important as the pre-planning. The interviewee was asked to sign a release form, which reflected the intended use of the interview as communicated in the initial request. A thank-you note was sent after each interview. In addition to being a requisite civility, the note often provided a way to extend the dialogue. For example, this follow-up could be used as a means to elucidate any points that were not clearly addressed during the interview and could also be an occasion to request a second interview.

Recordings were backed up and converted to an archival file format. Then the interviews were transcribed. Once the transcript was edited, it was sent back to the interviewee so that he or she had the opportunity to make clarifications or corrections. The recordings, transcript, and release form were archived in a long-term digital asset repository.

5. CASE STUDY: INTERVIEW AS A COMPONENT OF ARTIST COLLABORATION

Prior to initiating the Artist Interview Program, Chief Conservator at the Hirshhorn, Gwynne Ryan, had been working with artist Ann Hamilton for 2 years to create a preservation plan for *Palimpsest*, a work in the Hirshhorn's permanent collection (fig. 2). Utilizing the tools of the newly structured interview process, Ryan and Hamilton summarized their discussions with a recorded face-to-face interview.

Fig. 2. Installation view. Ann Hamilton, in collaboration with Kathryn Clark, *Palimpsest*, 2004, Pencil on newsprint, map tacks, beeswax tablets, wood shelf, electric fan, steel and glass vitrine, cabbages, snails, dimensions variable, Hirshhorn Museum and Sculpture Garden, Smithsonian Institution, 04.29 (Courtesy of Hirshhorn Museum and Sculpture Garden)

Palimpsest is an installation artwork that was collaboratively made by Ann Hamilton and Kathryn Clark. Originally constructed for the New Museum of Contemporary Art in 1989, *Palimpsest* was first installed at the Hirshhorn in October 2005. Hamilton has described *Palimpsest* as "a room lined with yellowed newsprint, memories, public and private, penciled by hand on palm-sized paper, rustling in the fan's rotation, stories embedded in a floor of beeswax tablets, obscured and marked, a vitrine with cabbage heads, stripped and consumed by snails" (Hamilton, unpublished data).

In anticipation of its reinstallation in 2012, learning the meaning behind each of the components was essential in determining the appropriate approach to take toward its preservation. During the many discussions between Hamilton and Ryan that occurred between 2010 and 2012, it became clear that the topic of memory—in the loss of memory and the creation of communal memory—were at the heart of the artwork's meaning. An example of how this meaning relates to the preservation of the elements in the room is illustrated well by the artist, demonstrated well by the use of an oscillating fan positioned over the entrance to the installation (fig. 3). This fan functions to pass air current across note papers (the written memories) that are pinned to the walls, causing them to lightly flutter. However, the conceptual underpinnings of this element go deeper in that this was not just any fan; it was a fan owned by Hamilton's grandmother. The artist considers the fan's connection to her grandmother to be critical to the conceptual meaning of the work and its connections to her own personal memory. Thus, when the fan broke down a few weeks after the opening of the installation, replacing it with another fan was not an option. Instead, Hamilton's grandmother's fan was repaired.

Fig. 3. Detail of the artist's grandmother's oscillating fan that is essential to the conceptual aspects of the artwork (Courtesy of C. Carver)

In contrast, the artist does not fetishize many of the other components in the room. For example, Hamilton noted that the vitrine that holds the snails and cabbages may be refabricated if needed, as long as it is made to the same dimensions and has a similar general appearance. In addition, although Hamilton would prefer that snails were used in the vitrine, she has provided the option that slugs be used considering the challenges encountered in obtaining snails in the Washington, DC area. Even the dimensions of the room are variable, within limits. Hamilton offered the option of building a room to line up with the coffers in the Hirshhorn's ceiling, giving the space a trapezoidal, rather than rectangular, footprint.

The beeswax floor proved to be another topic of concern, as beeswax is not a material that holds up well under foot traffic, becoming sticky and embedded with the materials that are tracked into the gallery. During the initial 2005 installation at the Hirshhorn, the wax quickly became a logistical nightmare for the conservators on staff charged with keeping it clean. In fact, much of the preliminary discussion with Hamilton in preparation for the 2012 installation was motivated by the desire to prevent this cleaning/maintenance issue of the wax floor. After consultation with the artist, a water-based, matte polyurethane coating was applied to the floor, fulfilling both the artist's request that any coating used not disrupt the appearance of the wax and the conservators' goal in having a reversible coating (that can be pulled up with tape after the artwork is deinstalled) that protects the wax below. Just as importantly, the coating made the installation much easier to maintain.

The atypical preservation plan for the handwritten notes that line the walls of the installation was a direct result of the recorded interview between Ryan and Hamilton. These notes presented multiple preservation challenges due to their inherent fragility, consisting of ephemeral newsprint paper that the artist had artificially aged in the sun to achieve a yellowed appearance. As mentioned previously, these papers are pinned to the wall and are meant to flutter in the air current generated by the oscillating fan while on display. The aged newsprint on which the notes are written is an inherently ephemeral material, and even if stored at low temperatures in the dark, the notes will eventually degrade to the point that they will not be able to be displayed in this format (fig. 4).

Fig. 4. Detail of note papers pinned to the wall, fluttering in the current caused by the fan (Courtesy of C. Carver)

Conceptually, the handwritten notes on the paper also have significance because they are intricately tied to the conveyance of communal memory. The text of the notes is handwritten in graphite by about 50 of Hamilton's friends and acquaintances of varying ages, including notes written by her mother. The writings that fill the front of each sheet are either memories that are personal to the writer of the note or are excerpts from memoirs, biographies, or autobiographies, signifying the transference of memory from author to reader during the process of being copied onto the notes.

Having access to the artist, in conjunction with an upcoming installation, provided the opportunity to inquire about a preservation plan for the notes. Hamilton indicated during the recorded interview a distinction between "preservation" of the artwork and "keeping the piece alive" as two diverging but equally important actions. Preservation, from a materials standpoint, can be achieved by storing the original notes in cold storage and caring for them as long as is possible. The action of keeping the artwork "alive" could involve the fabrication of new notes, written by people of different generations absorbing the memory of a text by writing it on new notes. In this way, the true spirit of the artwork would be reflected and preserved, as the process of creating communal and generational memory can be continued. To achieve this goal, Hirshhorn conservators enlisted the help of teens participating in the Hirshhorn's ArtLab+ program, as well as museum docents and interpretive guides who represent an older demographic. New note papers were prepared in accordance with instructions provided by the artist. However, the new note papers were dyed to match the original papers rather than artificially aged as a measure to mitigate the rate of degradation.

The blank papers were given to the museum docents, guides, and teens, who then composed new notes that met the artist's specifications. To distinguish the new notes from the artist-provided originals, the writer's name and the date were recorded on the back of each new note. After curatorial review, these notes will be incorporated along with the originals into *Palimpsest* the next time the work is installed.

In addition to summarizing years of informal conversations, the face-to-face interview led to a defined preservation plan for *Palimpsest*. Parameters were set regarding which elements of the installation are variable and which are fixed. The resultant guidelines clarified many of the ambiguities that existed between the conceptual and physical aspects of the work. The interview also gave authorization for conservators to create new note papers in the spirit of the installation, a preservation tactic that would not have been considered without the artist's suggestion. These recorded details will guide future generations as they continue to care for and install Hamilton's work.

6. POSITIVE OUTCOMES

Since the end of O'Banion's fellowship in 2014, Hirshhorn conservators have continued to review the processes and identify the positive outcomes of this project. A primary positive outcome is that the laboratory is now outfitted with the equipment necessary to record a wide variety of interview formats, ranging from the casual to the formal.

As a result of conducting so many interviews over a relatively short period of time, the ability to move through a good portion of the learning curve was able to occur fairly rapidly. This learning curve not only encompassed the logistical planning considerations involved but also the evaluation of interviews that seemed to result in richer dialogue. This last point is worth emphasizing, as recorded interviews are an artificial type of conversation that do not necessarily encourage relaxed, open dialogue. The staged format of seating the artist and interviewer in a formal studio-lighted setting is utilized less, as the dialogue is found to be much richer when the setting and format is more organic (fig. 5). However, this may sacrifice the ability to utilize the footage for interdepartmental uses (e.g., communication or education departmental needs for social media dispersal) and is therefore a decision made on a case-by-case basis.

Fig. 5. Interview with artist Seibren Versteeg (center) in his Brooklyn studio, providing a relaxed and familiar atmosphere where richer dialogue can emerge (Courtesy of C. Carver)

In many cases, like that of the aforementioned Hamilton interview, these recorded discussions can be quite useful as a way to recap previous conversations that have occurred over the course of a more long-term collaboration. Here the established rapport lends itself well to reducing the disarming impact that an audio/video recording setup can have on the exchange (fig. 6). However, this interview format may not be considered appropriate or feasible in all situations.

Another benefit that emerged through the development of the Hirshhorn Artist Interview Program is that the processes put in place around the setup and planning of an interview resulted in greater collaboration with other departments in the museum. Due to the overall collaborative nature of the program, the step of carrying out an interview became a factor of the museum's acquisitions and exhibition project team discussions. Now included in the same kinds of conversations where discussions relating to arrangements for shipping of a new acquisition or pedestal needs of an exhibition might occur, the question of whether conservation would like to conduct an interview and its timing is also a part of the discussion.

7. CHALLENGES

The implementation of an artist interview program has brought several challenges to light. The most immediate challenge is one of resources, as existing staff is required to manage and oversee the program. Orchestrating the various participants, schedules, transcriptions, and archiving process is a significant additional workload. As a result, identifying those on the Hirshhorn staff with the skill sets required to

Fig. 6. Interview between Hamilton and Ryan discussing *Palimpsest*, providing an example of using an interview to recap the discussions that have occurred over the duration of a multiyear collaboration. (Courtesy of C. Carver)

keep the workflows running smoothly is an ongoing process. Currently, management of this program has been assigned to the Variable Media Conservator Briana Feston-Brunet, as archiving of the video and audio files and management of equipment is similar to workflows associated with the care of the media art collection. However, each conservator is responsible for initiating and scheduling his or her own interviews. The assignment of these additional tasks can be challenging for an already busy museum staff and is not necessarily a sustainable model.

Another topic that the Hirshhorn Artist Interview Program has brought to the fore is the process of disseminating interview documentation. Within the conservation field, there exists a general trend in prioritizing the sharing of research, analysis, and knowledge. As such, there is advocacy for the information gathered from an interview to be dispersed. The benefits of sharing the information gained from an artist interview is evident, as the various interviews are building a broader body of knowledge about the artworks in the collection. However, although a release form may be in place, the conservation profession has not had the opportunity to fully process the ramifications of disseminating such collaboratively created records, leaving a question as to what degree of sharing may or may not be appropriate.

The information obtained during an interview is based on a foundation of trust with the interviewee, who may not necessarily have a clear stance on the degree to which this information can or should be shared. Therefore, it has been important to reflect on the ability to ensure that specific requests about confidentiality can actually be met. In a digital age, it becomes even harder to ensure that transcripts and files are not shared without permission.

In sum, while conservators are forging collaborative projects, carrying out recorded interviews puts one into an interesting territory. While looking to other professions such as anthropology, oral history, ethnography, and journalism for guidance is largely helpful, there will be both legal and ethical considerations unique to conservation because of the complicated network of relationships among artists, conservators, institutions, private collectors, and galleries. It is important to remain aware that conservators are part of a larger picture that involves various stakeholders with different goals and priorities. Indeed, this will impact and influence the way the field of conservation will set up its best practices over time.

ACKNOWLEDGMENTS

We are very grateful to Steven O'Banion for all of his work and research and for putting in place a framework to coordinate, capture, and archive these interviews. We would also like to thank Susan Lake for supporting the project and Nicholas Kaplan for sharing his technical knowledge. This project would not have been possible without the Smithsonian Office of Fellowships and Internships Conservation of Museum Collections Program and the Smithsonian Office of the Chief Information Officer.

SOURCES OF MATERIALS

Sennheiser G3 SK 100 Wireless Microphone System with ME-2 microphone, Zoom Q3HD Handy Video Recorder (discontinued)

B&H Photo
420 9th Ave.
New York, NY 10001
800-221-5743
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PRESERVING WHAT IS RIGHT: FINDING SIMILARITIES BETWEEN COLLABORATING WITH A LIVING ARTIST AND BUDDHIST MONKS

CÉLINE CHRÉTIEN

This article draws a parallel between two experiences. The first one, in the context of contemporary art, involved collaboration with the artist Richard Fauguet for the conservation of his piece, *Mirida*. The second experience, in the context of religion and ethnography, took place in the Buddhist monastery of Matho in Ladakh, India, and involved collaboration with Buddhist monks and owners. Numerous similarities emerge from this comparison, such as the importance of the immaterial value, the object's status, and the conservation approach that consist in an active participation and conversation from the conservator with artists and stakeholders. A potential collaborative approach is proposed between the conservation of ethnographic objects and the conservation of contemporary art.

KEYWORDS: Richard Fauguet, Immaterial, Contemporary art, Buddhism, Religious, Ethnographic, Interview, Religion, Silicone, Immateriality

1. INTRODUCTION

Conserving cultural heritage can be challenging when an intangible value that constitutes the integrity of an object comes into conflict with Cesare Brandi's *Teoria del Restauro* (1977), the influence of which is still strongly present in European conservation practice. First of all, his theory concerns fine art artifacts and architectural monuments only. Moreover, these artifacts are considered from a contemplative perspective only. As a result, the religious value, the functionality of some cultural heritage objects, and the aesthetical experience desired by some contemporary artists are some of the aspects that are not considered by his theory. I will highlight two of my projects in which the immaterial characteristic had an eminent place in the integrity of the objects. One was in the context of contemporary art, involving collaboration with a living French artist, Richard Fauguet, for the conservation of his piece, *Mirida*, from 1994; the other was in the context of ethnography and religion, which took place in the Buddhist monastery of Matho in Ladakh, India, and involved collaboration with Buddhist monks and owners. These two experiences involved similar issues regarding an intangible heritage value, and they enabled me to compare the way they were approached. This article presents those two projects and leads to a comparative analysis.

2. *MIRIDA*

For my graduation project at *L'Institut National du Patrimoine* (INP, National Institute for Cultural Heritage) in Paris, France, in 2010, I studied a contemporary piece called *Mirida* (fig. 1). Fauguet made the piece in 1994. The institution *Fond Regional d'Art Contemporain* (FRAC, Regional Fund for Contemporary Art) of Franche-Comté, situated in Besançon, in France acquired it in 1999.[1] This three-dimensional piece is composed of a trio of horse heads made from translucent silicone rubber—one component silicone rubber with acetic acid crosslinking—and glass marbles. As the silicone rubber is hollow, the heads are very soft and deformed.

Through his art, Fauguet enjoys expressing his vision of the world in a poetic and humoristic way. With *Mirida*, the glass marbles from children's game and the deformation of the heads are characteristic of his dreamlike world. This piece is a satire of the relationship between the artist and his art dealer. The artist

Fig. 1. *Mirida* in 1999 at its accession at the Frac Franche-Comté. Richard Fauguet, *Mirida*, 1994, silicone rubber, glass marbles, each element 77 × 34 × 56 cm. Frac Franche-Comté, FR-1999-13 (1 to 3). (Courtesy of Frac Franche-Comté)

represented himself between two artist friends, Michel Aubry and Daniel Schlier, as drunken racehorses on which the art dealer would have wrongly bet. The first syllable of each name forms the title *Mirida*.

The piece has not been displayed since 2003 because of tears caused by the artist's mount, which relied on screws fixed in silicone to fasten the heads to the wall. Due to the weight—each head weighs around 10 pounds—several tears have increased from the screw holes (fig. 2) and one area of the silicone

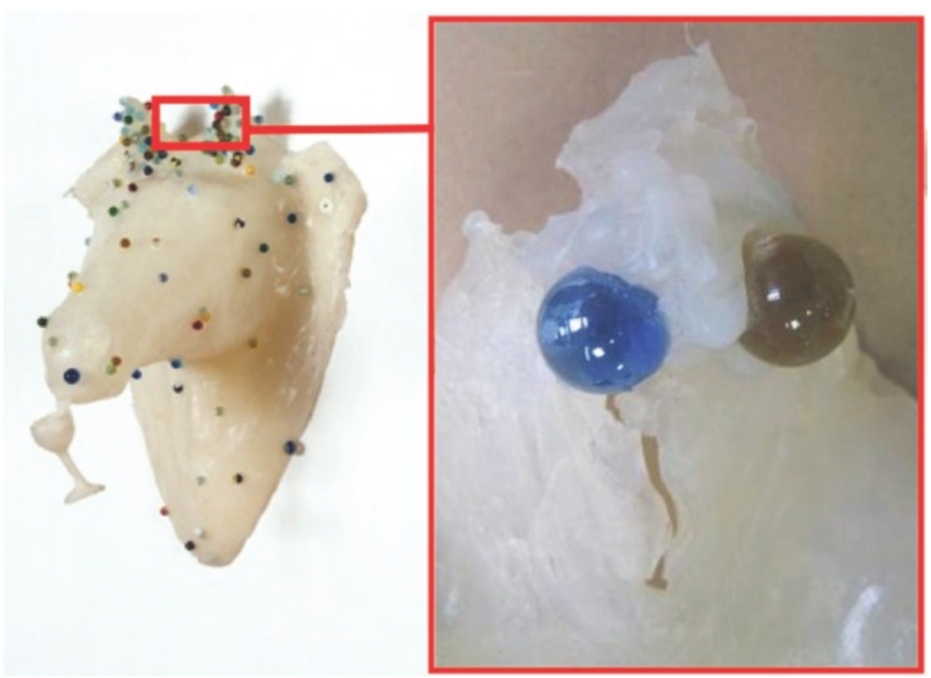

Fig. 2. Tear and former repairs (Courtesy of Frac Franche-Comté/Céline Chrétien)

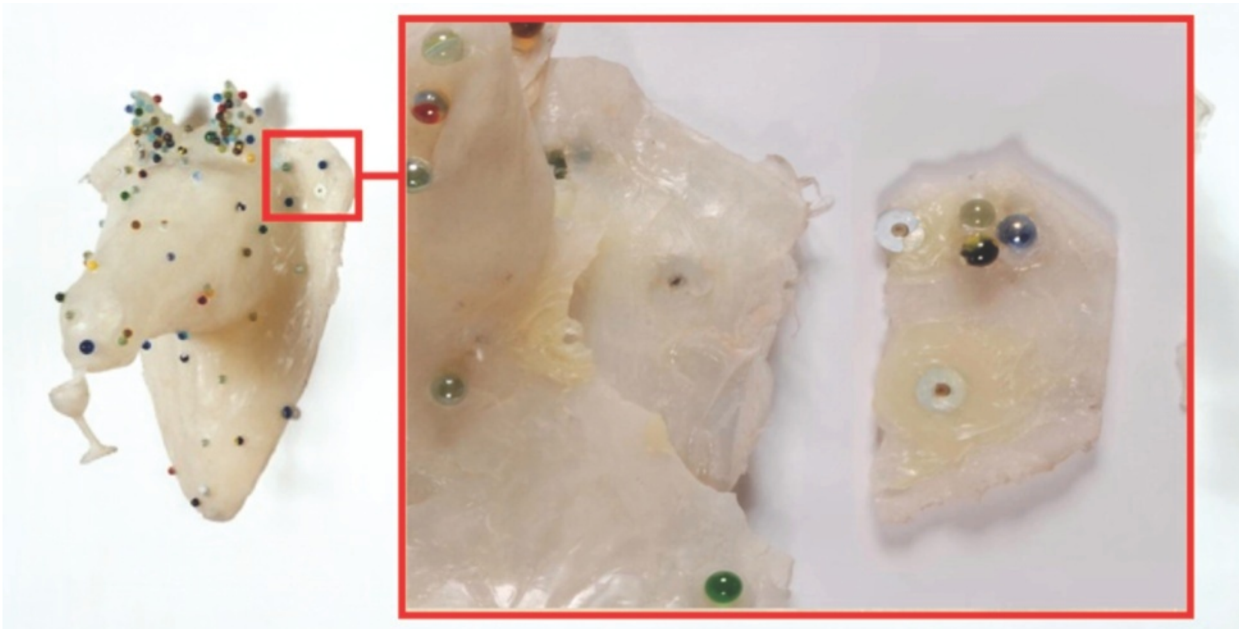

Fig. 3. Fragment of *Mirida* (Courtesy of Frac Franche-Comté/Céline Chrétien)

detached from the piece (fig. 3). The piece also showed other alterations, such as a slight yellowing of the silicone. Deformations and tears in the folds were apparent, as the piece was stored folded (fig. 4).

Collection manager Norbert Robert and myself agreed that collaboration with Fauguet was necessary for several reasons:

- He retained moral rights on his piece even though ownership has been transferred since the FRAC acquired it in 1999.[2]
- At the time of the purchase, the necessary conditions for the respect of the integrity of *Mirida* had not been stipulated in the sale contract, and no artist interview had been performed. As a result, the description of the meaning of the piece, the information about its execution, and the way it should be exhibited were all missing.

Fig. 4. *Mirida* at its arrival at the INP in September 2009, tear on a fold (Courtesy of Frac Franche-Comté/ Céline Chrétien)

2.1 DOCUMENTING AND REDISCOVERING THE PIECE

In response to this missing documentation, I gathered information from exhibition catalogues and archived documents that were exchanged between Fauguet and the FRAC of Franche-Comté. I also interviewed Fauguet, his assistant at the time of the creation of the piece Rainier Lericolais, and his art dealer Jean-François Dumont. From the facts I gleaned from those documents and interviews, information about the description of the piece—as Fauget and his two friends' portrait—has been re-established. Moreover, the artist's intention has been updated: Fauguet wanted the public to live an aesthetic experience. The ghost-like translucence and the deformed aspect of the horse heads, as well as the marble decoration, were supposed to generate feelings of rapture and curiosity. The interview has also revealed that the memory can be selective and inconsistent; for example, Fauguet's assistant remembered using some tools that the artist forgot to mention.

2.2 A COLLABORATIVE INTERVENTION WITH THE ARTIST

After the documentation, it was necessary to learn about Fauguet's expectation regarding the conservation of his piece. The first time I contacted him on the phone, it was clear that he wanted the piece to be refabricated, and he did not mind about doing it himself or letting me do it. I wanted to understand why he felt the need to make the piece again. He feared that the silicone has become too discolored—which would have affected the aesthetic experience—and he thought that it would be too complicated to put the fragment back. The problem with this proposition was that the piece would have lost its original material, the evidence of the hand of the artist, and its historical value. Moreover, Fauguet wanted to improve the execution of the piece, which would have changed its "DIY" appearance. As a consequence, the collection manager of the FRAC refused to consider this option. Since Fauguet had not seen his piece since 2003, I asked him to come to the INP to see it. He noticed that the silicone was not

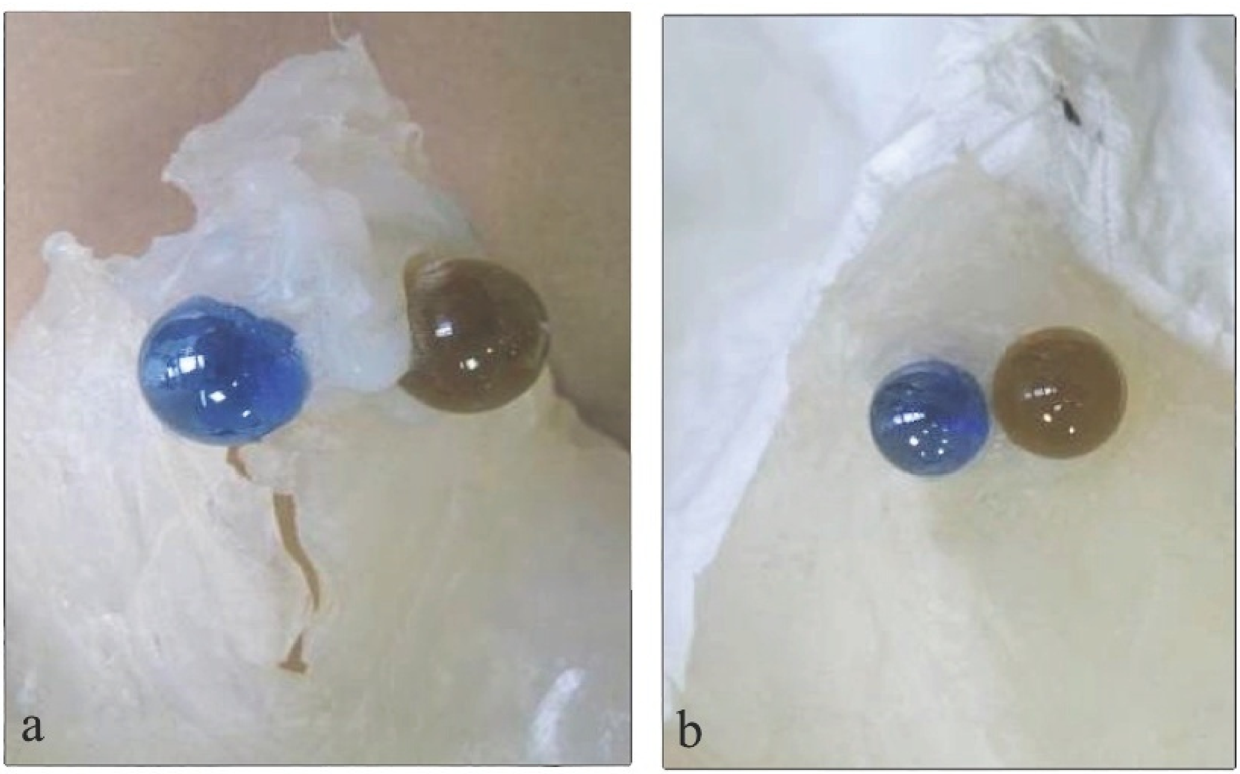

Fig. 5a. Tear before treatment; 5b. Tear after treatment (Courtesy of Frac Franche-Comté/Céline Chrétien)

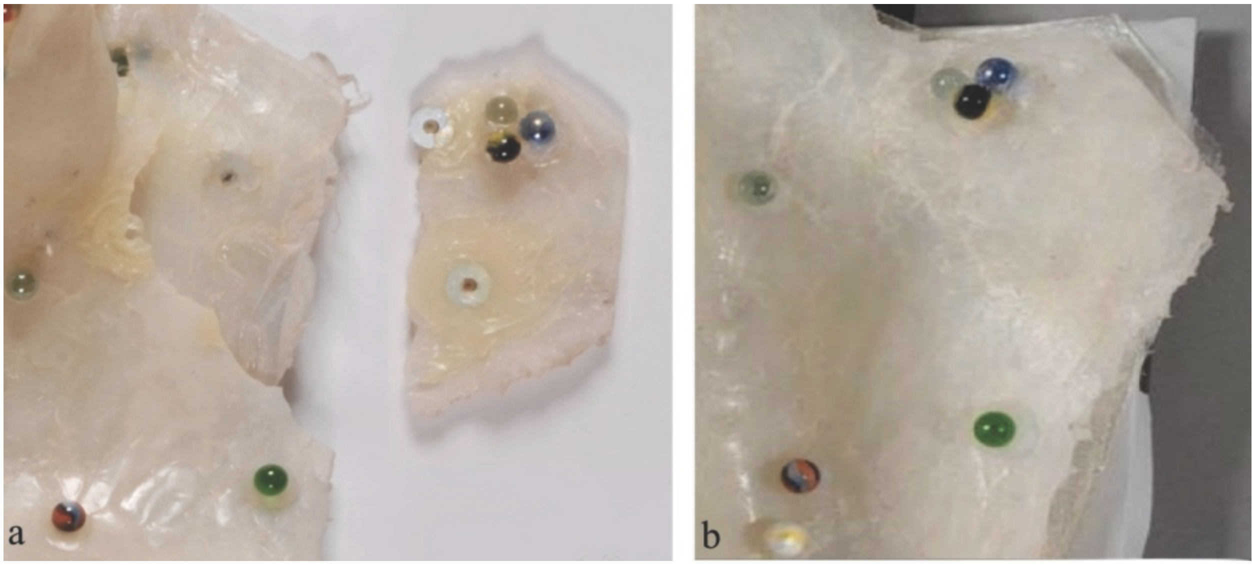

Fig. 6a. Fragment before treatment; 6b. Fragment after treatment (Courtesy of Frac Franche-Comté/Céline Chrétien)

as yellow as he thought and that its appearance was still acceptable. Moreover, I organized a survey among the students and faculty at the INP: I took note of people's reactions and feelings in regard to *Mirida*. The result showed that the piece was still efficient in provoking the aesthetic experience that Fauguet sought. As a result, Fauguet recognized that his piece could still embody his intention, and he no longer felt the need to refabricate it.

From there, I could start working on the treatment proposition. I first had to find a way to put the fragment back and consolidate the tears. This intervention required that I test several adhesives—silicone Rubson SP2, Plextol D360, and Beva 371 film—and to make samples to show the final aspect to the artist. After the research, Fauguet agreed with my suggestion of a reversible bonding, with fumed silica and Beva 371 film, as aesthetically satisfying. With his agreement and the collection manager's agreement, I carried out the stabilization treatment of the tears and the bonding of the fragment with this method (figs. 5, 6).

Last, as the original hanging method led to the deterioration of *Mirida*, a new mounting had to be created. As before, Fauguet's contribution was helpful to understand the requirements of the project. The intentional deformation and the translucence of the piece had to be respected. Fauguet also showed me how he stretched the silicone rubber when fastening the heads to the wall himself. After seeing a prototype of the supports that I devised with a polyester resin and fiberglass, Fauguet agreed that it fulfilled his request. The supports are located inside each of the heads, which are hollow. The support structure helps to distribute the weight over a larger surface, inside the forehead, and keeps the rest of the head hollow to preserve the intentional deformation. After receiving the artist and the collection manager's agreements, the final supports were fabricated using translucent conservation-grade materials: polymethyl metacrylate and polyethylene terephthalate glycol (fig. 7). The heads are fixed on the supports with neodymium magnets.

As the three-dimensional volume of the piece needed to be maintained during storage, three crates were created and the supports and some polyethylene foam help to maintain the volume inside the heads (fig. 8).

After the treatment of the piece, an annual checking by the collection technicians of the institution has been recommended. Even though the silicone rubber is currently stable, it might disintegrate in the future, and this might lead to a non-exhibitable state. The successors of the current collection manager may conceivably need to deal with the refabrication of the piece. If that situation occurs, the precise documentation that I have undertaken would be an important tool.

Fig. 7. Support to be introduced in the hollow part of each head (Courtesy of Frac Franche-Comté/ Céline Chrétien)

Fig. 8. Crate for *Mirida* (Courtesy of Frac Franche-Comté/Céline Chrétien)

3. MATHO MUSEUM PROJECT

The second project took place in the Buddhist monastery of Matho, situated in Ladakh in the north of India and founded in the 15th century. The monastery owns a collection of liturgical objects and *thangkas*, many of which are still used and some of which date back to the ninth century. A subset of the collection was publicly available in the meditation rooms. The others were exhibited in a room used as a museum. In this museum the objects were difficult to access, as the showcases were closed with nails. Deteriorations such as dust, grime, flaking paint, deformations, cracks, gaps, breaks, and missing parts were noticeable on the objects. Dungsey Gyana Vajra Rinpoche, senior lineage holder of the *Sakya* order of Tibetan Buddhism and manager of the Matho monastery, wished to build a new museum and wanted the damaged objects to be treated. He entrusted the French association Himalayan Art Preservation with this project, led by Nelly Rieuf, painting conservator.

It is in this context that I joined the team for a month in 2011 to handle the inventory and conservation assessment of the unfired clay objects. A year after, with the help of a French grant from the Carnot Foundation, I came back for two months to perform the conservation treatment of some selected objects. The unfired clay objects comprise portraits of Sakya masters, Buddha figures, and ceremonial masks worn by the monks (fig. 9). By examining the objects during the collection assessment, and by visiting the Central Institute of Buddhist Studies (Choglamsar, Ladakh, India), which still teaches traditional clay sculpture making, I found that those objects were actually made of a blend of clay, animal glue, cotton fibers, cotton cloth, threads, and wood.

3.1 UNDERSTANDING THE RELIGIOUS STATUS OF THE OBJECTS

Preliminary to the conservation treatment proposal, an interview with the monks was essential to know their expectations and to understand the role of those objects in the monastery, as well as the importance of their aesthetic appearance and their history.

First of all, those objects still have a religious value for the believers. When we visit monastery museums in the area, we can notice that people still perform offerings to the objects in the museums,

Fig. 9a. Ceremonial leopard mask. Creator unknown, date unknown, cotton, clay, animal glue, pigments, 34.5 × 23 × 23 cm. Matho monastery, Ladakh, India, St 13; 9b. Chitipati mask. Creator unknown, date unknown, cotton, clay, animal glue, pigments, 43 × 33.5 × 19 cm. Matho monastery, Ladakh, India, St 9. (Courtesy of Himalayan Art Preservation/Céline Chrétien)

such as oil lamps, incense, water, sculptures made of butter and barley flour (*tormas*), fruits, and flowers. For Buddhists, the deities live in the artifacts that represent them: when a newly made artifact is complete, a ceremony is celebrated to invite the deity to embody the picture or the object that has been dedicated to it. Once the object is damaged, the deity leaves the object, as it is not worthy of being inhabited. Therefore, the religious use of these objects is inextricably linked to their aesthetic condition, and their religious value can be restored only if their aesthetic integrity is rehabilitated.

3.2 A COLLABORATIVE INTERVENTION WITH THE MONKS

To our knowledge those objects have never been treated by anyone other than natives of this region. Moreover, they were still going to be used by them. This context differs from Western museums and necessitated finding an approach that would be compatible with the Buddhist culture.

In accordance with their belief, the monks initially wanted the missing parts of the objects to be completed and have a polished finish. This interfered with Brandi's wish to have the ability to recognize the restored parts at near distance. In agreement with the monks, we decided to proceed step by step, from a minimal conservative intervention to a restorative intervention, acknowledging the monks' point of view between each step. We started with stabilizing the objects, by dusting, cleaning, consolidating, and filling the gaps. To differentiate the restored parts from the original ones, we proposed the use of different materials, such as a mix of Klucel G, cellulose powder, chalk, and pigments. We carried out a minimal aesthetic improvement by reshaping the masks with a humid treatment (fig. 10). Upon request

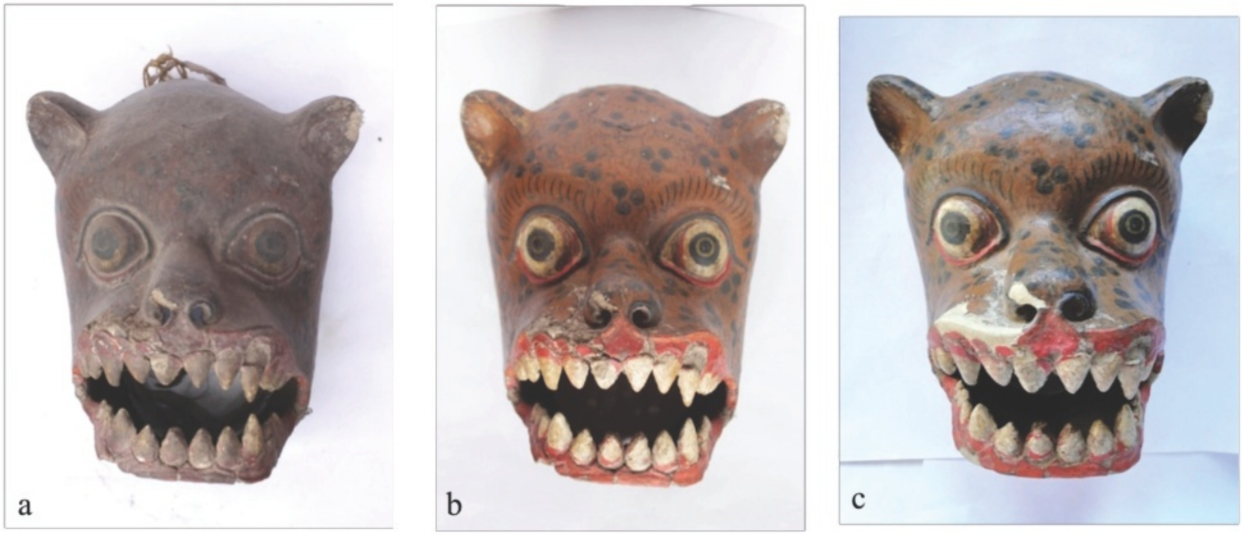

Fig. 10a. Leopard mask before treatment; 10b. After consolidation, cleaning, and reshaping; 10c. After gap filling. (10a. and 10b. Courtesy of Himalayan Art preservation/Céline Chrétien; 10c. Courtesy of Himalayan Art Preservation/ Anne-Laure Goron)

of the monks, we reconstituted the two missing skulls of one of the Chitipati masks. At this point, and unexpectedly, the monks, who at first wanted a visually cohesive restoration, were satisfied with the appearance of the masks after the gap fillings and the reconstitution of the two missing skulls. They did not feel the need to have them painted with the original colors (fig. 11).

During this project, locals have been trained to provide the maintenance necessary for the good conservation of the pieces. And the new museum has been built with a view to ensure satisfying conservation conditions, such as a stable climate and a low exposure to light.

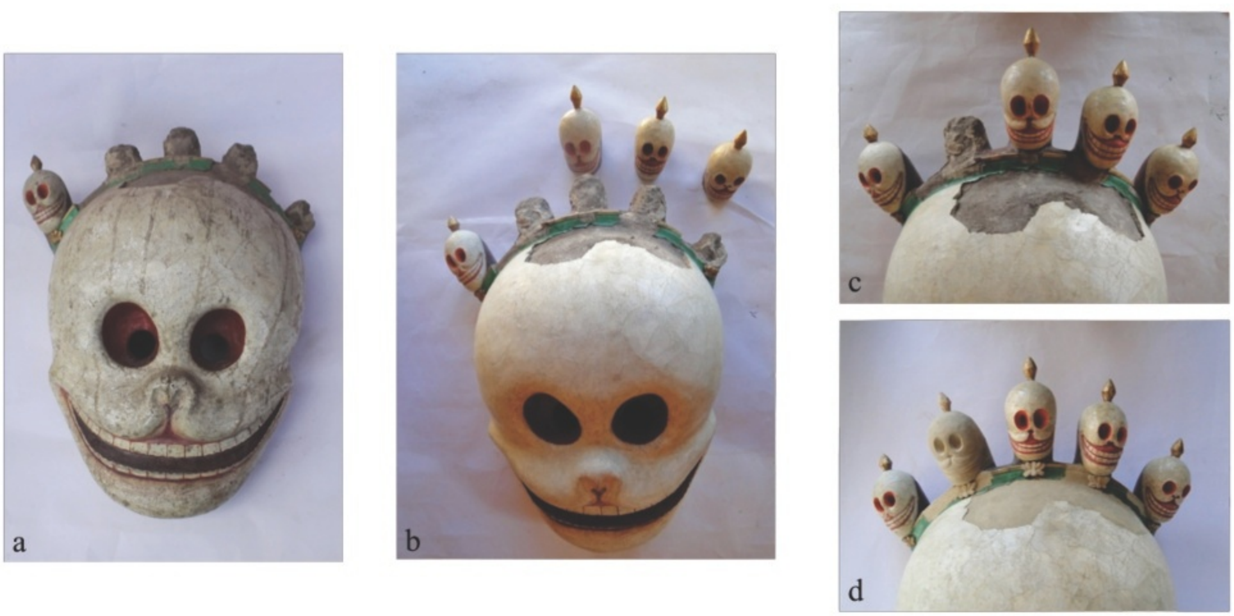

Fig. 11a. Chitipati mask before treatment; 11b. After cleaning; 11c. After bonding fragments; 11d. After gap filling and missing ornamental skull reconstitution. (11a. and 11b. Courtesy of Himalayan Art Preservation/Céline Chrétien; 11c. and 11d. Courtesy of Himalayan Art Preservation/Anne-Laure Goron)

4. ANALYSIS

Despite the differences between *Mirida* and the Buddhist clay objects, those two experiences reveal many similarities, which can be classified as discussed next.

4.1 BOTH ETHNOGRAPHIC AND CONTEMPORARY OBJECTS

Both *Mirida* and the Buddhist clay objects meet the definition of ethnographic objects by Benedicte Rolland-Villemot: they are "witnesses of social systems and of modes of thinking" (Rolland-Villemot 1998, 16). Moreover, the comparison performed by Hal Foster (1995) between the artist and the ethnographer, and the one made by Vivian van Saaze (2009) between the conservator and the ethnographer of contemporary art, reinforce this idea: the artist observes the world and transposes his observation into his art, and the conservator explores the artist's world with the ethnographer's tool—the interview.

Mirida and the Buddhist clay objects also both have characteristics of contemporary objects: *Mirida* could not be approached like an artwork from previous centuries due to the importance of the artist's intention for this piece. The liturgical objects in Matho still have a role to play in the current activity of the monastery. As a result, and despite their traditionalism, they could not be approached like the ethnographic objects present in Western museums.

4.2 THE CONSERVATION OF THE IMMATERIAL VALUE AS A PRIORITY

At first these two projects presented comparable conflicts between the artist and the religious believers and Brandi's theory, which implies a minimal intervention and a recognizable restoration on behalf of the respect of the authenticity of the piece:

- Fauguet wanted his piece to still be able to express his dreamlike world. To him, his artistic intention induced the necessity for his piece to have a perfect aesthetic, and this prevailed over the conservation of the original material.
- The monks needed the deities to embody their objects again. To do so they needed their objects to have a perfect aesthetic, and this was at first more important to them than conserving the marks of their history.

4.3 AN ACTIVE RELATIONSHIP WITH THE OBJECTS

During these projects, I understood that the origin of this conflict was due to the fact that the artist and believers still had an active relationship with their objects, which is not considered in Brandi's theory:

- As Fauguet is the creator of *Mirida*, he still considered his piece from a creation process perspective. As he evolved, his consideration of his piece evolved as well.
- The religious believers considered that these objects were alive, endowed with a spirit, as deities embody them according to Buddhism. Moreover, these liturgical objects still had a place in the believer's everyday life.

4.4 AN ETHNOGRAPHIC APPROACH

As both contexts were different from the conservation of ancient objects in Western museums, I had to adapt my approach to the different characteristics of these objects. I wished to avoid an ethnocentric perspective: instead of considering the need of the objects according Brandi's theory only, I attempted to consider the artist and the monks' requests according to their culture.

The solution was to start by studying the objects in the most neutral way possible. This required interaction with the artist and the monks. In both cases, the interview was a successful tool for performing this work, as it enabled me to understand how these people related to these objects. In addition, I had an outside position regarding these objects because I came to the projects with a distance that they did not have, with a conservator's point of view, with different references, and with an ethic to respect. As a result, the interview also enabled my subjects to discover and understand the different options offered by conservation. Fauguet was eager to learn about the best conservation conditions to conserve his pieces, and the monks were quite involved and enjoyed following the evolution of the treatments.

The fact that this approach worked in both projects is easily explained if we consider that before being commonly used in contemporary art conservation, the interview was an ethnographic tool. To me, studying the artist's world is just like exploring a newly discovered society: they both have their own codes and references that need to be deciphered.

5. CONCLUSION

Despite the clear and important differences between this contemporary piece and these active religious objects, the comparison has exposed some similarities in their issues and their approaches. Starting from those case studies, this article seeks to provoke thought about contemporary art conservation and ethnographic objects conservation from a wider perspective. These two fields occasionally present values not considered by Brandi's theory. As a response to this issue, and despite their parallel evolution, these two disciplines have adopted at times similar approaches. For both disciplines, dialogue and collaboration with the creators or the owners of the pieces has often been the key to solve ethical issues. This latter resemblance tends to reinforce the legitimacy of these approaches. As a result, it highlights the benefit of collaboration between these two disciplines: learning from each other and legitimizing new approaches.

ACKNOWLEDGMENTS

The initial project was undertaken at *L'Institut National du Patrimoine* (INP), Paris, France, on a piece by Richard Fauguet that belongs to the Fond Regional d'Art Contemporain Franche-Comté, Besançon, France. I want to thank artist Richard Fauguet and collection manager Norbert David for entrusting me with the conservation of *Mirida*. I want to acknowledge Juliette Levy, head sculpture conservator at the INP, Marie Payre, assistant sculpture conservator at the INP, Sylvie Ramel, conservator of modern materials in private practice, and Alain Pouchelon, expert in physical chemistry of surfaces and polymers, for their time, encouragement, and support.

The second project was undertaken at the Buddhist Monastery of Matho, with the French association Himalayan Art Preservation (HAP), and was supported by a French grant from the Carnot Foundation. I want to express my gratitude to Nelly Rieuf, painting conservator and manager of the Matho Monastery Museum Project, for inviting me to join the team working on the project and for putting her trust in me. I am grateful to the monks of Matho monastery for entrusting me with the conservation of their liturgical objects. I would like to acknowledge the Carnot Foundation, which has made this project possible. I would like to thank the Central Institute of Buddhist Studies (Choglamsar, Ladakh, India), its teachers and its students, for sharing knowledge of the traditional clay sculpture making, and Anne-Laure Gauron, sculpture conservator in private practice, for her involvement in the conservation treatment of the clay objects.

NOTES

1. A FRAC is an institution by which each French region finances, collects, and broadcasts current creations.

2. In France, the artist's rights are defined by the articles L. 121-1 to L. 122-12 of the Intellectual Property Code. Conservation of contemporary art is particularly concerned with the right of the respect of the integrity of the piece with which these articles deal.

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SOURCES OF MATERIALS

Beva 371 film; Fumed silica; Cellulose powder
Talas
330 Morgan Ave.
Brooklyn, NY 11211
212-219-0735
http://talasonline.com

Neodymium earth magnets
Adams Magnetic Products
34 Industrial Way East
Eatontown, NJ 07724
https://www.adamsmagnetic.com

Klucel G
Kremer Pigments
247 West 29th St.
New York, NY 10001
212-219-2394
http://www.kremerpigments.com

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SOL LEWITT'S WALL DRAWINGS: CONSERVATION OF AN EPHEMERAL ART PRACTICE

JOHN HOGAN AND CAROL SNOW

Sol LeWitt's Wall Drawings create an entirely new point of departure in the creative processes of idea, visualization, variants, realization, immutable repeatability, and intellectual implications for artists. LeWitt's Wall Drawings are not physically artist generated and are non-artifact oriented. When the artist's intellectual intent and production are intended to be of a temporary but repeatable nature, how are the standards explained and maintained long term? What are the implications related to conservation, connoisseurship, and technical art history when dealing with practitioners of ephemerally based arts—reinstallation versus repair, disappearance of original materials, repeatability, human participation in realization, concepts of non-cultural rarity, maintaining artistic integrity, cultural historical context, avoiding making an "Identical Copy" but respecting the parameters of the "Idea"? Training future "draftspersons" in the materiality, scale, process, and nature of a democratic hand is a critical component. This article addresses the role of the archivist of historical and current installations working with conservators at Yale utilizing their expertise to inform realizations of the Wall Drawings far into the future.

KEYWORDS: Sol LeWitt, Conceptual Art, Drawings, Wall paintings conservation

1. BACKGROUND AND CONTEXT

The evolution of conservation theory and practice can be a slow progression or a sudden leap. In the case of Sol LeWitt's Wall Drawings at the Yale University Art Gallery, it is the latter. Therefore, a quick review of wall paintings in the Art Gallery's collections and the relatively standard conservation practices for these works allows a better understanding of current and future approaches to LeWitt's ephemeral artworks.

1.1 WALL PAINTINGS AND DRAWINGS OVERVIEW

Among the oldest wall paintings in the Art Gallery's collections are Egyptian fragments dating to the second millennium BC and the once-polychromed Assyrian wall reliefs, dating from 883 to 859 BC, from the Palace of Ashurnasirpal II, Nimrud, now Iraq. The Assyrian reliefs with inscriptions were recently examined using visible-induced luminescence digital photography in a collaborative project with conservation scientist Jens Stenger and Near Eastern Languages and Civilizations PhD candidate Shiyanthi Thavapalan, who is studying Mesopotamian ideas of color (Salas 2014). The palace wall reliefs that remained in situ at Nimrud have tragically fallen victim to the abhorrent acts of Islamic State militants (Danti et al. 2015), thus increasing the importance of the Art Gallery reliefs.

The Art Gallery is renowned for its collection of ancient wall paintings from the Greek, Parthian, and Roman site of Dura-Europos in modern-day Syria. In addition to a wide range of artifacts, the joint excavations by Yale University and the French Academy of Letters between 1928 and 1937 yielded many significant wall paintings and drawings, including military graffiti, representing multicultural and polytheistic traditions. At the time of excavation, Dura wall paintings were backed with plaster, wood, and hemp. A comparison of their relative states of preservation found that the paintings left on these field backings, including the Synagogue paintings in the Damascus National Museum, are better preserved than paintings that were transferred to fiberglass backings (Snow 2011).

Art Gallery collections also include wall paintings and drawings from 15th century Europe and China. New installations include late 19th century wall and ceiling paintings in the Department of American Painting and Sculpture. Installation of the first Sol LeWitt Wall Drawing was done as part of the Art Gallery's 2006 renovations of the 1953 Louis Kahn building. That drawing is the focal point of the lobby and receives significant visitor traffic (fig. 1).

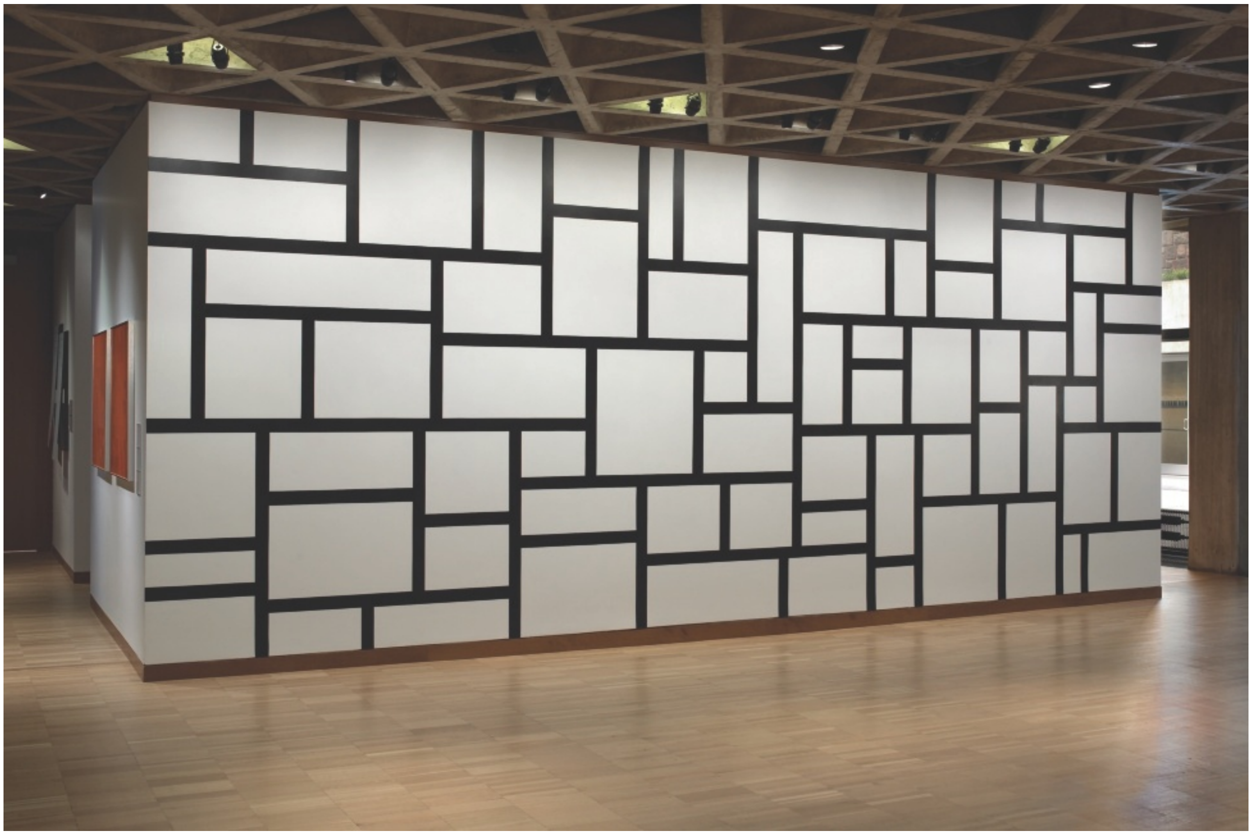


Fig. 1. Sol LeWitt, Wall Drawing #614, 1989, India ink. Yale University Art Gallery
(Courtesy of Yale University Art Gallery)

1.2 TRADITIONAL APPROACHES TO CONSERVATION OF WALL PAINTINGS AND DRAWINGS

As with all other disciplines in conservation, treatments of wall paintings range from minimally interventive to structural transfers. Significant developments arose in wall painting conservation after the 1966 Florence floods when "Mud Angels" worked to save frescoes (Spande 2009). The Opificio delle Pietre Dure (OPD) continues to research and teach new techniques in conservation of mural paintings. The Courtauld Institute of Art, University of London, offers a three-year MA program that covers topics such as documentation, technology, materials, environment, cleaning and consolidation, passive and remedial intervention, fieldwork, and research.

With the arrival in 2008 of a new team of conservators at the Yale University Art Gallery, and during the extensive conservation campaigns done for reinstallations in the renovated gallery spaces for a 2012 reopening, treatment of wall paintings and drawings were divided among object and painting conservators. Ancient wall paintings and drawings were assigned to object conservators, whereas ceiling paintings and wall lunettes on canvas were assigned to painting conservators. Various structural systems were used, including new linings and honeycomb aluminum panels.

The 2006 Sol LeWitt Wall Drawing remained something of an anomaly. When it was damaged by floor polishers or nicked by caterers, who would do the repairs? When it was inadvertently spattered with wine or leaned on by visitors, who would do the surface cleaning? A painting conservator? An object conservator?

1.3 NEW DIRECTIONS AT YALE

In 2012, conservation science was brought to Yale through the establishment of the Technical Studies Laboratory, followed soon after by the move of the Art Conservation Research Laboratory from Carnegie Mellon University to Yale, where it is now known as the Aging Diagnostics Laboratory. Both of these labs have become a part of the Institute for the Preservation of Cultural Heritage (IPCH). A new, shared Conservation Laboratory and Digitization Laboratory are also part of IPCH.

In 2013, Art Gallery director Jock Reynolds enthusiastically reported to the Conservation Department that he was creating a position for a conservator of Sol LeWitt's Wall Drawings. Painting and object conservators responded by asking: a Sol LeWitt conservator—does this make any sense? What would this person do? Where would she or he work? Generous funding was received to endow the position of the Mary Jo and Ted Shen Installations Director and Archivist for Sol LeWitt Wall Drawings. This position has expanded traditional concepts of conservation and how we collaborate across disciplines to rethink the confines of movable and immovable works of art.

2. SOL LEWITT WALL DRAWINGS

Sol LeWitt is considered a seminal figure in the movement that became known as Conceptual Art. In 1969, he was asked to participate in a benefit exhibition at the Paula Cooper Gallery for "Students against the war in Viet Nam." His contribution was a work drawn directly on the wall in graphite based on serial combinations of lines in four directions: 1 Vertical, 2 Horizontal, 3 Diagonal Right, and 4 Diagonal Left.

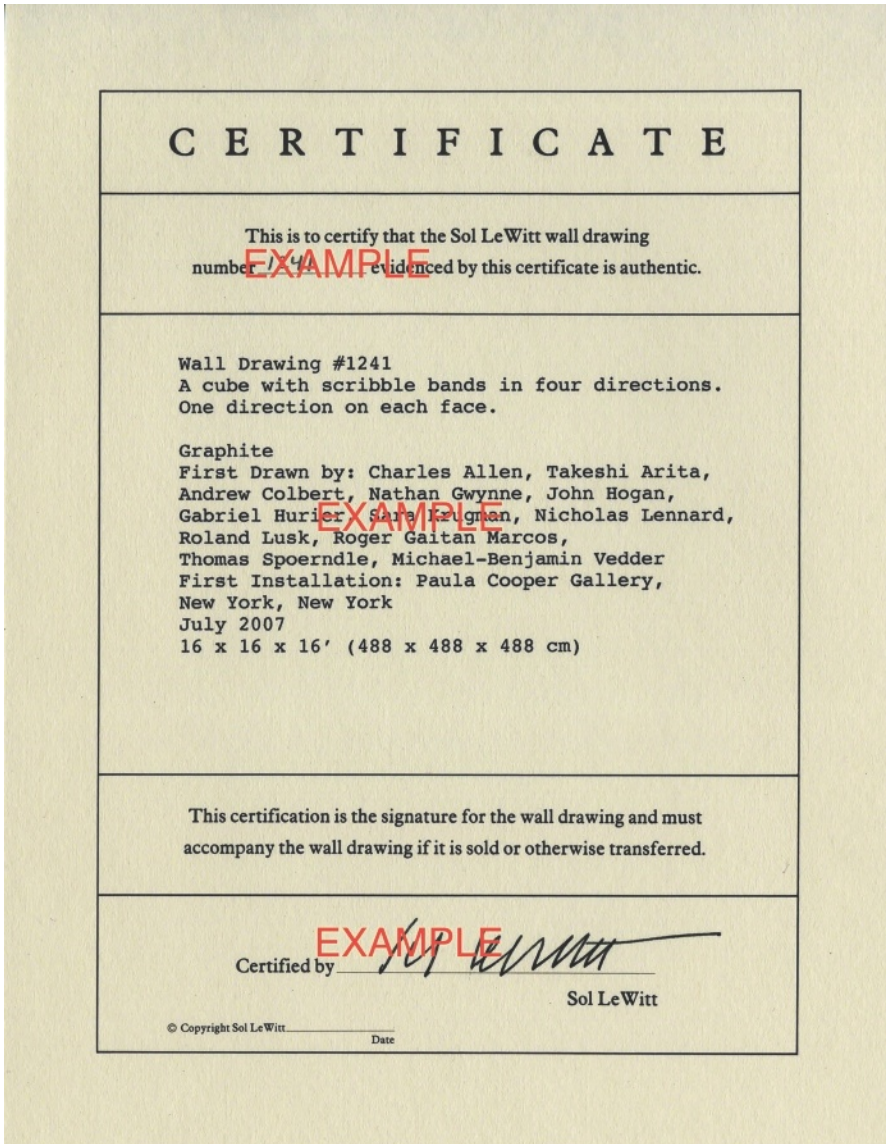
Upon completion of the exhibition, when asked by Paula Cooper what to do with the drawing, he said, "paint it out." This began his 38-year-long exploration that created more than 1,300 wall-based works exploring language and systems-based decisions made in advance and executed according to the parameters for each work; he named the works "Wall Drawings." This avoided the historical reference of murals and recognized the source point of works that were in conception drawn.

LeWitt made a decision shortly later in 1969 with Wall Drawing #3 to no longer execute the drawings himself. His position was a logical conclusion and proof of the concept as art to have others entirely install the work, thereby eliminating the norm of the artist's hand as essential and precious as a moment in time.

He further supported this approach with the implementation of certificates for each Wall Drawing, as each was created with an accompanying diagram. They are language- or reductively based images of the essence of the work's content. The certificate and diagrams became the economic vehicle and documentation of each Wall Drawing, listing the individual draftspersons who executed the work the first time (fig. 2).

LeWitt's position was that there was an essential symbiosis between the idea and the execution of the work. The concept idea stood alone, but to complete its essence it required realization. However, the realization need not be permanent; the idea had pre-eminence as a repeatable concept not fixed in time or place. Often this structure has been compared to musical compositions—that is, the work is conceived by the artist/composer and then performed by others but is in essence and reality the work of the artist who creates the original concept of the work. When the composition is not followed in execution, it becomes improvisation and the work of that individual, denying the formative concept of the work and the artist's intention.

The certificate and diagrams are the "object" aspect of the work and may in fact require traditional paper conservation. These documents are not replaceable; if lost or destroyed, the work is lost. The documents added the further structure of proper authorship/ownership and were a solution to the question of un-authorized copying based on access to the instructions for any given work.



CERTIFICATE

This is to certify that the Sol LeWitt wall drawing
number 1241 evidenced by this certificate is authentic.

EXAMPLE

Wall Drawing #1241
A cube with scribble bands in four directions.
One direction on each face.

Graphite
First Drawn by: Charles Allen, Takeshi Arita,
Andrew Colbert, Nathan Gwynne, John Hogan,
Gabriel Hurier, Sara Krugman, Nicholas Lennard,
Roland Lusk, Roger Gaitan Marcos,
Thomas Spoerndle, Michael-Benjamin Vedder
First Installation: Paula Cooper Gallery,
New York, New York
July 2007
16 x 16 x 16' (488 x 488 x 488 cm)

EXAMPLE

This certification is the signature for the wall drawing and must
accompany the wall drawing if it is sold or otherwise transferred.

Certified by

EXAMPLE

Sol LeWitt

© Copyright Sol LeWitt
Date

Fig. 2. Certificate example (Courtesy of Yale University Art Gallery)

LeWitt was emphatic that the documents were not replaceable, and the Sol LeWitt Estate continues to support this position.

LeWitt wrote at length on his working position with his "Paragraphs and Sentences on Conceptual Art," which is often quoted as a foundation in the Conceptual Art Movement (Zevi 1995). He also wrote his thoughts about aspects inherent to the qualities and execution of the early Wall Drawings that involved basic skill groups and understanding of the processes. Over the next 38 years his explorations of the ideas came to the use of other materials and processes. Individuals with basic skills and the ability to follow the written instructions frequently could install early works. Over time the nature of the work became more demanding in skill groups, and knowledge of processes required a practiced studio draftsperson's involvement with local assistants for the installations to be within LeWitt's expectations and concept for the work (LeWitt 2006).

The evolution of the ideas and materials utilized by LeWitt continued to quantify in a manner consistent with the underlying concept, structuring execution methods to remain consistent in realization.

He asserted the theory of a human but democratic hand in the installation of the work. LeWitt created structured approaches with all systems involved in the installation process. The ink Wall Drawings are based on predetermined color combinations using individual applications of ink process colors. These combinations produce an infinite range of color but remain individual applications of red, yellow, blue, and gray ink upon one another.

All of the materials utilized in his entire body of Wall Drawings have set formulation of materials and specific application and process standards. This systematic approach provides for consistent realization, be it here or in another location across the globe.

2.1 WORKS IN YALE COLLECTIONS

There are 15 LeWitt Wall Drawings on exhibit at the Yale University Art Gallery and promised as future donations from the LeWitt Estate. Of these works, six are placed in semi-permanently installed locations outside the Art Gallery, such as at the Smilow Cancer Center at Yale–New Haven Hospital and at the Yale Campus in Singapore, presenting a somewhat different demand of condition, of proper reporting and conservation. These works, as with many of LeWitt's Wall Drawings placed in public places, demand a different approach requiring active participation of on-site facilities staff or scheduled condition reports.

When the Wall Drawings are damaged, there is a decision process that determines if minor treatments are practical or if simply reinstalling the work is called for. When the works are outside Art Gallery collections, responsible conservators should contact the Archive/Estate and determine through dialogue if minor treatments utilizing the correct formulas, color combinations, and process information from the reference working diagrams are possible or if a complete reinstallation is appropriate, given the time required and desired result. Frequently, because local artists have assisted in the installation, they are of value both for their knowledge and ability to perform minor treatments cost-effectively. In all cases it is the responsible and practical approach that the Archive be contacted to make the determination of what is the most efficient solution. That said, many of the mediums are not practical to treat, and it is simply best to reinstall the damaged area if possible or the entire Wall Drawing if called for to maintain the integrity of the work. There are no costs involved for this assistance; if reinstallation is called for, only the direct costs of the studio draftsperson's labor and materials are incurred. Neither the LeWitt Estate nor Yale University Art Gallery have any financial involvement and only seek to maintain LeWitt's standards of realization and condition.

On a few occasions conservators who were not familiar with LeWitt's conceptual approach and the nature of process have not contacted the Archive/Estate and instead attempted to treat Wall Drawings utilizing a traditional approach, creating a less than desired result. This type of approach is not only costly but also contrary to the nature of the work.

2.2 MASS MOCA

Sol LeWitt, in conversation with Jock Reynolds, determined that a reference exhibition would be of value for the Wall Drawings to continue to be properly installed after LeWitt's death. LeWitt made a promised gift of a large number of Wall Drawings to the Art Gallery with the understanding that a long-term museum exhibition would be created, presenting the work in a historical time line. The Art Gallery, in cooperation with the Massachusetts Museum of Contemporary Art (MASS MoCA), raised funds to renovate one of the buildings at MASS MoCA and create the "Sol LeWitt Retrospective," a 25-year-long exhibition. LeWitt determined the works and placement for the exhibition. The exhibition opened in 2008, a year after LeWitt's death. It continues to provide an immersive opportunity for the general public, as well as scholars who are focused on LeWitt's contribution to art history as a seminal figure in the Conceptual Art Movement (fig. 3).

Fig. 3. Sol LeWitt, Wall Drawing # 413, 1984, Color ink washes. Sol LeWitt Estate. MASS MoCA. (Courtesy of Yale University Art Gallery)

2.3 WALL DRAWING CONSERVATION

As described earlier, it was Sol LeWitt's intent that his Wall Drawings not be conserved in any traditional manner, such as transferring them to other supports or locations, but rather that they be intentionally destroyed, as seen in figures 4 through 7. They are by LeWitt's intention repeatable, and works that are "permanently" installed may be loaned and installed simultaneously for exhibitions with fixed duration with the understanding that they be destroyed at the end of the exhibition.

3. SOL LEWITT ARCHIVE AT YALE

The Archive provides controlled access to scholars. It will function as a resource center to the individuals involved in the execution of the Wall Drawings. It is located in the Yale West Campus Collection Studies Center, which incorporates a new conservation laboratory and provides access to a multifaceted spectrum of conservation disciplines. The addition of the LeWitt materials provides another dimension to the growing concern of addressing new issues and theoretical approaches to the field. LeWitt is but one example of an artist whose practice is in many aspects outside the norm of conservation. Creating the archive of his work at Yale is an initial step in what is rapidly becoming a widening field of concerns as more contemporary art utilizes ephemeral practices and media in addition to theoretical ones in the creation of art.

The responsibilities of the Archive in this environment will include:

- Creation of a comprehensive set of archival reference samples of all materials, wall preparations, formulas, and process standards.
- Creation of an analog and digital record of all hand skills involved in the execution of the work.
- The provision of scaling parameters or scaled working plans for Wall Drawings where scale is not predetermined in the original conception for the Wall Drawing.




Figs. 4–7. Sol LeWitt, Wall Drawing # 1241, 2007, Graphite pencil on plasterboard, 16 x 16 ft. Sol LeWitt Estate. (Courtesy of Paula Cooper Gallery and Yale University Art Gallery)

- The provision of logistical support for installations requiring the supervision of draftspersons trained in the processes and standards involved in the execution of the works. Prior to his death, LeWitt reviewed the Wall Drawings and indicated which required the supervision and involvement of trained draftspersons and which did not.
- Maintenance of material standards and formulas when current products are discontinued to conform to the original application process for each medium. To date this has been addressed for two of the materials utilized: (1) the original inks for the ink drawings were discontinued, new formulas were developed that would conform to the installation process and match the color and surface qualities of the original work as conceived, and (2) the 2-mm color leads used for the color pencil drawings were discontinued and are now manufactured for the Estate to facilitate the installation of those drawings.
- Training of draftspersons in the proper use of materials and the standards for installation and conceptual aspects of the work as LeWitt intended.
- The provision of access and information for researchers to historical and related process materials.

4. FUTURE DIRECTIONS

Conservation of Sol LeWitt's Wall Drawings is an evolutionary process based on how the information can go forward in time, maintaining a knowledge base that provides the information required to properly execute the Wall Drawings. It is essential that new individuals be trained in the skills involved and in an understanding of the conceptual root of each work. Research is already well under way for a historically accurate catalogue raisonné, which is scheduled for digital publication in 2016 by Artifex Press and later as a multivolume book by Yale University Press. This will become a reference document of the realization of each drawing. It will contain photographs of the work installed in its original location, names of the original draftsperson's materials, dates of conception and realization, and any related notes of importance. The digital format will continue to record new installations and their related documentation, as well as related historical documents, catalogs, films, and critical material. A materials and methods section will be added to the digital record at the Archive for each Wall Drawing, indicating installation specifics required, skill groups involved, materials, scaling parameters, and type of wall preparation information required to execute the work properly. With the development of future technology, new systems will update all digital files to conform to new standards. This will be maintained as part of the LeWitt Wall Drawing Archive at Yale.

Collaborative research will continue with conservators and conservation scientists to find practical solutions for materials that are no longer manufactured or that are determined to be unhealthy and/or unstable. Although it may seem ironic that ephemeral works of art require materials that can last, a goal in the execution of the artwork is that it be done to the highest standards with safe and stable materials.

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JOHN HOGAN received his MFA from the School of the Art Institute of Chicago. He has been a principal draftsperson for the Sol LeWitt Studio since 1982 and Installations Director for the LeWitt Estate since shortly after LeWitt's death in 2007, overseeing numerous LeWitt installations, such as the U.S. Mission to the UN, Center Pompidou Metz, Museum M, and the creation of the MASS MoCA retrospective, as well as works in private collections. In 2013, he became the Mary Jo and Ted Shen Installations Director and Archivist for Sol LeWitt Wall Drawings at the Yale University Art Gallery, a unique position of collaboration among conservators, curators, and artists. This position helps realize LeWitt's vision to maintain the interiority of the work into the future and provides a resource for the related materials and methods utilized in the installation of the Wall Drawings. Address: Yale University Art Gallery, PO Box 208271, New Haven, CT 06520. E-mail: John.Hogan@yale.edu

CAROL SNOW, Deputy Chief Conservator and the Alan J. Dworsky Senior Conservator of Objects, is a graduate of Skidmore College and the Winterthur/University of Delaware Program in Art Conservation. She worked at the Walters Art Museum, on archaeological projects around the Mediterranean, including a Fulbright Scholarship to work in Turkey, and then as a private conservator primarily in the Boston area for nearly 20 years. Carol joined the staff of the Yale University Art Gallery Conservation Department in 2008 and is responsible for the conservation and preservation of an encyclopedic collection spanning from ancient to contemporary three-dimensional works of art in a wide range of media, including stone, metals, ceramics, glass, wood, ivory, textiles, plastics, kinetic art, and digital media. Address: Yale University Art Gallery, PO Box 208271, New Haven, CT 06520. E-mail: Carol.Snow@yale.edu

THE BUTTERFLY EFFECT: A CASE STUDY ON THE VALUE OF ARTIST COLLABORATION IN THE CONSERVATION OF EPHEMERAL MATERIAL

CRISTA PACK, MINA THOMPSON, AND TASHA OSTRANDER

A recent acquisition by the New Mexico Museum of Art provided conservators at the Museums of New Mexico with the unique opportunity to collaborate with artist Tasha Ostrander in the preservation of her artwork *Seventy-three in a Moment*. Consisting of 26,645 Xeroxed paper butterflies glued to Masonite, the 10-ft. diameter artwork presented conservators with the challenge of preserving the concept of the piece while faced with the transient nature of ephemeral materials.

The conservation of this artwork is discussed as a case study of the challenges presented by such a treatment. Meeting these challenges often requires a slight shift in conventional conservation practice. Collaborations with other conservators, scientists, and specialists in allied fields are becoming more frequent and can allow for new insights into traditional approaches and techniques. However, one of the most significant changes in conservation practices in the past few decades has been the integration of the artist's voice and opinion into preservation strategy.

Interviewing the artist provides valuable insight into the artist's materials, techniques, and goals for the piece. From the standpoint of the conservator, this aligns with our ethical mandate that all actions must be governed by an informed respect for the cultural property, its unique character and significance, and the people or person who created it. Full collaboration often takes this a step further and invites the artist to participate in the conservation process. This collaboration sometimes leads to treatments that may feel more (or less) interventive than with which a conservator is comfortable and requires a thorough consideration by the conservator as to the merits and disadvantages of the desired outcomes. It also requires an open dialogue between conservator and artist to ensure that concerns and goals are sufficiently addressed.

For this case study, conservators Mina Thompson and Crista Pack discuss these issues in relation to their experiences with the treatment of *Seventy-three in a Moment* and the artist collaboration it required. Additionally, artist Tasha Ostrander provides a meaningful look at the conservation process from the artist's perspective. The goal of this article is to emphasize the value of artist collaboration through a look at a specific treatment project involving ephemeral materials.

KEYWORDS: Paper, Butterfly, Masonite, Artist interview, Collaboration, Contemporary art, Ephemeral, Tasha Ostrander

1. INTRODUCTION

> "But on paper, things can live forever.
> On paper, a butterfly
> never dies."
>
> – Jacqueline Woodson, *Brown Girl Dreaming*

The idea that a paper butterfly could live forever is alluring, especially when one considers the relatively short life span of an actual butterfly. Achievement of material immortality is a concept that may also resonate with those charged with the preservation of cultural property. However, as conservators know all too well, paper is not the most eternal of materials.

The case study presented here will look at the conservation challenges of an installation piece composed primarily of paper that was encountered by conservators working for the Museums of New Mexico (MNM). Specifically, we will focus on the collaboration with Santa Fe artist Tasha Ostrander for the treatment of her artwork *Seventy-three in a Moment*, which is composed of 26,645 photocopied paper butterflies arranged in concentric circles on a 10-ft. diameter Masonite substrate. The conservation of this piece presented the unique challenge of preserving the concept of the artwork while faced with the ephemeral nature of the materials. This challenge was successfully met as a result of the direct input and collaborative work with the artist herself.

Involving the artist in the conservation process for contemporary artwork is becoming more common. Over the past few decades, there has been a noticeable increase in the integration of the artist's voice and opinion into the preservation strategies for contemporary works. Often, this is accomplished through an interview with the artist and provides valuable insight into the artist's materials, techniques, and goals for the piece. From the standpoint of the conservator, this aligns with the ethical mandate that all actions must be governed by an informed respect for the cultural property, its unique character and significance, and the people or person who created it (American Institute for the Conservation of Historic and Artistic Works 1994).

For the conservation of *Seventy-three in a Moment*, the artist not only was consulted but also was invited to participate in the conservation process. This collaboration required thoughtful review of the desired outcomes and effective communication to ensure that concerns and goals were sufficiently understood by both parties. This article will discuss these issues in relation to the conservators' experiences with the treatment of *Seventy-three in a Moment* and the artist collaboration that entailed in spring 2013. Additionally, Tasha Ostrander will provide a meaningful look at the conservation process from the artist's perspective. The goal is to emphasize the value of artist collaboration through a look at a specific treatment project involving ephemeral materials.

2. *SEVENTY-THREE IN A MOMENT*

Santa Fe–based artist Tasha Ostrander spent eight hours a day, seven days a week, for an entire year creating the 10-ft. artwork *Seventy-three in a Moment* in 1996. The 26,645 paper butterflies represent the number of days in seventy-three years, which was considered the average life span for an American at that time. Comparatively, most species of butterfly have a very short life span of mere days to a few months. The image of the butterfly was chosen specifically by the artist to reinforce the idea of the transience of life, as well as the concept of metamorphosis. As noted by New Mexico Museum of Art curator Laura Addison:

> The labor-intensiveness of the project was an important aspect of creating the meaning of the work. Because the work takes the form of a mandala, it reinforces its own symbolism as a meditative work or spiritual endeavor. To have the 26,645 butterflies seen in one glance is to demonstrate the intensity of a lifetime in a single moment. (Addison 2013, 78)

When *Seventy-three in a Moment* was first exhibited in a Santa Fe gallery in 1996 (fig. 1), it was immediately purchased by a private collector. The collector subsequently placed the artwork outdoors, under a portico, for several years. In this environment, it was exposed to the wind and sandstorms that are regular occurrences in New Mexico. Animals, pests, and humans interacted frequently with it, as evidenced by the spider webs, shed lizard skins, animal fur, and gum wrappers, and even a burnt matchstick that would be later found stuck within the piece. Birds also took advantage of its placement and picked off paper wings to weave into their nests.

When the piece was donated to the New Mexico Museum of Art in 2012 and brought to the conservation lab, it was clear that deterioration of the paper and adhesive had progressed rapidly as a direct result of its previous environment. There were numerous tears and losses throughout the brittle, distorted, and faded paper. Adhesives and coatings were discolored and becoming unstable, and, in many areas, actively flaking (figs. 2, 3).

Before addressing these issues, it was pertinent to understand exactly how the piece had been created. Many of the questions regarding materials and techniques could have been deciphered through careful observation, material analysis, and research. However, the option to obtain such information from the artist firsthand was understandably preferable to secondhand hypothesis. This would also give conservators the opportunity to ask questions regarding the conceptual aspects of the work and artist's intent.

Fig. 1. The artwork shown just after its creation in 1996. Tasha Ostrander, *Seventy-three in a Moment*, 1996, Masonite, coffee and tea-stained Xerox paper, and gum arabic, 3 × 0.07 m. New Mexico Museum of Art, 2012.19. (Courtesy of Tasha Ostrander)

Fig. 2. Two of three parts to Ostrander's *Seventy-three in a Moment* in 2013, before treatment and just after its acquisition by the MNM system. New Mexico Museum of Art, 2012.19. (Courtesy of the MNM Conservation Unit)

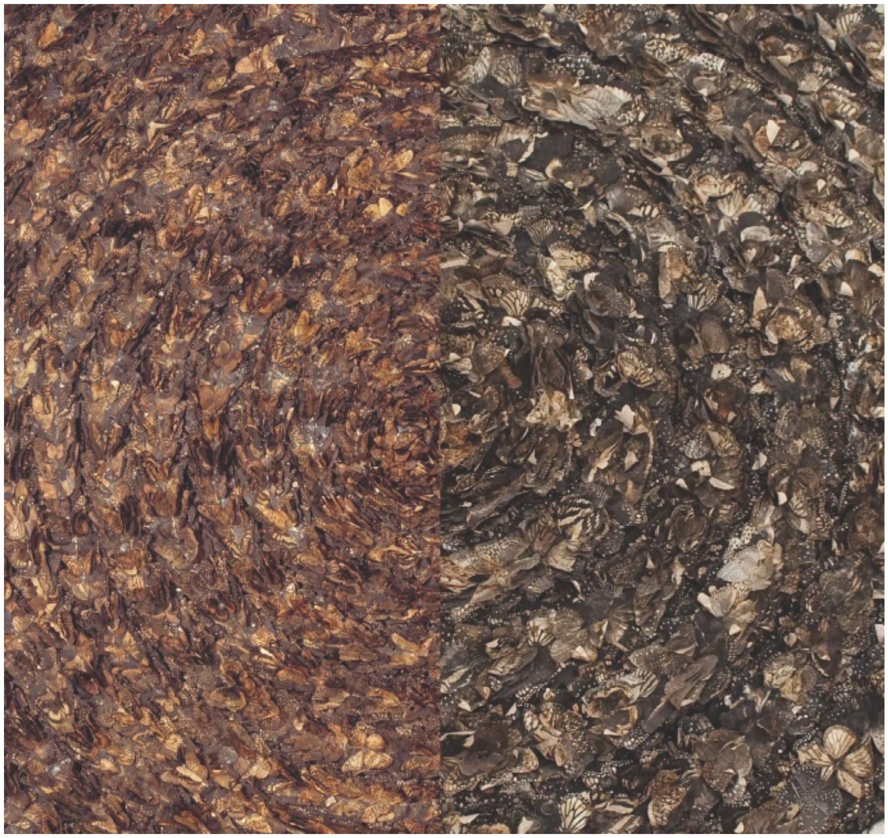

Fig. 3. Detail of the artwork at two different points in time: the left side shows the center of the piece in 1996; the right side shows the same area in 2013. (Courtesy of the MNM Conservation Unit)

3. PRE-TREATMENT INTERVIEW

Tasha Ostrander agreed to an initial meeting in the conservation laboratory with MNM conservators Mina Thompson and Crista Pack in January 2013. Thompson had often consulted with artists and source communities as part of her role as Associate Conservator in the museum system. Pack, a third-year intern from the Winterthur/University of Delaware Program in Art Conservation, also drew upon previous experiences with source communities and conservation work performed in consultation with contemporary artists. The curator and conservators determined questions ahead of time, but equally important in any consultation is explaining conservation to the artist. With the artwork spread over two tables, the conservators and artist discussed the artwork, tenets of conservation, and her expectations for her piece over time. Ostrander provided a detailed account of the creation of *Seventy-three in a Moment*, including challenges she encountered during the process. Additionally valuable was hearing Ostrander reflect on her thought processes when she assembled the piece. She had not expected her piece to be displayed outdoors, but she stayed in communication with the owner, occasionally supplying new butterflies to replace missing ones. One question always asked of an artist is, "when does the artwork lose its essence? At what point should (if at all) the artwork be retired?" Ostrander knew that her artwork was ephemeral but thought it still had many years left, with care.

3.1 MATERIALS

Ostrander recalled that to create the butterflies, she photocopied 20 to 30 different species from a field guide—the 1992 *Eyewitness Handbook of Butterflies and Moths* by David J. Carter. Each butterfly was then hand cut and stained with tea and coffee. Ostrander would dip them multiple times to get the desired effect, drying them on blotter paper after each round. She noted that the butterflies would often curl a bit as they dried.

The back of every paper butterfly she created in 1996 was numbered in pencil with a year (1–73) and day (1–365) to ensure that there would be an accounting of every single day in the life span (fig. 4). When the artwork was examined upon arrival in the conservation lab, it was noted that some of the paper butterflies were not numbered on the back. The artist explained during the interview that the numberless butterflies were replacement pieces. These had been applied by Ostrander during previous, ad hoc restoration campaigns requested by the owner when the piece had begun to exhibit numerous losses due to its outdoor placement. These replacement butterflies were identical to the original but without numbers on the back. Later, the owner had an assistant make additional replacement butterflies. These replacements were easily identifiable, as they were simply black and white (no tea/coffee stains) and were sometimes glued in the opposite direction of all other butterflies.

Fig. 4. Detail of the back of two butterflies: the lower clump of butterfly shows the artist's original numbering system, with "27" representing the year and "17" representing the 17th day of the year; the butterfly at the top shows a new butterfly marked with 2013, the year it was made. (Courtesy of the MNM Conservation Unit)

The last material component that was discussed with the artist was the yellowed, flaking substance that appeared to be splattered across the top surface of the butterflies. Ostrander stated that it was gum arabic, applied to add some sheen and sparkle to the piece. During the discussion, she expressed that she would like to see the discolored, flaking material removed and more gum arabic added to replace the lost sheen.

3.2 ASSEMBLAGE

The 10-ft. diameter circular Masonite support separates into three panels, consisting of a central circle and two outer arcs. Ostrander began her process in the center of circle and worked her way out. She said the hardest part was aligning the butterflies so that they matched, exactly, on the two outer arc pieces once the whole ensemble was put together.

To assemble the piece, Ostrander stacked and interleaved the butterflies, generally placing smaller, more heavily stained butterflies in the top layers and larger butterflies toward the bottom. Ostrander noted that in its current condition, there were several areas where the smaller, heavily stained butterflies were missing, making the larger, lighter-colored butterflies more visible. Ostrander recalled that the stacking and grouping was not planned out but rather was based on the look and feel of the piece. She would group a few in her hand, interleaving the wings, and glue the stack onto the Masonite board using a lot of Yes! Paste, a commercial starch paste made from corn dextrin and preservatives (Yes! Paste 2015).

Once all of the butterflies were placed, Ostrander dipped a bamboo sketching pen into liquid gum arabic and flicked droplets of the gum all over the piece. The gum arabic dried into shiny spots, proud of the paper, that reflected light in a way pleasing to the artist, contrasting nicely with the duller appearance of the paper butterflies.

3.3 ARTIST'S INTENT

The last question for Ostrander during this interview was aimed to better understand her intent for the piece. The conservation team was curious to learn how she viewed the natural aging process of the piece and in what ways that might inform the work and any treatment in the future. Initially, the life span of the piece—or the potential point where she may no longer consider it exhibitable—was not something the artist had previously considered, and she did not have an immediate answer for that question. In later discussions, she indicated that she knew there would be a point when the piece would reach the end of its life and would no longer be exhibitable. The fragile nature of the materials was meant to underscore the ephemeral and transient nature of life. However, the accelerated aging due to its initial outdoor location was not acceptable and had compromised the integrity of the piece.

4. THE CONSERVATION PERSPECTIVE

The pre-treatment interview also provided conservators an opportunity to discuss the proposed treatment for the artwork with the artist. Proposed conservation materials and methodologies needed to preserve the artist's concept of the piece in addition to its physical structure. These discussions served as a springboard for additional conservation measures, as well as a discussion on the merits of restoration for the numerous losses throughout the piece.

For the conservators, a restoration project that brought the piece back to a state similar to its original appearance was more interventive than had originally been envisioned. The initial treatment discussion among conservators focused on cleaning, humidification of distorted paper, stabilization of loose elements, and infilling losses of the Xerox toner. Stabilization options for the degrading gum arabic were also discussed. The artist, however, expressed a desire to see it reapplied rather than simply stabilized, as she did not feel that it served its intended function any longer.

From there the discussion led to filling in paper losses with butterflies that had previously become detached. However, it was clear that the small amount of detached butterflies that had been saved would not be enough to fill in all the losses. Ostrander then offered to create more butterflies as she had for the previous restoration campaign with the previous owner. This would provide a more uniform look, which was something the artist felt was integral to the concept of the piece. Although it had not been a treatment option initially considered, once it was proposed, both conservators agreed that adding butterflies made by the artist would be the best option. Furthermore, the conservators felt that not only should Ostrander create replacement butterflies, but she should be the one to reapply them, as there was no specific pattern for their placement and it was solely based on a certain aesthetic the artist wished to portray. The conservators also requested that all new additions be marked on their back with the year "2013" to make the replacement pieces easily identifiable (figs. 4, 5).

Fig. 5. The artist, on the right, in the downtown conservation lab, numbering new butterflies (Courtesy of the MNM Conservation Unit)

Throughout the treatment process, it was imperative that both parties were communicating to ensure that materials and methods were appropriate. Problems with the gum arabic's longevity and tackiness prompted experimentation with other options, which were then presented to the artist to make sure that the one chosen by the conservation team also matched the desired aesthetic of the artist. The team ultimately found Aquazol 200 to be an appropriate substitute, as it did not remain tacky at room temperature and had an appropriate viscosity, a wide solubility range, and a sheen similar to the gum arabic. It also has good aging properties and, in a controlled museum environment, should remain stable for the remaining life of the artwork. Ostrander applied the new butterflies in small batches, using a mixture of wheat starch paste and Lascaux 498 HV in lieu of Yes! Paste, and she consistently updated the conservation team on her progress. Wheat starch paste was chosen for its consistency with the artist's materials, as Yes! Paste is starch-based, and for its better aging properties. Lascaux was added for both strength and flexibility, as the paste alone proved too brittle for an adhesive on a substrate as flexible as Masonite. Ostrander kept count of how many she added and strove to add only what was needed to prevent altering the original aesthetic (fig. 6).

Fig. 6. *Seventy-three in a Moment*, after treatment and on display in the New Mexico Museum of Art (Courtesy of the MNM Conservation Unit)

What became almost immediately apparent was the value of having not only the artist's voice as an integral component of the treatment decision process but also having the artist available to perform the more subjective components of the treatment. This shift from artist as consultant to artist as collaborator reflects a change in strategy for the conservation of the artwork and was critical to the success of the treatment, enhancing the team's sensitivity to the concept of the artwork and the artist's intent for how the piece is to be perceived.

It also is the result of the trust and respect that both parties have for each other, as well as the willingness to understand each other's desired outcomes and find ways to align them. It was not always easy. The conservators had to constantly evaluate the work and determine if we were overstepping any ethical boundaries of conservation. Often, the conservators were also working on other projects and had to step away from *Seventy-three in a Moment* for short time periods. This would slow down the artist's work, as she had to wait for us to finish cleaning a section or wait for a time we could be in the lab to allow her in to work. Luckily, a woman who is willing to dedicate eight hours a day every day for a year to creating an artwork is a patient person and was understanding when our schedules were complicated.

5. THE ARTIST PERSPECTIVE

Thompson interviewed Ostrander about her experiences working with conservators to treat her own piece to gain her perspective on the project. Questions posed to the artist were the following:

How did you feel about the piece when you saw it in the [conservation] lab?

What did you think of the conservation process?

Fig. 7. Still image from a video of the artist, Tasha Ostrander, sharing her perspective on the conservation of *Seventy-three in a Moment*, excerpted from an interview by Mina Thompson (Courtesy of Mina Thompson). Video available here: https://youtu.be/dnGpeNpaHRk

What did you think of using different materials than the original?
Did you feel like we were improving the piece or changing it?
Does the improvement relate to the piece as symbolizing a life?
What do you think about the fact that there probably aren't 26,645 butterflies anymore?
Is there anything that surprised you about conservators or the conservation process?

6. CONCLUSION

The desired outcome for both parties was first and foremost to preserve the concept of *Seventy-three in a Moment*. Second to that was preserving the materials that remained intact and stable. Ultimately, the artist identified the deterioration and resulting treatment of the artwork as analogous to the life cycle concept on which the piece is based.

Full collaboration with the artist is not a decision that can be entered into without some forethought by all stakeholders. The artist, curators, and conservators must be able to communicate effectively and be receptive and respectful to the needs and desires of the other. In this case, the artist was able to communicate her desires for how the piece should look. Equally important was that the conservators understood those desires, took them into consideration along with the history of the piece, and then communicated to all parties the ethical and material concerns regarding any changes to the piece and what might happen as it continues to age.

Direct collaboration with an artist was a definite benefit and one that does not present itself frequently for conservators who do not work in a museum or lab dedicated solely to contemporary art. Most importantly, it informed the treatment decisions and activities in a way that preserved the unique character and significance of the piece better than if the artist had not been involved. It also provided a unique opportunity to work with materials that are not as commonplace in an objects lab and required the experimentation and development of new techniques for its treatment. Most of all, it forced a paradigm shift in the thought process for the treatment from conservation of original material to restoration of artist's intent.

The project also provided numerous opportunities for outreach through local interviews and articles to publicize the work that we were doing. The uniqueness and large scope of the project garnered a lot of attention locally and provided the opportunity to share the work that we do as conservators with the public.

The most unforeseen benefit to the project was the resulting professional relationships and friendships that developed from working in such close proximity with the artist. We were able to learn more about each other's professions and lives on a much greater scale than would have resulted from a single interview. We believe that these relationships were not only beneficial to the time period surrounding the conservation treatment but for the long term as well. Each of us has been inspired and transformed by the project, and it is our hope that the outcomes will last longer than the life of a paper butterfly.

ACKNOWLEDGMENTS

The authors would like to thank New Mexico Museum of Art Curator Laura Addison, without whom this collaboration would not have been possible. Thanks as well to the Conservation Department staff for supporting this long-term project; to Emma Goos for helping to vacuum dust and debris from the 26,000 butterflies. Ms. Pack and Ms. Thompson would especially like to thank Tasha Ostrander for her unwavering support and dedication to this project. Without the artist, the treatment would not have been nearly so successful.

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SOURCE OF MATERIALS

Aquazol 200, Lascaux 498 HV, and Wheat starch paste
Talas
330 Morgan Ave.
Brooklyn, NY 11211
212-219-0770
http://talasonline.com

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NEUTRALIZING THE NUCLEAR OPTION

DONNA WILLIAMS

The late Los Angeles artist Chris Burden (1946–2015) originally assembled his anti-war diorama *A Tale of Two Cities* 35 years ago. By 2013, the installation had become sufficiently dilapidated that he publicly expressed his intent to invoke the "nuclear option," which would involve blowing it up as a final performance piece. "The work would still exist," said the artist during his first visit to the author's studio, "but as rubble" (Burden, pers. comm.). Presentation of a fully treated mock-up panel, as well as initiation of an ongoing dialogue between artist and conservator, concluded that an extensive conservation campaign was a viable alternative. Over the course of several months, the installation was cleaned, repaired, refabricated, and packed in custom-made travel crates. Following conservation, *A Tale of Two Cities* occupied a major place in the artist's one-man survey *Chris Burden: Extreme Measures* at the New Museum in New York in 2013.

KEYWORDS: Chris Burden, Diorama, Seminal, Rubble, Mock-up, Dialogue

1. INTRODUCTION

The treatment of *A Tale of Two Cities*, recounted here, could not have occurred without the opportunity for direct interaction between artist and conservator. Over the course of three studio visits and multiple telephone conversations, the developing dialogue between Chris Burden (1946–2015) and the conservator provided the artist an opportunity to observe the conservation process and the conservator to understand the level of the artist's personal engagement in the work (the artwork contained many of Burden's childhood toys). It was this dialogue that permitted the possibilities of conservation and the sensibilities of the artist's intent to converge in a uniquely personal and productive way.

A Tale of Two Cities, Burden's first significant post-performance work, is a large-scale installation depicting war between cities of differing scale (fig. 1). The artwork is assembled on a panoramic landscape of 17 cubic yards (26 tons) of sculpted white sand, populated by two tons of assorted rock, ocean coral, bougainvillea, and ball cactus, and approximately 60 specified small to medium live houseplants, with appropriate drip irrigation. Over this, approximately 5,000 model buildings and toys in HO, N, and Z model scales, mounted to cardboard panels, are arranged according to the artist's instructions. Assembled in a variety of venues, Burden's diorama has varied in size from 800 to 1,300 square ft., with an average installation time of approximately 600 hours. Whereas the two city components, with their matrix of street grids, required that they be assembled in a specific pattern, other areas of the installation were more fluid, adapting to different exhibition spaces as per the artist's intent.

1.1 A LINE IN THE SAND

Over the course of three decades of exhibition and storage, the artwork's city areas—composed of model buildings, streets, and cars glued to a substrate of abutting cardboard panels—had become damaged and distorted, their paper foundations warped and delaminated, the undersides encrusted with mold.

Based on its condition, the artist made the decision to deny the New Museum/Orange County Museum of Art (OCMA) request to exhibit this seminal artwork in his upcoming one-man survey show at the New Museum in New York. If exhibited at all, Burden declared, he wished to exercise his right, handwritten into this contract by Burden, to alter the work by blowing it up as a final performance piece—a fitting conclusion to this broad depiction of futuristic warring states. Whether the artwork was exhibited or not, the OCMA was committed to restoration of the artwork.

Fig. 1. Detail of the installation in 1988 at the Newport Harbor Art Museum. Chris Burden, *A Tale of Two Cities*, 1981, multimedia, dimensions variable. Orange County Museum of Art, 1987.002 (Courtesy of Chris Burden)

1.2 SOME ASSEMBLY REQUIRED

Preparation of a treatment plan began with examination of installation components at the OCMA. The artwork was displayed on tables and in boxes throughout the museum storage area. The cardboard substrates were warped with evidence of mold, lifting plastic and paper models, partially detached road surfaces, and missing landscape features. All elements exhibited an uneven layer of surface grime and sand.

The installation was delivered to the studio packed in 18 boxes with dimensions of 24 × 48 × 24 in. The loose items were organized by city size and geographic location within the installation. The OCMA registrar and a preparator spent two days assembling the two city components for review by the artist. The preparator was the only individual at the OCMA who had participated in the last installation of the artwork

Fig. 2. Detail of the installation in 1988 at the Newport Harbor Art Museum (Courtesy of Chris Burden)

Fig. 3. Before treatment, a partial view of installation components on display in the storage area at the Orange County Museum of Art (Courtesy of Donna Williams)

Fig. 4. Before treatment, showing some of the installation components on display in the storage area at Orange County Museum of Art. Note bullets mounted to cardboard substrate, coral, and random toys. (Courtesy of Donna Williams)

in 2007—an exhibition purposely not viewed by the artist because of the piece's poor condition. Although Burden did not issue specific instructions for *A Tale of Two Cities*, photographic documentation from previous installations provided a structure to establish the basic relationships of the artwork's many elements. During this assembly process, it became clear that the OCMA preparator—the only one with past experience in installing *A Tale of Two Cities*—possessed the institutional memory to not only assemble and direct the level of infill required but also to engage with the installation components as well.

The scale model architectural components define the city installation elements. Big City and Little City have both airport and harbor components. The rest of the installation has geographic locations and sites including but not limited to "shanty town," a nuclear blast site, and a city dump. These sites are assembled in the surrounding sand and rocks.

The cities are divided by "bullet fencing" (live rounds of .22 caliber and 9-mm ammunition) and toys in respective scale with the architectural components. The toys were partially unpacked and displayed for viewing.

2. THREE STAGES OF DETENTE

2.1 FIRST MEETING WITH THE ARTIST: *"THIS PIECE IS DEAD TO ME."* CONSERVATION STUDIO: JUNE 24, 2013

Attendees at the initial meeting with the artist included the following: the OCMA and New Museum directors, the exhibition curator, the OCMA collection manager and preparator, the artist and

Fig. 5. Installation of Big City in the background and Little City in the foreground with airport and harbor components (Courtesy of Donna Williams)

his two assistants, a Gagosian Gallery representative and preparator, conservators Donna Williams and Chris Stavroudis, Williams Art Conservation Inc. (WAC) assistants who would work on the project, and a student intern/note taker.

Upon entering the studio, Burden remarked, “This piece is dead to me. I have more important things to do.” This comment was greeted with impenetrable silence.

Over several hours of discussion, the artist’s response to the displayed components ranged widely over issues related to broken toys and damaged elements—what could be repaired, what should be replaced—as well as addressing numerous missing components: a small foam space shuttle, toys, corals, and sponges. The decision to remove buildings from their substrates and combine three to four existing panels onto a larger honeycomb aluminum panel substrate was approved. Buildings would be adhered in conjunction with new landscaping substrates and light posts. The artist provided photographic documentation from exhibitions at the Newport Harbor Art Museum in 1981 and his favorite installation in 1988. A mock-up of a portion of Little City was to be prepared for review in one week. In addition, representative repairs to damaged toys would be performed.

In conclusion, Burden remarked: “Part of me thinks we should put this in the warehouse somewhere, and redo the whole thing—with parts from the old” (Burden, pers. comm).

2.2 SECOND MEETING WITH THE ARTIST: *"SEE THIS BURNT MUFFIN? THE FOAM 747?"* CONSERVATION STUDIO: JULY 8, 2013

Although Burden had initially approved the panel mock-up, he continued to voice reservations about the conservation process. He spent several hours examining Big City components and identifying damaged toys, repeatedly voicing his sense of there not being enough, that a critical volume of toys was missing. Contractually, the OCMA had the right to add new elements to the installation; the subtraction of components was never implied or approved.

Eventually, the decision was made to prepare a full mock-up of Little City, combining several cardboard panels onto sheets of honeycomb aluminum not to exceed 40 × 40 in., with buildings conserved and various components added and/or replaced. The new panel dimensions were given an inventory ID and measurements were documented.

With assistance from the OCMA staff, a full count of the installation components was tallied, which included information essential for packing and crating bids. Individual toys were sorted by scale and type; loose components were identified by content, cleaned, and catalogued.

Fig. 6. Four Little City cardboard panels combined onto one honeycomb aluminum panel and approved by the artist (Courtesy Donna Williams)

2.3 FINAL MEETING WITH THE ARTIST. "*IT'S A LOT OF WORK. DECISIONS AND WORK. BUT IT'S DOABLE.*" CONSERVATION STUDIO: JULY 25, 2013

Burden began the third studio meeting as he had the previous two: "The artwork will not be included in the survey exhibition," he announced, to the continued consternation from those in attendance, which included the OCMA director, a Gagosian Gallery representative, and WAC staff.

But the conservator asked for clarification: Why had he cut out this seminal piece from his body of work? Was he too far removed from the artwork in its current condition? Did he understand the extent to which conservation could restore it?

To the conservator's respectful questions, Burden was somewhat taken aback. He paused, considering, then strode over to a full reconstruction of Little City laid out in a sculpted mantle of sand. For a full minute, Burden squatted in silence on the studio floor, examining the mock-up of Little City from every angle, every detail. Eventually he spoke, asking, "How many weeks until it ships?" (Burden, pers. comm).

The OCMA director replied that it would be seven weeks for conservation and one week for crates. Burden followed with inquiring if the OCMA was committed to including the purchase of new toys and the fabrication of appropriate storage and shipping crates, to which WAC replied yes.

Turning the tables, Burden now addressed the conservator directly and memorably. "Is it doable," he ground the question out of himself, "in the amount of time we have?" "Yes," the conservator replied. "But we need to go now."

Affirmative responses in hand, the artist paused again. "There does not seem," he said slowly, "to be a reason not to proceed" (Burden, pers. comm). Burden seemed a little surprised by his choice. It was

Fig. 7. Little City completed for mock-up review (Courtesy of Donna Williams)

clearly an effort for him to revisit such a major decision. It was also clear that close examination of the Little City mock-up not only had demonstrated that the work could be completed to his satisfaction but also that the opportunity for the artist to experience the reworked piece in context had returned to the artwork a spark of life, reanimating the story to the *Tale*.

3. TIME AND SPACE

By the time the decision had been made to proceed with a full treatment of *A Tale of Two Cities*, the timeline for conservation had narrowed from seven to five weeks, plus one week for packing and crating the piece. The OCMA had demonstrated a commitment to restore the artwork regardless, so by the time of Burden's final decision, some essential work and organization had already taken place. Five thousand toys were inventoried for scale, prioritized for significance as Burden saw it, assessed for condition, and packed, by type, into boxes stacked eight ft. high against the walls of the 1,400-ft. studio.

Individual workstations were set up, assigned to a variety of specific tasks: One conservation technician worked exclusively to vacuum and detach buildings and toys from the artwork's damaged paper substrate; another cut, shaped, and prepared the artwork's new interlocking aluminum base panels. At the request of Burden, the preparator from Gagosian, Burden's gallery, repaired specific elements while scouring local stores and the Internet to locate replacement toys, coral, and sponges. The conservator, with help from a member of the OCMA staff, prepared ground cover for Big City panels, populating the freshly fabricated panels with treated buildings, new road surfaces, and a variety of landscaping.

4. BULLETS AND BALL CACTUS

Although the addition of sympathetic elements to *A Tale of Two Cities* was deemed appropriate—with Burden's input and approval—subtraction from the piece was not. The expectation was to replace

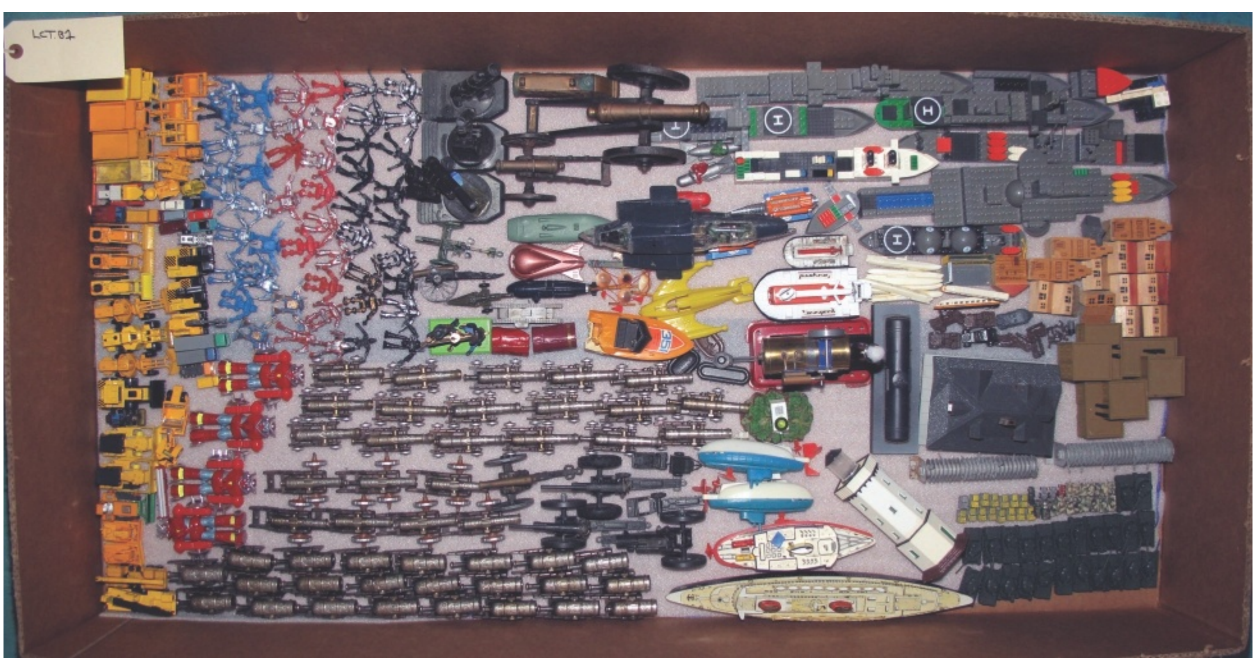

Fig. 8. Toys sorted and organized by size city affiliation (Courtesy of Donna Williams)

Fig. 9. Corals and sponges that could be legally obtained were purchased. The blue coral on left is original and no longer available for purchase. (Courtesy of Donna Williams)

damaged or missing components to match the original as closely as possible. This acquisition stage of the restoration process proved to be a test of patience, resourcefulness, and luck.

The artwork, for example, included four identical models of an "eagle transporter"—taken from the British 1970's sci-fi TV series *Space: 1999*—which were intended to be suspended by wires hanging from the ceiling. However, one transporter was missing. Although a variety of similar models were located, only one perfect match could be found and acquired, on eBay, at considerable expense.

Burden's chosen representative from Gagosian Gallery was tasked with sourcing the many sponges and corals that the artwork required. After much searching, a single dive shop in San Pedro provided all necessary materials. A single section of blue coral, its sale now heavily regulated, was the only piece of original sponge or coral to survive.

Due to both the legal and practical difficulties of shipping live plants across the country, gallery representatives in New York began the task of locating the many flora, much of it common to Southern California, specified for the installation. The artist provided a list of plants, but this eventually required some amendment due to availability problems. Three ball cacti were eventually located. Dried bougainvillea vines with thorns intact would be used to wrap around several lengthy rows of bullets, forming frontline fences in the battle.

Bullets in particular became a singular issue. The OCMA was obligated to exhibit *A Tale of Two Cities* with live ammunition: 9-mm rounds for Big City and .22 caliber for Little City. But Burden was forced to alter his original specifications because the New Museum now operated under a moratorium on live ammunition. This decision was the result of previous problems encountered during a past exhibition that featured a candy bowl filled with live bullets, which visitors were encouraged to handle.

Turning live rounds into blanks proved to be more difficult than expected. The exhibition took place while memories of the Sandy Hook, Connecticut, shooting were still fresh, and ammunition in general was in short supply. Gun shops and bullet makers quoted a price of $3 per blank round, which was an untenable cost given the hundreds of shells required. Eventually the conservator contacted the only gun person in her Rolodex, a veteran and frequent subcontractor to the studio. He placed a call to

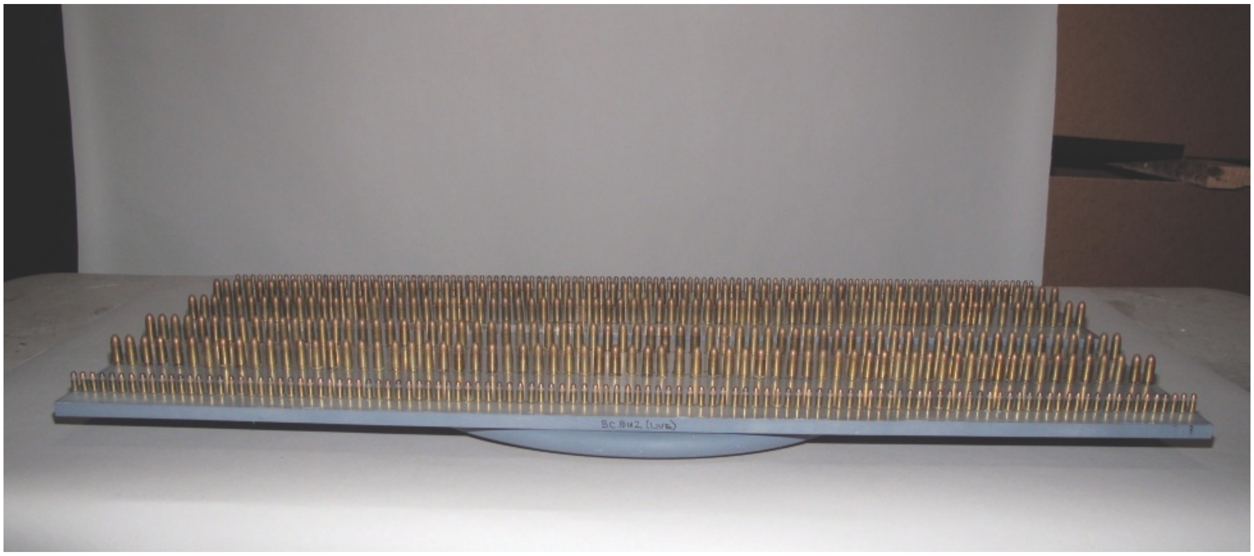

Fig. 10. After treatment, showing bullets adhered to aluminum honeycomb panels (Courtesy of Donna Williams)

his son, a West Point–trained sharpshooter, who agreed to do the work for a nominal fee. Soon a large box of blanks, polished to a bright sheen as Burden required, arrived from Dallas, Texas, to be set down in ruler-straight lines and pasted into the installation.

In the meantime, Burden was busily shopping online and elsewhere for models to repopulate the two expanding cities. Communicating regularly via phone and e-mail, Burden had his assistant bring a series of white canvas pup tents to be arranged on a panel for his approval. Bags of freshly purchased models and toys arrived at the studio to be shipped with the rest of the pieces for installation in New York.

"I might even add a new scale to the piece," Burden suggested, somewhat impishly, in a private conversation with the conservator (Burden, pers. comm.). "We can handle that," the conservator replied. But in the gathering momentum of his show, the artist never mentioned this idea again.

5. TRUST AND INTENT

Although repair of Burden's work was traditionally performed by assistants in his studio, the demands of the New York show had tapped this resource to full capacity. Burden was now involved in other aspects of his show, and after the final mock-up meeting, he was not seen again at the conservation studio but kept in touch by phone calls and email.

Used to evaluating objects in varying conditions of damage and disrepair, the conservator was better able to evaluate what could be done and Burden came to accept this as the relationship developed into a mutual understanding of what mattered and what was possible.

On the one hand, Burden issued little direction about the artwork's architecture or landfill. He wanted the cities to appear fully populated with trees, mailboxes, light posts, people, cars, and so forth, but beyond that he remained hands-off and conservation became an independent operation.

However, Burden was specific and adamant about certain objects. Rows of white apartment buildings, formed of paper ammunition boxes, looked dirty and dilapidated, and they were carefully reconstructed through a combination of repair and replacement with paper of similar weight and gloss.

Fig. 11. After treatment, showing Big City components at 90% completion (Courtesy of Donna Williams)

Whereas the tarmac runways of the Big City airport were replaced with sections of fresh tarpaper, the original reflective material covering the airport's rooftop, which was rumpled and deformed, was retained at Burden's request, requiring careful flattened and re-adhesion to achieve the proper look.

Historically, the many vehicles of *A Tale of Two Cities* had never been permanently attached to the substrate, with Burden preferring instead to include their placement as part of the artwork's fluid installation process. But time constraints prevailed, and the cars were permanently glued into position. Many of the cities' light posts required replacement, prompting questions about lighting, as some of the piece's existing lamps could be electronically lit. Burden first suggested that wires be cut but then, keeping his options open, decided instead to wrap the wires and tuck them inside the honeycomb panels to be hooked up possibly at a later date.

6. PACKING

Packing Burden's installation took place over the course of four days and required 16 crates. Small items were fit in custom-cut foam shelves layered in boxes, whereas larger items and populated panels were placed into labeled, custom-fitted crates. Along with the new crates, the OCMA now possesses a fully documented list of both the components and the process for the installation of *A Tale of Two Cities*.

Fig. 12. Before treatment, the white apartment buildings were cardboard bullet boxes. The box material was changed to plastic, and a plastic replacement apartment building was added at some point. (Courtesy of Donna Williams)

Fig. 13. After treatment, the paper buildings were remade with paper closely matching the original box material. The original dividers were cleaned, straightened, and reused. The artist approved the plastic replacement. (Courtesy of Donna Williams)

Fig. 14. Big City panel before treatment (Courtesy of Donna Williams)

Fig. 15. Big City panel after treatment (Courtesy of Donna Williams)

Fig. 16. Toys packed for shipping. Cardboard shipping crates were packed into larger wood crates. Shipping crates also serve as storage containers. (Courtesy of Donna Williams)

Fig. 17. Panel components located in the shipping crate (Courtesy of Donna Williams)

Fig. 18. View of packing in progress over four days (Courtesy of Donna Williams)

7. POST-TREATMENT ARTIST INTERVIEW

A post-treatment telephone interview was conducted with the artist approximately one year after the exhibition's opening. The artist then revealed his three main reasons for initially rejecting inclusion of *A Tale of Two Cities* in the survey show:

1. Concern that there was not enough time to complete the work, as Burden had believed at that time that 80% of the work could not be salvaged and that it would need a year to complete the conservation treatment.
2. Concern that a larger space would be necessary to lay out the entire installation prior to conservation, when in fact the process of conservation was undertaken section by section.
3. Concern that the available funding would be insufficient for such a massive conservation and packing effort.

What changed his mind?

1. The mock-ups, invaluable in demonstrating that the work could be restored to Burden's satisfaction, were completed in a single week.
2. By working section by section, *A Tale of Two Cities* could be restored without the space requirements of a full installation.

Fig. 19. View of the installation at the New Museum, "Chris Burden: Extreme Measures" in 2013. The white pedestals hold binoculars for viewing. New binoculars were purchased for this installation. (Courtesy of Chris Burden)

3. The OCMA demonstrated their commitment to fully fund the building of storage/transportation crates and to provide funding for the purchase of additional installation elements. As far as conservation was concerned, Burden's issues about the cost were based on his own approach to restoration. A trained conservator was better able to assess and address the piece's condition needs more accurately and with less emotion.

Contractually, the artwork may be installed to fit a variety of exhibition spaces and new toys may be added. According to Burden, this introduces "chance and change." *A Tale of Two Cities* was in his words "alive," unlike another Burden installation, *Pizza City*, in which the artist had been contractually required to secure all components, becoming in his words "petrified."

Although Burden admitted during this telephone conversation that the nuclear option was "somewhat rhetorical," *A Tale of Two Cities* appeared to the artist to be "damaged to the point of having to start over." Had Burden chosen to invoke his contractual option, he said, the artwork would have been installed as a post-apocalyptic pile of rubble. It was never his intention to alter *Tale* as a nuclear performance piece (Burden, pers. comm.).

8. CONCLUSION

If the definition of communication is an experience in which both parties are changed, the interaction between Chris Burden and the conservator was certainly one of those.

On the one hand, it took an act of faith for the artist to revisit a difficult decision and, through the process of conservation, return a seminal piece to his body of work. On the other, Burden's repeated lamentations during studio visits over the loss of individual pieces in the installation revealed to the conservator the interconnection and significance of small, specific elements as they related to the whole.

After two intense months of treatment, the city of Los Angeles began to look like a model, whereas the tiny streets and buildings of Burden's *A Tale of Two Cities* became reanimated as its own gigantic world.

SOURCES OF MATERIALS

Honeycomb Aluminum Panels
Paneltec Corp.
11111 E. 53rd Ave., Ste. A
Denver, CO 80239
800-466-3914
Brian Kerr, 303-664-1420, ext. 1

HXTAL NYL-1 Epoxy
Conservation Support Systems
PO Box 91746
800-482-6299
www.conservationsupportsystems.com

Landscaping/Scenery Materials
Walthers Model Railroading
Wm. K. Walthers Inc.
5601 W. Florist Ave.
Milwaukee, WI 53218-1622
http://walthers.com

Golden Acrylic Paint
Golden Artist Colors Inc.
188 Bell Rd.
New Berlin, NY 13411-9527
800-959-6543
http://www.goldenpaints.com

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DRY ICE BLASTING IN THE CONSERVATION OF METALS: A TECHNICAL ASSESSMENT AS A CONSERVATION TECHNIQUE AND PRACTICAL APPLICATION IN THE REMOVAL OF SURFACE COATINGS

CASSY CUTULLE AND SEOYOUNG KIM

There is a growing necessity within the field of conservation to seek out new methods of cleaning that are safe, effective, and sustainable. The use of dry ice blasting to clean museum objects has been investigated as a potential option in recent years. To continue such research, an experimental methodology was devised to evaluate the risk of abrasion using this method and its efficiency in removing traditional and modern conservation surface coatings from metallic artifacts. Additionally, an assessment of dry ice blasting as a conservation cleaning technique was conducted. Two types of experiments were carried out to measure the performance and efficiency of dry ice cleaning. The first experiment utilized brass, cupronickel, and mild steel metal coupons that were coated, blasted, and assessed under a Hitachi S-3400N scanning electron microscope to evaluate the risk of surface abrasion as a result of dry ice cleaning. The second experiment evaluated the practical efficacy of dry ice blasting in the removal of coatings from historic and modern objects, such as gilded brass furniture mounts and steel musket lock replicas. All experiments were undertaken using the Cold Jet i3 MicroClean dry ice shaving unit. Various coating materials, such as natural and synthetic waxes, petroleum jelly, Paraloid B-72, Paraloid B-48N, Incralac, nitrocellulose lacquer (Ercalene), and shellac were tested in the experiments. The results revealed that the risk of surface abrasion on the metal surfaces using dry ice blasting is minimal at the tested durations and settings used. Effectiveness in coating removal was seen to be variable. Wax-based and petroleum jelly coatings were more effectively removed compared to polymer-based coatings. This project was completed as dissertation research for University College London's Masters of Science in Conservation for Archaeology and Museums degree program.

This article also presents a case study that focuses on the practical application of dry ice blasting for the cleaning of mail (often known as chain mail) on the Oriental helmets at the Wallace Collection in Central London. The mail on the helmets had previously been coated with petroleum jelly, which interacted with the metal over time, resulting in discolored, tacky, and greasy mail. Dry ice blasting was employed to remove the aged surface coatings on the mail as an alternative technique to conventional chemical cleaning methods. The detailed process of the project, with an evaluation of its effectiveness and the practical limitations, is outlined.

KEYWORDS: Cold Jet i3 MicroClean, Dry ice blasting, Mail, the Wallace Collection

1. INTRODUCTION TO DRY ICE BLASTING

In the conservation care of historic metals, cleaning is one of the more challenging jobs undertaken. The careful removal of dirt, dust, tarnish, corrosion products, and previously applied coatings is vital to the future stability and condition of the object (Grossbard 1992; Garcia et al. 1998; Caple 2000; Harris 2006b). In the case of social history objects, cleaning is often focused on the removal of a previously applied coating. Such coatings were applied in the past to protect the metal from moisture, pollutants in the environment, and handling, all of which can cause tarnishing and corrosion (Grossbard 1992; Garcia et al. 1998; Harris 2006a, 2006b). Often these coatings have degraded, affecting the condition and appearance of the object. In these situations, removal should be considered (Grossbard 1992; Harris 2006b). Ideally, the methods employed to remove the coating should be safe, efficient, and environmentally responsible. It is therefore vital that appropriate techniques are available to conservators charged with the cleaning of historic metals.

In recent years, dry ice blasting has been explored as such an option. Hailed as a dry, non-toxic, sustainable, and gentle technique, conservators have tested, researched, and used this method on a range of objects (Spur et al. 1999; Silverman 2008; Brush 2010; van der Molen et al. 2010; Higginson and Prytulak 2012; Lizarraga 2012; Posner 2012; Sullivan 2013; CleanLink 2014). The process of dry ice blasting is carried out with the use of dry ice—solid carbon dioxide or CO_2.

Typically, the process of dry ice blasting includes a mechanized dry ice shaving or pellet unit, which is used in conjunction with compressed air to transport and emit the dry ice particles (Spur et al. 1999). Depending on the machinery, the dry ice can be shavings less than 1 mm in size or pellets that are approximately 3 mm in length (Brush 2010). On the mechanized unit, pressure (in bar or pounds per square inch) and mass flow (in kilograms per minute) control the speed and volume of the dry ice transported through the hose and a specially constructed nozzle (Spur et al. 1999; Cold Jet LLC 2004; Otto et al. 2011). In addition to this type of dry ice cleaning, there is also the single-stage unit, whereby compressed liquid CO_2 is converted to a fine, solid CO_2 "snow" within the nozzle, without the use of compressed air (Lizarraga 2012).

Research on the mechanisms of dry ice blasting examines several effects that are responsible for the removal of surface accretions. First, there is the impact force of the dry ice particles, which prompts the cracking and weakening of the accretion through the forced contact of the jetted dry ice (Spur et al. 1999; Liu et al. 2011; Otto et al. 2011; Zhou et al. 2012). Second is the kinetic effect that is the mechanical action of the high-velocity dry ice working against a surface accretion (Spur et al. 1999). The freeze-fracture effect is another mechanism aiding in the removal of contaminants. The extremely low temperature of the dry ice creates contraction of an accretion or coating on a surface, rendering it brittle (Spur et al. 1999; Cold Jet LLC 2004; Otto et al. 2011; Zhou et al. 2012). This also generates a contraction differential between the coating and the substrate, weakening the adhesion between the two as one shrinks at a different rate than the other (Otto et al. 2011).

The sublimation effect also plays an important role in removal. As solid dry ice hits a surface at room temperature, it sublimates. During this process, it expands to approximately 800 times its size, exploding at the surface as it does. The energy transfer as a result of this expansion and explosion consequently aids in the removal of surface accretions (Cold Jet LLC 2004; Hailstorm Industrial Cleaning Solutions 2009; van der Molen et al. 2010; Otto et al. 2011; Cryogenesis Ltd. UK 2014b; Yara CO_2 and Dry Ice 2014). Together with the drag force, or the effect of the jetted air lifting/pushing a coating from the substrate, these mechanisms combine to make dry ice blasting a successful means of surface cleaning (Otto et al. 2011; Zhou et al. 2012).

2. DRY ICE CLEANING AT THE WALLACE COLLECTION: A TECHNICAL ASSESSMENT AND PRACTICAL APPLICATION

In preparation for the creation of a new Oriental Arms and Armor catalog at the Wallace Collection, it was decided that dry ice blasting should be employed to aid in the cleaning of the Oriental Helmets collection. In December 2013, the Cold Jet i3 MicroClean dry ice shaving unit was rented for a week to conduct this work. This project allowed for a practical assessment of the method and revealed its benefits and limitations. During this time, conservation intern Cassy Cutulle was permitted to conduct experiments for her Masters of Science dissertation at University College London (UCL).

2.1 UNIVERSITY COLLEGE LONDON DISSERTATION PROJECT

2.1.1 Introduction to the Experiments

Two experiments and qualitative observations were conducted to answer three primary research questions:

1. Is there any risk of abrasion associated with this method of cleaning?
2. Is this method a successful means of removing coatings from metal museum objects?
3. Is this method a practical one for museum conservation use?

The dry ice shaving unit utilized was the Cold Jet i3 MicroClean. Table 1 lists the technical properties for this machine. The settings for all experiments discussed in this article remained constant at a mass flow of 0.45 kg/min. and 1.4 bar. These settings were chosen because the increased amount of dry ice at 0.45 kg/min. was thought to make the cleaning process more efficient, whereas the lower pressure setting mitigated the risk of abrasion. During blasting, heat supplied by a hot air dryer on low settings was used to prevent the freezing of the coupon or object and to increase the temperature difference between the object/coupon and the dry ice. This methodology was suggested to the authors by the Senior Furniture Conservator at the Wallace Collection, Jürgen Huber, who has had experience in utilizing this method for object cleaning. Additionally, research has shown that the use of heat can intensify the freeze-fracture effect by producing a larger energy transfer during the sublimation of the dry ice particles—a result of the increased temperature difference between the dry ice and the contaminant (van der Molen et al. 2010; Cold Jet LLC 2004). The use of heat is therefore regarded as a means of increasing the likelihood of contaminant removal. This, of course, is also dependent on the type and chemical properties of the coating to be removed, such as glass transition temperature (Tg), freezing point, and melting point.

2.1.2 Experimental Methodology: Risk of Abrasion Assessment

For the first of the dissertation experiments, 12 metal coupons were used to assess the risk of abrasion as a result of dry ice blasting. Four mild steel, brass, and cupronickel coupons[1] were each sectioned into four quadrants, whereas the center area was maintained as the control (table 2). For the cupronickel coupons, the quadrants were square in shape and measured 2.5 × 2.5 cm. For the brass and

Table 1. Technical Properties of the Cold Jet i3 MicroClean Unit (Cold Jet LLC 2014c)

Pressure	1.4–9.7 bar or 20–140 psi.
Mass Flow (Feed Rate)	0–0.50 kg/min.
Size of Unit	55.9 × 40.6 × 53.3 cm
Weight of Unit	59.1 kg
Hopper Size	9.1 kg
Single- or Two Hose	Single-hose system
Nozzle Type	“Advanced ‘MERN’” nozzle (blasting span 6.6 mm and 7.4 mm)
Pellets or Shavings	Shavings emitted from dry ice block (size of block is 5 × 5 × 10 in.)

Table 2. Coatings Applied to Metal Coupons

Metal Coupons	Coatings
Mild Steel Coupons	• One coat of Paraloid B-72 (ethyl methacrylate copolymer) 10% w/v in 1:1 IMS: acetone applied by brush • One coat of Paraloid B-48N (methyl methacrylate copolymer) 10% w/v in 1:1 IMS: acetone applied by brush • Two coats of Renaissance Wax (80% White Spirit and 20% Blended Micro-crystalline waxes) applied by brush and buffed in with a cotton cloth • One coat of petroleum jelly applied by brush
Brass and Cupronickel Coupons	• Two coats of Ercalene (cellulose nitrate chloride-free lacquer) applied by brush • Five coats of blonde shellac approx. 15%–20% w/v in IMS applied by brush • One coat of Incralac (74% Paraloid B-44, 20% toluene, 5% ethanol or butyl acetate, 0.5% benzotriazole, 0.5% epoxidized soya oil) applied by brush • Two coats of Renaissance Wax applied by brush and buffed in with a cotton cloth • Five coats of Briwax (xylene, mixed isomers: 90%–99%, 1-butanol: 10%–30%) applied by brush

mild steel coupons, quadrants were in the approximate shape of an isosceles triangle with a rounded base measuring 2.5 × 2.5 × 3.8 cm. Prior to imaging and experimentation, each coupon was cleaned using 1:1 acetone: Stoddard solvent (aliphatic solvent with an aromatic content of 16%).

A small triangle was engraved into each quadrant (fig. 1a) and two images per quadrant were taken before dry ice blasting in a Hitachi S-3400N scanning electron microscope (SEM) on secondary electron imaging at 20 kV. The first image was an overall photograph of the triangle at 20x (fig. 1b), whereas the second was a photomicrograph of a specific reference point on each triangle at 650x (fig. 1c). This reference point varied between the top, bottom left, and bottom right corners of the carved triangle. The use of the location-specific point made before and after comparison images of the surface at high magnification possible. A coating was then applied to each quadrant and the control area was covered with 3M Performance masking tape to prevent it from being affected by the blasting. Two quadrants were used per coating type for replication of the results (see table 2).

Blasting took place for approximately 15–20 seconds per quadrant. This time limit was chosen due to the small surface area of the quadrant. The nozzle angle varied within the range of approximately 35–50°. Two images of the same areas on each quadrant were again taken in the SEM after blasting to determine whether abrasion had occurred on either a macroscopic or microscopic scale. The settings in the SEM were kept as consistent as possible for the "before" and "after" blasting images.

2.1.3 Experimental Methodology: Coating Removal Tests

For the coating removal tests, the aim was to get an idea of the machine's efficiency in removing coatings from actual objects with differences in surface morphology and structure (fig. 2). Prior to coating and blasting, all objects were cleaned. The furniture mounts were previously coated with shellac and had to be placed in an industrial methylated spirits (IMS; 95% ethanol, 5% methanol) vapor

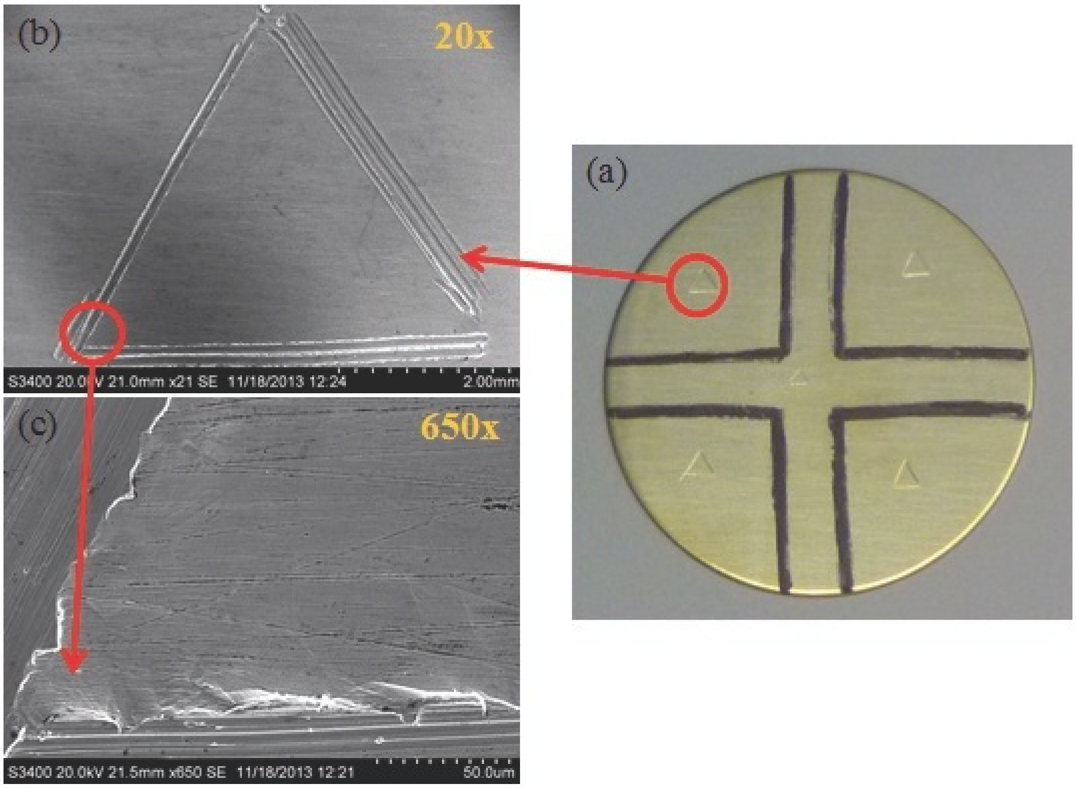

Fig. 1a–c. Photograph of the coupon preparation for SEM photography. A small triangle etched into the metal (a) coupon was photographed at 20x (b) and a location-specific point was photographed at 650x (c) to assess for micro-abrasion. On this quadrant of the brass coupon, a picture of the lower left corner of the quadrant triangle was used. (Courtesy of Cassy Cutulle, University College London)

Fig. 2. All objects and coupons used in the experiments for this dissertation project prior to dry ice cleaning (Courtesy of Cassy Cutulle, Trustees of The Wallace Collection, ©The Wallace Collection, London)

chamber to enable the shellac's removal. The musket locks were de-greased using a 1:1 acetone: Stoddard solvent solution. After cleaning, the objects were coated; one half of each furniture mount was used for coating and blasting. Three sections on that half of the mount were taped off, and each section was coated. Each musket lock was coated with one type of coating applied to the front (fig. 3, table 3).

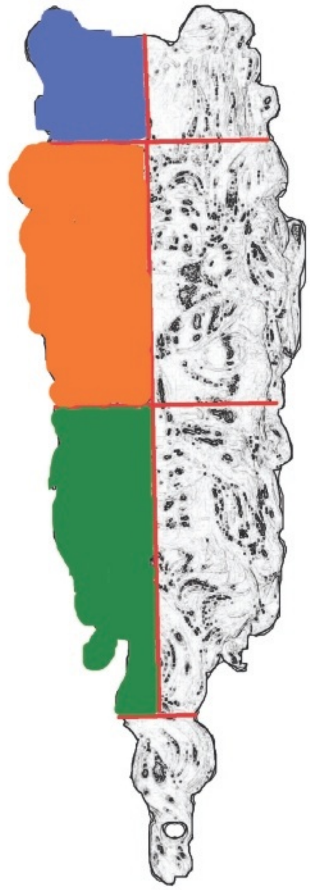

Fig. 3. Diagram of Mount #1 displaying the setup for the coating application. Paraloid B-72 was applied in the blue area, shellac in the orange area, and Briwax in the green area. (Courtesy of Cassy Cutulle, Trustees of The Wallace Collection, ©The Wallace Collection, London)

Table 3. Coatings Applied to Furniture Mounts and Musket Locks

Objects	Coatings
Three Furniture Mounts (each coating applied to each mount)	• One coat of Paraloid B-72 10% w/v in 1:1 IMS: acetone applied by brush • Four coats of Briwax buffed into the surface using furniture brushes • Eight coats of shellac approx. 15%–20% w/v in IMS applied by brush
Three Musket Lock Replicas (one coating per musket lock)	• One coat of Paraloid B-72 10% w/v in 1:1 IMS: acetone applied by brush • One coat of Paraloid B48N 10% w/v in 1:1 IMS: acetone applied by brush • One coat of petroleum jelly applied by brush

Table 4. Risk Rankings and Corresponding Percentages

1: 0%–25%: Low Risk
2: 25%–50%: Low–Medium Risk
3: 50%–75%: Medium–High Risk
4: 75%–100%: High Risk

Each section on the objects was blasted for approximately one minute. Nozzle distance, angle, and object position varied throughout. Particular aspects like surface changes, the removal process on the objects, and general ease of use were observed.

2.1.4 Results: Risk of Abrasion Assessment

To estimate the risk of abrasion, each metal and type of surface alteration observed (polishing, micro-abrasion, movement of metal, etc) was listed alongside the occurrence for that type of alteration. A total percent occurrence was then approximated for all cleaned quadrants. A risk-potential ranking system was used to correlate the percent values to a number that corresponded to a risk level (table 4). The various categories for surface alterations include:

- *New abrasion*: New scratch marks apparent on the surface in the "after" images
- *Impact marks*: Small, circular areas present marking the impact point of the dry ice shavings
- *Polishing effect*: The disappearance or reduction of previously established surface features indicating a polishing effect on the surface
- *Movement of metal*: The movement or loss of established metal material between the "before" and "after" SEM images.

Based on the results, the potential for surface alterations is low when dry ice blasting at the durations and settings employed in this project. Comparing across metal types, the brass and cupronickel coupons ranked the lowest in risk for potential surface alterations with an average between 8% and 10%. However, the smaller amount of cleaned quadrants for both metal types has also skewed this data. The mild steel coupons displayed the highest average percent occurrence of surface change at 12.5%. The larger amount of cleaned quadrants on the mild steel coupons can also account for this higher average. At any rate, the risk of surface alterations as a result of blasting is still considered low. Additionally, with the surface changes exhibited, many of them were miniscule in nature and could not be viewed by the naked eye (fig. 4).

2.1.5 Results: Coating Removal Tests

Coating removal was assessed visually and the percent removed estimated. The total space of a coated section represented 100%. If half of the coating was removed from that section, it was estimated as having been 50% removed. For the coupons, each quadrant represented one section.

Although the coating removal tests focused on the removal of coatings from objects, it was interesting and useful to look at the results of coating removal from the metal coupons as well, and thus those results are included in appendix 1. On average, 90% of the Briwax coating was observed as removed from the furniture mounts, whereas the removal averages for Paraloid B-72 and shellac were considerably less at 2.5% and 0%, respectively. For the musket locks, the Paraloid B-72 and petroleum jelly coatings were each assessed as 25% removed, whereas approximately 7.5% of the Paraloid B-48N coating was estimated as removed.

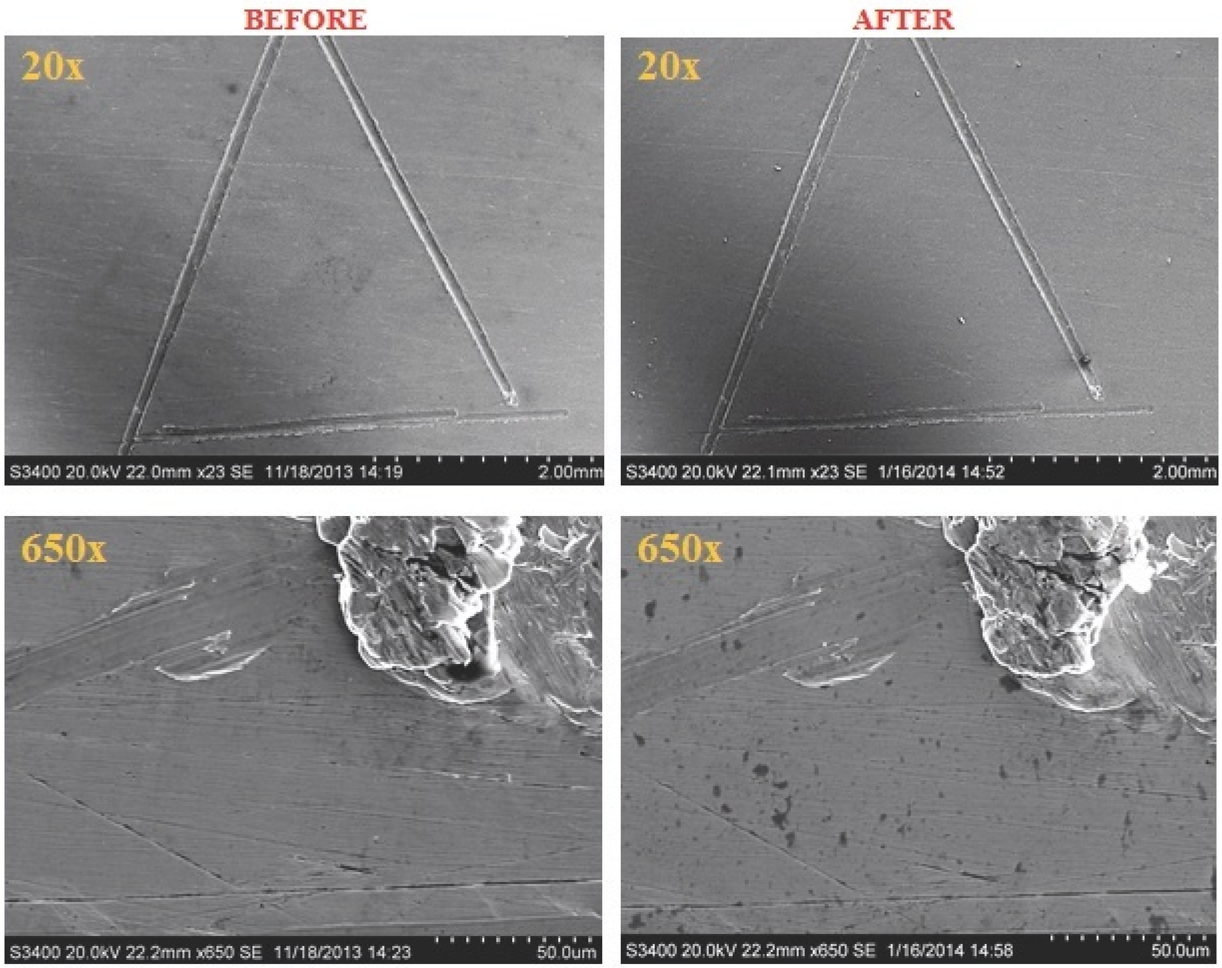

Fig. 4. SEM images of a brass coupon quadrant coated with Briwax at 20x and 650x before and after dry ice blasting (Courtesy of Cassy Cutulle, University College London)

The results have revealed that the settings utilized were sufficient for removal of Briwax and Renaissance Wax coatings (fig. 5a, b). The partial removal of petroleum jelly and Paraloid B-72 indicated that the mass flow and pressure settings were adequate, but a longer blasting time was needed to completely remove those coatings. Since Paraloid B-48N, shellac, Incralac, and Ercalene were not totally removed, a change in settings or blasting method would be needed for removal in a timely manner.

2.2 CLEANING THE ORIENTAL HELMETS AT THE WALLACE COLLECTION: A PRACTICAL CASE STUDY

2.2.1 Background

The Wallace Collection is a national museum within a historic house situated in central London, housing superb collections of decorative art, paintings, and furniture, as well as world class collections of European and Oriental arms and armor. The previous catalog of the Oriental Arms and Armor collection was published in 1914 without any illustrations, and the need for a new illustrated catalog has since been sought. The entire Oriental Arms and Armor collection, comprising around 1,000 objects, is currently being assessed, conserved, and photographed for the upcoming catalog.

(a)

(b)

Fig. 5a, b. Furniture mount #2 before (top) and after (bottom) dry ice cleaning of Briwax (Courtesy of Cassy Cutulle, Trustees of The Wallace Collection, ©The Wallace Collection, London)

There are 74 helmets among the collection. A helmet usually consists of bowl and mail. The surfaces of most helmets, like many other objects in the collection, had previously been coated with petroleum jelly and other oils in the 1980s. These are now badly aged, discolored, and tacky. Interlinked mail rings were often clogged with these previous coatings along with accumulated dust and dirt, resulting in the loss of intended mobility and flexibility (fig. 6). Mail is conventionally cleaned with chemicals (e.g., Stoddard solvent, acetone, ethanol), often immersed in chemical baths in combination with mechanical cleaning. However, the cleaning of such intricate objects is often difficult to execute and demands a great deal of resources. Although it is considered a fast and effective method, chemical cleaning can have undesirable implications in terms of environmental sustainability, costs, and health and safety.

The application of dry ice blasting was first initiated at the Wallace Collection several years ago for the cleaning of furniture mounts, which had been coated with shellac and various waxes. Following successful results of those trials, it was decided to employ dry ice blasting for cleaning the mail on helmets as an alternative to chemical cleaning methods (fig. 7).

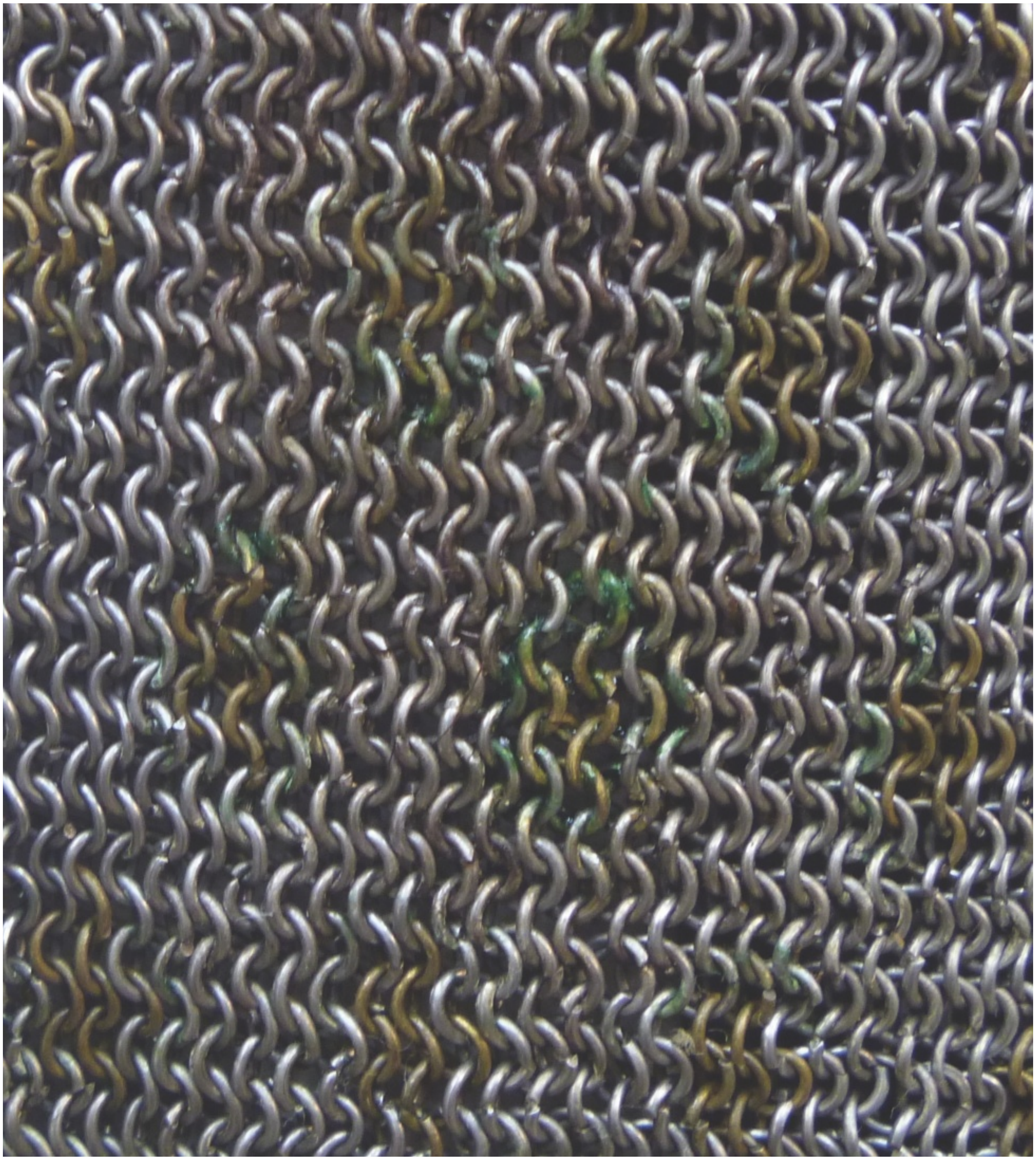

Fig. 6. Copper corrosion products within the links of the mail (Courtesy of Seoyoung Kim, Trustees of The Wallace Collection, ©The Wallace Collection, London)

Fig. 7. Several helmets on stands before dry ice blasting (Courtesy of Seoyoung Kim, Trustees of The Wallace Collection, ©The Wallace Collection, London)

2.2.2 Application Methods

The Cold Jet i3 MicroClean unit was rented for a week to clean the mail on the helmets (see table 1). Various settings of mass flows (0.09–0.45 kg/min.) and pressures (0.5–2.0 bar) were tried, and different nozzles were tested to find an efficient working method and to reduce any risks associated with this cleaning technique. A hot air gun was used to minimize the build-up of condensation on the blasted surfaces. The mail was initially cleaned with dry ice only. Dry ice blasting was effective in removing soft accretions from the surface; however, it was considered time-consuming and often required several rounds of blasting in one area to achieve satisfactory results. Due to limited resources within the restricted time scale, the working method had to be altered to complete the project within the given time (fig. 8).

The use of Stoddard solvent was consequently introduced to aid in the removal of accretions and old coatings. After preliminary dry ice blasting, Stoddard solvent was locally applied to areas where further cleaning was required with brushes, and then the helmet was dried with cotton cloths. This added step improved the overall appearance of the mail, resulting in an even surface cleaning. However, this method required thorough inspection, which expended more time. For heavily soiled mail, it was less time-consuming to briefly immerse the mail in a Stoddard solvent bath for one to two minutes with gentle agitation. The mail was then completely air-dried before dry ice blasting was undertaken as a second step.

The choice of cleaning methods was mainly determined by the condition of the mail. Out of 74 helmets, mail on 16 helmets required no treatment or minor localized cleaning due to previous cleaning treatment. Mail on 8 helmets was cleaned with dry ice blasting only, and mail on 12 helmets was cleaned

Fig. 8. Dry ice blasting the mail (Courtesy of Cassy Cutulle, Trustees of The Wallace Collection, ©The Wallace Collection, London)

with dry ice blasting first with further localized chemical cleaning. Mail on 38 helmets was cleaned with chemical immersion, followed by dry ice blasting. Twenty-two liters of Stoddard solvent was used for the chemical immersion of 38 helmets. Although the actual quantity of Stoddard solvent used was more than initially anticipated, it was still significantly less than using the conventional chemical cleaning method alone, which would have exhausted more than 100 liters of Stoddard Solvent to clean 38 helmets.

Cleaned mail was buffed with a brass bristle brush to improve surface sheen. Mail was then waxed on both interior and exterior surfaces with Renaissance microcrystalline wax, and the waxed surface was then heated with a hot air dryer on a low setting to melt any lumps of wax in crevices among the interlinked rings.

2.2.3 Results and Evaluation

Dry ice blasting was found to be effective as a complementary method for the cleaning of the interlinked mail rings of helmets (fig. 9) and a good alternative to traditional chemical cleaning, particularly for its environmentally friendly benefit. The success of dry ice blast cleaning does depend on the project aims and object types. Despite the practical limitations and issues, it was a worthwhile endeavor to apply dry ice blasting to the mail cleaning. Overall results were satisfactory. In particular, its environmental benefits can be immensely advantageous when it is used for the right project and suitable objects. Although chemical cleaning was reintroduced in this project to maximize limited resources and to alleviate time restrictions, it is possible that dry ice blasting can produce good results as a solitary technique. An evaluation of its practicality in the museum is discussed further in Section 4.

Fig. 9. Patterns on the mail after dry ice blasting and chemical immersion (Courtesy of Seoyoung Kim, Trustees of The Wallace Collection, ©The Wallace Collection, London)

3. VARIABLES AND LIMITATIONS

3.1 BLASTING PROCESS

A range of variables influenced the experimental approach and results achieved in the projects discussed earlier. First, the success with which objects were cleaned varied according to how the object was blasted and in what environment. In a test conducted by the authors, it was observed that dry ice blasting a brass coupon without the use of heat caused freezing of the metal, resulting in an accumulation of condensation as the metal warmed after blasting (fig. 10). The use of a hot air dryer on low settings during blasting facilitated the cleaning process by preventing the freezing of the object or coupon, inhibiting the accumulation of condensed water.

Although details such as the temperature of the surface of the objects and coupons before, during, and after blasting were not monitored in these projects, the effectiveness of the use of heat during blasting was observed qualitatively. By varying the point in time at which heat is applied (before, during, after) or not applying heat at all, different rates of success can be observed. More research is needed at this time, particularly to investigate the variable of heat application in dry ice cleaning.

The position, movement, angle, and distance of the object and nozzle during blasting can also influence the effectiveness with which the coating is removed from the surface (Veloz 1993; Scott 2002; van der Molen et al. 2010). In some instances, leaving the object stationary will allow the user to focus on an area for cleaning. However, moving both the object and the nozzle can also aid in a more complete removal from crevices and areas of relief. These aspects varied throughout the experiments discussed.

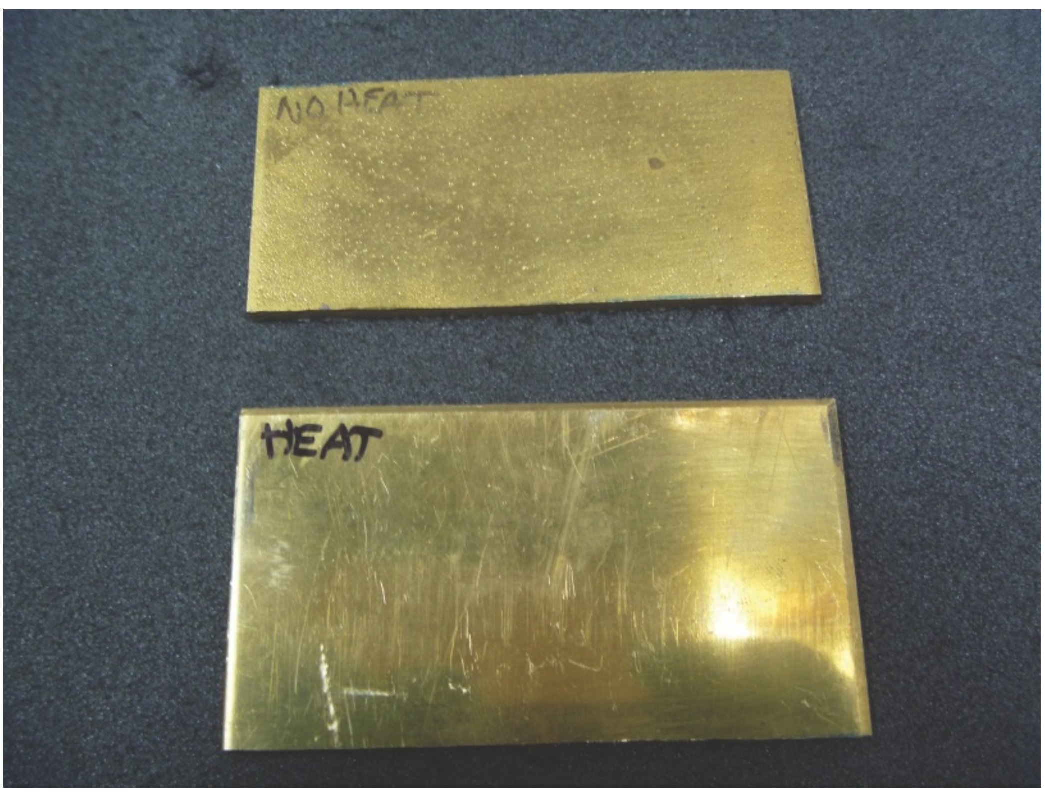

Fig. 10. Comparison between a metal coupon dry ice blasted with heat and one without heat. Note the presence of water on the surface of the metal coupon that was blasted without heat, which accumulated as the coupon warmed to room temperature after dry ice blasting. (Courtesy of Cassy Cutulle and Seoyoung Kim, Trustees of The Wallace Collection, ©The Wallace Collection, London)

Blasting duration utilizing the dry ice machinery is also an important variable to consider when undertaking dry ice blast cleaning. An effective blasting time will vary according to the coating to be removed and the structure of the object to be cleaned. Unfortunately, the time restrictions for these projects prevented the examination of the variable of time in dry ice cleaning.

3.2 OBJECT AND COATING

The type, composition, and structure of the object to be blasted are also important details to consider. The complexity of an object's structure can prevent the full removal of a coating, whereas differences in surface finishes will affect the adhesion between the coating and metal substrate.

Likewise, the nature of the coating to be removed is a substantial variable with a range of aspects, each of which will determine the success of the process. Details such as the composition of the coating, the age, and any interaction between the coating and object surface will heavily affect the ease of removal. For the dissertation experiments, artificial aging was not possible and therefore the coatings used were relatively new, having been applied approximately one week prior to blasting. In the case of the Oriental Helmets collection, the coating was approximately 30–35 years old. The overall results have thus been strongly influenced by this.

3.3 MACHINE, ACCESSORIES, AND SETTINGS

The machinery and accessories used are also factors that can dictate the outcome of the cleaning process. The machinery and settings control the pressure, the amount of dry ice being released, and *how* it is emitted. Ultimately this will determine the effectiveness of the dry ice blasting mechanisms (Otto et al. 2011). Likewise, accessories such as the nozzles, applicators, and air compressor units control the power and focus of the blasting. The use of pellets or shavings will also determine the efficiency of removal (van der Molen et al. 2010). Typically, pellets are considered more abrasive and are used with more tightly adhered coatings and accretions, whereas dry ice shavings are favored for their gentleness (Spur et al. 1999; Cold Jet LLC 2014e).

When analyzing the results from the abrasion experiment for the dissertation project, a range of variables also affected an understanding of the types of surface changes present and the extent of those changes. Differences in lighting, contrast, and charging of the metal surface in the SEM between the "before" and "after" images were common variables—a result of uncontrollable machine variations. These particular visual inconsistencies between images may have falsely indicated surface damage by obscuring previously established scratches—making it appear as though polishing had occurred—or altering the surface topography in the "after" image. Every effort was taken to consider these variations in the analyses of the "after" images.

3.4 LIMITATIONS

In addition to the variables inherent in these projects, some limitations also affected how the experiments were undertaken and the results gained. First, time constraints presented limits on how much preliminary research and testing could be done prior to conducting the experiments. This had a direct impact on the amount of time available for cleaning, ultimately restricting the blasting time. This was especially important in situations where a longer blasting time may have contributed to further removal of the coating.

There is also a learning curve associated with using this machinery. Although the unit is user-friendly and relatively easily operated, understanding which settings were appropriate for the cleaning job was more difficult. The availability of more time would have allowed for further testing and research; however, this was not possible given the circumstances of this project. As a result, this greatly influenced the experimental methodology and therefore the conclusions.

4. PRACTICALITIES OF DRY ICE CLEANING IN THE MUSEUM: QUALITATIVE OBSERVATIONS

The practical experience of using dry ice blasting at the Wallace Collection allowed for an assessment of the applicability of this cleaning method, both in terms of its use on actual objects and its viability in a conservation workshop setting. Observations were recorded on aspects that are considered particularly valuable to conservation work, such as ease of use, waste generated, costs, sustainability, health and safety, and accessibility, among other criteria. This information can be quite useful in providing an understanding of its utility and efficiency, thereby aiding in a decision about whether or not dry ice blasting is an appropriate means of cleaning metallic museum objects in any particular situation. It is important to note that these observations are subjective and refer to the use of the Cold Jet i3 MicroClean dry ice blasting machine for the projects discussed earlier.

4.1 USE IN THE MUSEUM

When considering the use of dry ice blasting as a cleaning method, the size of the unit and equipment must be taken into account. The dry ice shaving unit used in these projects measured 56 × 41 × 53 cm and weighed slightly less than 60 kg, allowing it to be easily situated on a laboratory bench (Cold Jet New Zealand LLC 2014). Additional equipment, however, was more difficult to position. Two large storage chests were needed: one in which to store surplus dry ice blocks in the long-term, and the other to store dry ice blocks for short-term use in the workshop. These storage chests kept the dry ice contained and decreased the evaporation rate, thereby increasing working time. When situating the machinery and accessories in the museum workshop, the large size and temperature requirements for the chests caused difficulties. In the case of this project, there was no large freezer available for the long-term storage of the dry ice, and thus one of the chests needed to be kept outdoors. This chest measured approximately .6 × .6 × 1 m. The second chest—the one that was placed in the workshop as temporary storage for the day's blasting—measured approximately 1 × .7 × .6 m. Additionally, the air compressor unit was needed in the blasting space, measuring approximately 1 m in length. Another consideration was the amount of power cords and hoses that occupied space and required close proximity to power outlets.

4.2 CONTROLLABILITY

In this project, *controllability* was defined as the ease of control of the machinery and ability to reach all areas of the object. For the cleaning of the furniture mounts and musket locks, it was difficult to reach tight spaces with the dry ice nozzle. This is concerning for the instrument's use in conservation, as it reveals that a complete cleaning of objects can be difficult to achieve. Additionally, concentrated blasting in tight spaces introduces the possibility of increased risk of surface damage, risk of condensation forming, or dry ice accumulation. However, since only one type of nozzle (MC29MH, with a length of 15.2 cm and blast range of 0.7 cm) was used in these projects, there is the possibility of more successful results with the use of different nozzle types.

Overall the machinery is user-friendly and easily operated by one person. A relatively simple setup, the dry ice shaving machine is connected to the air compressor unit and plugged into an electrical outlet. The hose that transports the dry ice and connects to the nozzle is also hooked up to the shaving machine. A block of dry ice can be easily inserted into the shaving machine by lifting the top lid and placing it in horizontally. The gun and nozzle work by way of a pressure-sensitive trigger. Due to the use of compressed air, there is a small kickback associated with blasting and objects must be held down to prevent movement during blasting.

4.3 ACCESSIBILITY

For use at the Wallace Collection, the machine and accessories were rented for a week from Cryogenesis Limited, UK. To avoid any delays, it was necessary to rent the machinery ahead of schedule and plan for the delivery and setup in the workshop. Since renting time was limited, this placed constraints on the work to be done. For these reasons, dry ice blasting was not seen as an incredibly accessible method of cleaning. This is in contrast to the use of solvent or air abrasive cleaning—both of which are usually located on-site. Additionally, in the case of the projects conducted at the Wallace Collection, dry ice blocks were supplied with the unit; however, this is not always the case, and oftentimes dry ice needs to be sourced separately from the machine.

The key to mitigating these challenges is to organize and plan the cleaning jobs to be done with the dry ice blasting machinery well in advance to avoid possible setbacks. These criteria are vital to understanding the worth of the machinery and in what situations it is best used. Knowing that it is not easily accessed may mean that it is only good to use dry ice blasting in situations where bulk or special cleaning is needed.

4.4 HEALTH AND SAFETY

Safety during operation is also an important factor to take into consideration. Heavy-duty gloves must be worn at all times when handling the extremely cold dry ice, which can burn if it comes in contact with skin. Additionally, the high noise levels of the air compressor can damage hearing at a range of 85–130 decibels (Cryogenesis Ltd. UK 2014a). It is therefore essential that protective gear such as goggles, ear defenders, and laboratory coats/long sleeves are worn at all times throughout the process.

Furthermore, although CO_2 is considered non-toxic, large gaseous amounts can be dangerous, especially in smaller workshops or laboratory spaces where it will replace the oxygen in the room (Cold Jet LLC 2014b; Health and Safety Executive 2014). The use of devices such as the Extech CO200 meter can allow for the monitoring of these levels (Air Concern Ltd. 2014). Adequate extraction and ventilation is therefore needed at all times when using this machinery indoors. Additionally, the air compressor generates fumes that can be considered noxious, and thus opened doors and extraction will aid in alleviating this.

Last, the user may also experience small-scale static electrical shocks when dry ice blasting metal, which can be remedied by connecting the object to grounding wires included with the blasting unit (Cold Jet LLC 2009d).

4.5 COSTS, RESOURCES, AND WORKING CAPABILITY

Conservators should be mindful of the costs involved and the usage of resources when undertaking dry ice blasting. Typically, the machinery is rented out through suppliers. Depending upon the supplier and location, prices will vary. Based on the work carried out at the Wallace Collection, the pricing range for one week of rental was approximately $1200.00, which included the dry ice, storage chests, two nozzles, gloves, air compressor, and hoses. Although this can be regarded as an expensive endeavor, it is important to note that the use of this machinery in cleaning negates the need for waste disposal (Cold Jet LLC 2004). In situations where this cleaning method is deemed appropriate and efficient and a bulk amount of objects are in need of cleaning, this method can be quite useful. Likewise, it may not be economical to rent the machinery for the cleaning of only a small number of objects.

In the case of dry ice shaving machines, working time is limited by the dry ice. The dry ice blocks will sublime and the size of the blocks will diminish over time. After a week of use for this project, remaining blocks had decreased by about 30%–45% of their original size in the surplus storage. This does depend on the thermal efficiency of the storage and whether or not freezers are available to store the dry ice, which would greatly enhance the working time.

The process of shaving down the blocks for blasting is another aspect to take into account. Depending on the mass flow setting, which controls the rate at which the blade shaving the ice operates, the ice block will be exhausted more slowly or quickly. At 0.45 kg/min., the maximum continuous working time was up to around 1.5 hours. Additionally, there is a drop in pressure when using a less powerful air compressor system. Less powerful systems will only yield a designated pressure before dropping off and needing a recovery time, as was evident in the work that was conducted at the Wallace Collection.

It is important to note that there are surface and material types for which dry ice blasting may not be an appropriate means of cleaning. Heavily decorated areas such as gilded, inlaid surfaces, or friable, softer, and delicate surfaces should be avoided because of the mechanical stresses caused by the blasting, which may lead to loss of material. Organic materials such as paper, wood, hard tissue, and leather require adequate testing before use to understand the potential hazards and benefits of dry ice cleaning on these materials.

4.6 SUSTAINABILITY

Since dry ice blasting utilizes non-toxic, recycled solid CO_2, which safely sublimates into the atmosphere, it is considered sustainable (Cold Jet LLC 2004; Continental Carbonic Products Inc. 2013; Cold Jet LLC 2014f). However, exhaust fumes from the air compressor can be considered harmful to the environment, so this should be taken into consideration. The ability to recycle the CO_2 would make this process even more sustainable, and more research needs to be conducted to determine if this is a viable possibility (US Department of Energy 2014).

4.7 WASTE GENERATED

During the cleaning of the furniture mounts, musket locks, and coupons, little to no waste was generated and virtually no cleanup was needed. Of course, this will differ according to the cleaning job undertaken—more objects with more coating increases the residual waste from blasting. The sublimation of the dry ice also prevents the need for disposal of the cleaning media. Although the dry ice blasting process does not produce new waste, the contaminant that is to be removed through blasting will relocate. Proper protection of surfaces in the working space is therefore needed.

5. CONCLUSIONS AND DISCUSSION

An important goal of these projects was to ascertain whether or not surface abrasion was occurring to the metal after dry ice blasting. Visually and at low magnification (20x), slight polishing and a low incidence of impact marks were observed. At the microscopic level (650x), minute surface alterations were evident, mostly in the form of the movement of loose metal around the area where the triangle had been incised in the coupon. This signifies that the risk of abrasion is low with the machinery, settings, and times used.

The use of the 0.45 kg/min. mass flow and 1.4 bar pressure settings allowed for the removal of 90%–100% of the Briwax and Renaissance Wax coatings within the allotted time on the coupons and objects, constituting the process and settings efficient for these coatings. This is a useful note for conservators interested in using this technique on metal objects.

For coating removal, the results also revealed that the object structure, coating type, and coating age are the main factors that will determine the time it takes to remove a coating.

Although some coatings remained untouched at the end of blasting, research does indicate the potential to remove such coatings (Veloz 1993; van der Molen et al. 2010; Liu et al. 2011; Zhou et al. 2012). For each coating, these suggested changes are detailed in table 5. These adjustments in settings or

Table 5. Coatings Used and Potential Adjustments Needed for Total Removal

Coating	Longer Blasting Time at Same Settings	Variation of Nozzle Angle or Distance, Nozzle Type, Object Movement	Change of Settings (Mass Flow, Pressure, or Both)	No Adjustment Needed
Renaissance Wax				X
Briwax				X
Petroleum Jelly	X			
Paraloid B-72	X	X		
Incralac		X	X	
Paraloid B-48N			X	
Shellac			X	
Ercalene			X	

blasting approach reveal the versatility of this cleaning method and the potential for greater efficiency in coating removal.

For coatings that were not removed, three main adjustments may aid in removal:

1. A longer blasting time at the same settings
2. Variation in nozzle type or angle, blasting distance, or object movement
3. Changing of settings (mass flow, pressure, or both).

The cleaning of the Oriental helmets at the Wallace Collection revealed that dry ice cleaning can sometimes be a lengthy endeavor, but benefits such as sustainability and reduction in exposure to toxic solvents can make it worthwhile to pursue.

Ultimately, to determine whether or not this method is a useful one, it is important to take into consideration the aspects discussed previously, to conduct thorough testing on sample materials, and to take time to find the most efficient settings and blasting approach for the object and coating type. Aspects of the job such as the amount of objects to be cleaned, the structure of the objects, the coating to be removed, and the amount of resources available—including staff time and money—need to be thoroughly considered prior to rental to understand whether or not this method of cleaning is an appropriate one in any situation. Further testing in the future will determine which changes in variables can remove specific coatings from metals. The projects discussed here are therefore just the start to a much wider investigation.

ACKNOWLEDGMENTS

The authors would like to acknowledge and appreciate the aid of Trustees of the Wallace Collection, London, particularly Head of Conservation David Edge and Senior Furniture Conservator Jürgen Huber. Gratitude is also owed to University College London and the steadfast support of Dr. Renata Peters, James Hales, and Kevin Reeves. Additionally, we would like to thank the team at Cryogenesis Limited, UK, which supplied the Cold Jet i3 MicroClean equipment. Last and certainly not least, we would like to thank our families who have supported us throughout this endeavor.

Appendix 1. COATING REMOVAL RESULTS FOR COUPONS

Percent of Coating Removed from Brass and Bronze Coupons

	Shellac	Incralac	Ercalene	Briwax	Renaissance Wax
Brass Coupon 1	Q1: 0%–1% Q2: 0%–1%	—	Q3: 0%–2% Q4: 0%–1%	—	—
Brass Coupon 2	—	—	—	Q1: 95%–100% Q2: 95%–100%	Q3: 95%–100% Q4: 95%–100%
Brass Coupon 3	—	Q1: 0%–1% Q2: 0%–1% Q3: 40%–50% Q4: 80%–85%	—	—	—
Brass Coupon 4 (EXTRA)	Q1: 0%–1%	Q2: 0%–1%	Q3: 0%–1%	—	—
Cupronickel Coupon 1	Q1: 0% Q2: 0%	—	Q3: 0% Q4: 0%	—	—
Cupronickel Coupon 2	—	—	—	Q1: 95%–100% Q2: 95%–100%	Q3: 95%–100% Q4: 95%–100%
Cupronickel Coupon 3	—	Q1: 0% Q2: 0% Q3: 0% Q4: 0%	—	—	—
Cupronickel Coupon 4 (EXTRA)	Q1: 0%	Q2: 0%–1%	Q3: 0%	—	—
Averages	.25% (average per 6 quadrants)	12.9% (average per 10 quadrants)	.33% (average per 6 quadrants)	97.5% (average per 4 quadrants)	97.5% (average per 5 quadrants)

Amount removed is approximate. Ranges are used to compensate for this. Averages are taken from the median of ranges.

Percent of Coating Removed from Mild Steel Coupons

	Paraloid B-72	Paraloid B48-N	Renaissance Wax	Petroleum Jelly
Mild Steel Coupon 1	Q1: 40%–50% Q2: 20%–30%	Q3: 0% Q4: 0%	—	—

Mild Steel Coupon 2	—	—	Q3: 95%–100% Q4: 95%–100%	Q1: 50%–55% Q2: 95%–100%
Mild Steel Coupon 3 (EXTRA, Blast First, Then Heat)	Q1:15%–20%	Q3: 0%–1%	Q4: 95%–100%	Q2: 95%–100%
Mild Steel Coupon 4 (EXTRA, Blasting at 90°Angle)	Q1: 20%–25%	Q3: 0%–1%	Q4: 95%–100%	Q2: 95%–100%
Averages	27.5 % (average per 4 quadrants)	.25% (average per 4 quadrants)	97.5% (average per 4 quadrants)	86.2% (average per 4 quadrants)

Amount removed is approximate. Ranges are used to compensate for this. Averages are taken from the median of each range.

NOTE

1. The coupons were bought as "phosphor bronze"; however, compositional analysis undertaken with a pXRF after the experiments were completed revealed that the bronze coupons were cupronickel.

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    http://www.ebay.co.uk
    http://www.ebay.co.uk/usr/hardware0utlet?_trksid=p2047675.l2559

Cold Jet i3 MicroClean Single-Hose Dry Ice Shaving Unit
    Cryogenesis Ltd. UK
    Units N1/N2
    Riverside Industrial Estate
    Littlehampton, West Sussex, UKBN17 5DF
    http://www.cryogenesis.co.uk/newsfeed/products
    Cold Jet Distributors: http://www.coldjet.com/en/company/distributor-locator.php

Cupronickel Coupons
Metals Supermarkets
11 Hanover West Industrial Estate
161 Acton Ln.
London, UK NW10 7NB
http://metalsupermarkets.co.uk/park-royal/

Hitachi S3400N Scanning Electron Microscope
Hitachi Hi-Technologies Corporation
http://www.hitachi-hightech.com/eu/product_detail/?pn=em-su3500

Incralac
Conservation Support Systems
PO Box 91746
Santa Barbara, CA 93190-1746
http://www.conservationsupportsystems.com/main

Paraloid B-72, Paraloid B48-N, Ercalene, and Renaissance Wax
Conservation Resources UK Ltd.
Unit 15 Blacklands Way
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http://www.conservation-resources.co.uk/index.php?main_page=index

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ELEPHANT IVORY: AN OVERVIEW OF CHANGES TO ITS STRINGENT REGULATION AND CONSIDERATIONS FOR ITS IDENTIFICATION

STEPHANIE E. HORNBECK

Elephant ivory has been considered a prized luxury material across world cultures from ancient times to the present day. Elephant ivory is the most highly valued of all ivories and describes the material comprising the tusks of Asian male and African male and female elephants, as well as that of their relative, the mammoth. Today the collection of ivory art and artifacts is inextricably linked to the plight of the African elephant and its status as a seriously threatened species, as demand for elephant ivory has risen sharply in the last decade. In 2014, international and US national laws were again strengthened to combat the rise in trafficking of elephant ivory. The 2016 revision of the African elephant rule under section 4(d) of the Endangered Species Act aims to achieve a near-total ban in commerce of raw and worked ivory and affects transit of legally documented worked ivory art and artifacts as well. As conservators may be involved in the identification and sampling of ivory materials, it is important to be aware of the methods to identify ivory and new regulations that apply to it.

KEYWORDS: Elephant ivory, CITES, Endangered Species Act, Ivory identification, Ivory regulation, Poaching, Trafficking, US Fish and Wildlife Service

1. INTRODUCTION

The collection of ivory art and artifacts is inextricably linked to the plight of the African elephant and its status as a seriously threatened species, as demand for elephant ivory has risen sharply in the past decade. According to the Wildlife Conservation Society, in 2012, an estimated 35,000 African elephants—the equivalent of 96 per day—were killed for their ivory tusks (Wildlife Conservation Society 2016). Consequently, in 2014, international and US national laws were strengthened to combat the rise in trafficking of ivory, including trade of ivory artworks and artifacts. The Illegal Wildlife Trade Conference convened in London on February 13, 2014, to discuss key actions to eliminate the illegal wildlife trade. In 2014, the United States, the second largest market in the world (after China), strengthened sanctions on importing African ivory. In February 2014, the US Fish and Wildlife Service (FWS) announced that it would temporarily ban the trade in African elephant ivory to the United States by prohibiting all commercial imports and exports of raw and worked ivory, regardless of age and including sales by auction houses and other art dealers; this administrative action was revised to allow for narrow exemptions under the new rule change to revise the African elephant rule under section 4(d) of the Endangered Species Act (ESA), which became law in July 2016 (US Fish and Wildlife Service, 2016b).

As conservators may increasingly be involved in the examination, and possibly sampling, of ivory artifacts, the objective of this article is to present a background context for, and discussion of, relevant aspects of new regulations and to provide a review of the criteria to identify elephant ivory. Responsible stewardship of worked ivory art objects and artifacts involves respect for the new regulations aimed at elephant conservation.

Fig. 1. Nimrud (Kalhu) Iraq, *Cow and calf furniture element*, 850–700 BC, ivory and metal. Collections of Bolton Library and Museum Service, BOLMG 1964.2.3.A. Copyright Bolton Council (Courtesy of Stephanie Hornbeck)

2. THE ART OF ELEPHANT IVORY

Elephant ivory has been considered a cherished luxury material across cultures from ancient times to the present day. Highly prized for its creamy luster and workability, ivory has been used for sculpture in Africa, Asia, and Europe for millennia and later in the Americas as international trade routes expanded. The inherent value of ivory, its attractive visual qualities, and its ability to be carved and worked, combined with royal patronage for the creations of highly skilled carvers, have yielded master artworks in many world cultures. Some of the most admired ancient works were derived from royal commissions for the Assyrian Empire (fig. 1). Historical accounts describe a colossal 10 m tall chryselephantine—ivory and gold—statue of Athena by master sculptor Phidias that once stood inside the Parthenon. Medieval Europe saw the rise of demand for ivory ecclesiastical objects, and Paris in particular became an important ivory carving center. Ivory carving centers existed throughout Asia and Southeast Asia.

This article will primarily present examples of African ivory artworks (figs. 2–4), as my ivory research has focused on the study of these works. Ivory, from the elephants that produce it to the intricately carved artifact, is a material closely associated with Africa.

Ivory is a relatively soft material, which enables it be worked with non-metal tools, and its surface can be highly polished, yielding the characteristic glossy, creamy, and semi-translucent surface for which

Fig. 2. Yoruba peoples, Owo region, Nigeria, *Bracelet*, 16th century, ivory, 14.5 × 10.5 × 10.5 cm. National Museum of African Art, 2005-6-8. Gift of Walt Disney World Co., a subsidiary of the Walt Disney Company (Courtesy of Franko Khoury)

it is much admired. As it ages, it often develops a yellow-golden patina. Ivory can be bleached to whiten it, and it can be stained with oils, dyes, and colorants to achieve a range of warm brown colors (figs. 3, 4). Paint and gilding were sometimes applied to ivory. Thus, the possible presence of a surface alteration or coating is important to consider when identifying ivory.

3. THE ELEPHANT IVORY MARKET

It is noteworthy that although ivory has historically been prized by cultures within Africa, perhaps most famously by the ancient Egyptians and the Kingdom of Benin (fig. 5), internal consumption was limited—often restricted to royalty—and did not put elephant populations at risk. However, the establishment of international trade with Africa had dire consequences for elephant populations throughout the continent. Demand for ivory, variously under the ancient Roman Empire, with India and the Far East, and eventually with Europe and North America, historically impacted elephant populations in various regions of the continent. Demand in the 20th and 21st centuries has seen the greatest decimation of African elephants, continent-wide. Trade networks brought the raw material to North America, where it has been widely used in the past two centuries to manufacture combs, handles, billiard balls, and piano keys, along with art objects. In the 19th century, the United States

Fig. 3. Note the pale cream coloration. Kongo peoples, Congo, *Tusk* (detail), ca. 1860, ivory, 72.4 × 14.6 × 6 cm. National Museum of African Art, 96-28-1. Bequest of Mrs. Robert Woods Bliss (Courtesy of Franko Khoury)

was the world's greatest consumer of ivory. For a period of about 150 years (1830s–1980s), the largest ivory processing plant in the United States operated in the village of Ivoryton in Essex, Connecticut, which at one time processed up to 90% of all elephant ivory imported into the United States (Malcarne and Milkofsky n.d.).

The populations of both African and Asian elephants have declined dramatically since the mid-20th century. According to the FWS (the federal agency that regulates and enforces compliance with national and international importation laws that apply to fauna and flora), although habitation destruction and fragmentation increasingly threaten elephant populations, the greatest threat to their survival is poaching—illegal killing—to supply the highly lucrative ivory market. Because both female and male African elephants have tusks, they are particularly susceptible to poaching. In 1900, the African elephant population was 10 million (Christy and Hartley 2013). In recent decades, their population has declined from 1.2 million in 1980 to 420,000 in 2012 (Wildlife Conservation Society 2016). The situation is more dire for Asian elephants, whose population is less than 45,000 (Nelleman et al. 2013).

Fig. 4. Note the deep red-brown coloration. Kongo peoples, Democratic Republic of the Congo, *Figure with Child (mvuala)*, late 19th to early 20th century, ivory, mirror, resin, pigment, 13.3 × 5.1 × 5.7 cm. National Museum of African Art, 86-2-1. Museum purchase (Courtesy of Franko Khoury)

At present, China is the largest consumer of elephant ivory, considered emblematic of status and wealth (fig. 6) and also used in alternative medicine. According to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Elephant Trade Information System (ETIS), most of this ivory is obtained illegally in Africa to be carved and sold in Asia (ibid.). Thailand is another large consumer, and Vietnam, Malaysia, and the Philippines are also major trade routes; most seized ivory is found in ocean vessel shipping containers from East African ports, primarily in Tanzania and Kenya (ibid.).

The fates of elephants are affected for good or ill by human activity. In regions with effective wildlife conservation methods in place, as in southern Africa, their populations demonstrate increases, whereas those in regions of civil strife show a population decline. In April 2015, the African Elephant

Fig. 5. Carved elephant tusks adorn a royal altar. Eliot Elisofon, *Benin Palace Ancestral Altar for Oba Ovonramwen*, 1970, photograph. Eliot Elisofon Photographic Archives, National Museum of African Art, EEPA EECL 07590 (Courtesy of Eliot Elisofon)

Summit convened in Kasane, Botswana, and announced that the African elephant could be hunted to extinction within 10 to 20 years (Beaudufe 2015). It is worth remembering that an ancient elephant sub-species native to Turkey, Iraq, and Syria, the Syrian elephant (*Elephas maximus asurus*)—the largest of the Asian elephant sub-species at 3.5 m tall—was hunted to extinction in the 8th century BC in direct relation to ivory demand for luxury objects.

Some southern African regions—mainly the countries affected by embargoes—are experiencing an increase in elephant populations. Yet poaching continues to be an enormous issue for regions that cannot adequately oversee vast elephant ranges. Attempts to staunch poaching and illicit trade, while addressing increasing stockpiles of ivory from elephants that have died of natural causes, are dilemmas that have international implications.

4. REGULATIONS: TOWARD ELEPHANT CONSERVATION

The intersection of the ivory trade with elephant conservation efforts has resulted in an international consensus for ivory regulation. Several laws instituted over the past 40 years strictly regulate its legal trade. These have broad application and affect museums and individual collectors, among other entities. Loopholes in laws and regulations, exemptions for trophy hunting, and differing interstate laws for African and Asian elephant ivory have contributed to a crisis situation in the making since

Fig. 6. An ivory shop in Hong Kong; note the placard displaying a rendering of a mammoth, implying the goods are mammoth ivory. 2016, National Geographic (Courtesy of Paul Hilton EPA)

before 1976 (when the first convention on the trade of animal parts was instituted) and are exacerbated by spiking demand since 2007. The stated reasons provided by the FWS for the increased restrictions on worked African elephant ivory include that the United States remains a significant ivory market and that the legal ivory trade can provide a cover for illegal trafficking of ivory (US Fish and Wildlife Service 2016c).

A series of international and national laws and regulations protect the trade of ivory. CITES, formed in 1975, became the only global treaty to ensure that international trade in plants and animals does not threaten their survival in the wild. It provides a framework for cooperation and collaboration among nations to prevent decline in wild populations of animals and plants. At present, 182 countries, including the United States, implement CITES. All Asian elephant populations and most African elephant populations are listed on CITES Appendix I, species that are most endangered—threatened with extinction. Although legally binding on the parties (countries that have voluntarily agreed to be bound by the Convention), CITES regulations do not take the place of national laws.

4.1 EMBARGOES

In 1989, CITES member countries agreed on a world-wide ban on the trade of ivory. This historic vote came after the African elephant was deemed "threatened" due to excessive poaching to meet market demand. Earlier that year, conservationist and Kenyan Wildlife Director Richard

Fig. 7. A pile of elephant ivory, valued at $3 million, confiscated by Kenyan game wardens and burned by authorities, July 1989, Nairobi, Kenya (Courtesy of Tom Stoddart Archive)

Leakey persuaded the Kenyan government to burn 12 tons of elephant tusks (fig. 7) rather than sell them to call international attention to the devastating effects of the ivory trade (Christy and Hartley 2013).

Additionally in 1989, the countries of Botswana, Namibia, South Africa, and Zimbabwe implemented ivory trade embargoes. At present, ivories carved before the 1989 ban are designated as “pre-Embargo” works of art. In 2007 and 2008, CITES eased the embargo by allowing these countries to sell government-owned ivory amassed before 1989 to Japan and China, respectively, stipulating that a

Fig. 8. Stockpile of confiscated elephant ivory before crush outside of Hong Kong in January 2014. Hong Kong is one of the largest commercial centers of illegal ivory. (Courtesy National Geographic Voices)

percentage of the proceeds must be directed toward elephant conservation. The sales to Japan and China were restricted to use within domestic markets; ivory from these sales could not be traded internationally. Yet these well-intentioned sales had the opposite desired economic effect of driving down the demand for ivory by increasing supply, and instead, since 2007, demand soared and poaching increased again (Christy and Hartley 2013).

4.2 SANCTIONED CRUSHES OF CONFISCATED STOCKPILES

The Wildlife Conservation Society has reported recent destruction of stockpiles of confiscated illegal raw and worked ivory by governments around the world (Wildlife Conservation Society 2016). Like the 1989 bonfire in Kenya, destroying the ivory by crushing or burning ensures that it cannot re-enter the market as the valuable commodity it once was. In 2013 and 2015, the FWS pulverized holdings of confiscated illegal ivory from the United States in a concrete crusher. Since 2014, more than 20 countries and territories, including Belgium, France, Kenya, Gabon, the Philippines, and Hong Kong (fig. 8), have also crushed confiscated ivory. In 2016, Kenya once again held the world's largest ivory destruction event when it burned 105 metric tons (ibid).

However, ivory artifacts with historical value may unfortunately be mixed in with the more recent carvings in crushes. National Museum of African Art Curator Bryna Freyer explains that when historically important artifacts are crushed, not just the animal is lost but cultural heritage "dies" as well (Freyer, pers. comm.). In an important precedent, before the 2015 crush in New York's Times Square, museum experts reviewed confiscated items, and two objects considered historically important were set aside from destruction.

5. US FEDERAL LAWS

Since the 1970s, the international trade of elephant ivory has been highly regulated by several laws; these apply to the importation and travel of artifacts across international and national borders. Sometimes the laws overlap, in which case the stricter law applies:

- *The Lacey Act (1900 and later amendments)*: Prohibits trade of wildlife taken in violation of any state or foreign wildlife law or regulation; affects interstate commerce.
- *The Endangered Species Act (1973)*: Designed to prevent the extinction of native and foreign species of wild fauna and flora; lists Asian elephants as "endangered" (in danger of extinction) and African elephants as "threatened" (in danger of becoming endangered). This act prohibits elephant parts and products, including worked ivory objects, from being imported into the United States except under certain conditions. This act was strengthened in 2016 with the implementation of a final rule revising section 4(d) of the African elephant rule, which narrows the number of allowed exceptions (see section 5.1) (US Fish and Wildlife 2016b, c).
- *The African Elephant Conservation Act (1988)*: Prohibits the import of raw or worked ivory into the United States with certain exceptions. This act also established a grant program to fund elephant conservation efforts. Figure 9 depicts an elephant herd in the wild near Namanga, Kenya.

In July 2013, while visiting Tanzania, President Obama issued an executive order committing the United States to increase efforts to combat wildlife trafficking (US Fish and Wildlife Service 2016b). Executive orders engage the entire US government, including all federal agencies. This executive order led

Fig. 9. Eliot Elisofon, *Elephants in Amboseli National Park*, West of Namanga, Kenya, 1959, photograph. Eliot Elisofon Photographic Archives, National Museum of African Art, EEPA EECL 24721 (Courtesy of Eliot Elisofon)

to new federal regulations in 2014, including a series of administrative actions with different timelines, implementing a nearly complete ban on commercial import of African elephant ivory into the United States. In July 2016, the FWS enacted the proposed 2015 rule change to rule 4(d) of the ESA to increase protection of African elephants by limiting commercial activities (ibid).

Federal law cannot stop ivory from being sold within a state's borders. Consequently, since February 2014, 14 individual states in the United States—California, Connecticut, the District of Columbia, Florida, Hawaii, Illinois, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, Vermont, and Washington—have introduced bills to comply with new FWS regulations to ban the commerce of African elephant ivory. New Jersey (implemented May 2014) and New York (implemented June 2014) were the first to implement state laws prohibiting elephant ivory commerce (Wildlife Conservation Society 2016).

5.1 IMPACT ON MUSEUMS AND PRIVATE COLLECTORS

Exceptions to the revised African elephant rule of the Endangered Species Act have been retained for legally documented antique (older than 100 years) worked ivory objects, which were temporarily impacted by the 2014–16 FWS restrictions, and objects that are part of a traveling exhibition (US Fish and Wildlife Service 2016b, c). Appendix I to Director's Order 210 describes acceptable documentation, requiring proof of age and designation of elephant species (US Fish and Wildlife Service 2016a). A new so-called *de minimis* exception to the rule has been added to allow for the commerce of objects with small amounts of worked African elephant ivory components (fig. 10), provided that specific criteria are met, including that ivory is not the primary material or in raw form and that ivory components total less than 200 g (US Fish and Wildlife Service 2016c).

The FWS has compiled a useful table and informative list of questions and answers about the ESA rule change to guide owners and stewards of African elephant ivory artifacts; topics include Import, Export, Sales across State Lines (Interstate Commerce), Sales within a State (Intrastate Commerce),

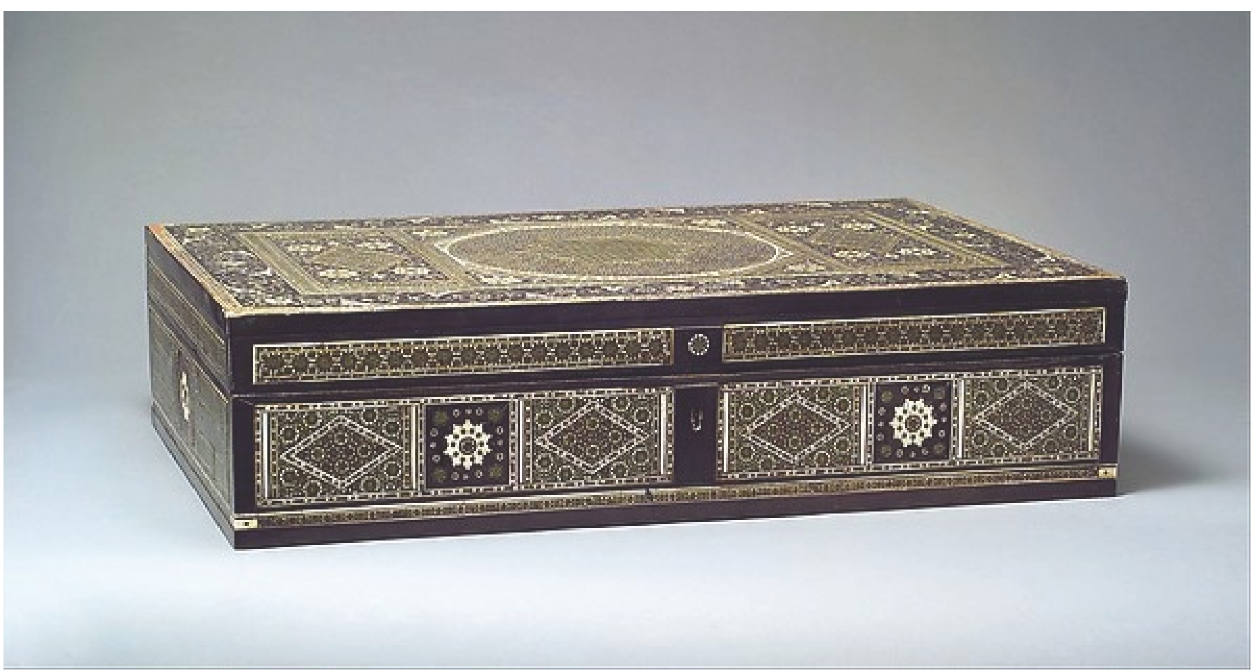

Fig. 10. Indian, *Writing box*, 16th century, wood inlaid with ivory, 34.3 × 53 × 13 cm. Metropolitan Museum of Art. Purchase, Pat and John Rosenwald Gift, 2004. (Courtesy of Metropolitan Museum of Art)

Non-Commercial Movement within US, and Personal Possession (US Fish and Wildlife Service 2016c). Among the questions and answers provided are two in particular that apply to museums and collectors (US Fish and Wildlife Service 2016c):

> **What requirements must be met to import African elephant ivory as part of a traveling exhibition?** Worked African elephant ivory may be imported as part of a traveling exhibition, such as a museum or art show, provided that the ivory was legally acquired prior to February 26, 1976; the person or group qualifies for a CITES traveling exhibition certificate; and the item containing elephant ivory is accompanied by a valid CITES traveling exhibition certificate or an equivalent CITES document that meets the requirements of 50 CFR 23.49. Raw African elephant ivory cannot be imported as part of a traveling exhibition. (p. 11)
>
> **How do I demonstrate that my item meets the criteria to qualify as an antique under the ESA?** We have provided guidance in the Appendix to Director's Order 210 on ways to demonstrate that an item qualifies as an ESA antique. We want to clarify that forensic testing is not necessarily required. Provenance and age may be determined through a detailed history of the item . . . [or] a qualified appraisal or another method, including using information in catalogs, price lists and other similar materials that document the age by establishing the origin of the item, can also be used. (p. 9)

When ivory travels into the United States from abroad, it must enter at one of 13 approved so-called antique ports. These are Anchorage, Baltimore, Boston, Chicago, Honolulu, Houston, Los Angeles, Miami, New Orleans, New York, Philadelphia, San Francisco, and San Juan, Puerto Rico.

The 2016 regulations:

- Render transit of artifacts more complicated, as different ivory products have differing legal requirements because laws differ across state, national, and international boundaries (e.g., CITES and ESA protections differ for African and Asian elephants).
- Involve stricter transit requirements designating species identification and age documentation, including those for ancient worked ivories of known provenance.
- Have complicated considerations for composite artifacts, some containing small pieces of ivory (see fig. 10) that are difficult to accurately identify or date. They have also complicated considerations for legal ivory artifacts that may have undocumentable ivory repairs.

The FWS can amend the regulations, as has happened for example for Director's Order 210, so it is important to check their website for current information.

5.1.1 Case Study: Traveling Museum Exhibition

A recent exhibition installation experience encapsulates these new issues. In October 2014, I assisted the Bolton Museum, based in Bolton, England, with the West Palm Beach, Florida, installation of an international traveling exhibition of ancient Egyptian artifacts. Among the objects were 13 ancient ivories (e.g., mirror handles, kohl containers, bracelets, cups, and plaques) composed of elephant (see fig. 1) and hippopotamus ivory.

The exhibition had been traveling since 2011 and came into Miami International Airport via Hong Kong in September 2014, where the ivories and several other organic artifacts, including human and animal mummies, which shared the same bill of lading as the ivories, were delayed release for 5 days by the Miami office of the FWS. All of the artifacts had CITES permits, although these had been renewed while the objects were in Hong Kong, perhaps signaling a red flag to the FWS agent, as Hong Kong is a major center for the ivory black market in China.

For 4 days, the ivories and animal mummies were held in their carrier airline's warehouse, to which we did not have access and to which we could not confirm if climate controlled. Miami has a tropical climate, with ambient relative humidity typically above 70%, which could yield structural damage or mold growth on organic artifacts acclimated to drier conditions. In compliance with the new

2014 regulations, the Miami FWS agent asked for species identification of the elephant ivories, which the curator could not readily provide from existing documentation about the artifacts. It is not atypical for the origin species of an ancient elephant ivory artifact to be unknown. Indeed, destructive analysis would be the only way to provide such information. These ivories had never undergone such testing. We cited the exception to the new regulations for documented worked elephant ivories that were part of a traveling exhibition to the FWS agent. Eventually, after this case was passed up to FWS headquarters in Washington, DC, the non-ivory artifacts were released. One day later, the ivories were released on the condition that species identification be provided on transit out of the United States, achieving a temporary reprieve for exhibition.

6. A REVIEW OF IVORY FEATURES AND METHODS OF IDENTIFICATION

As the new regulations are implemented, conservators may need to identify ivory or its substitutes, so a review of ivory features and methods of identification is useful. The material ivory includes the highly valued tusks and teeth of the following mammals: mastodons and mammoths (both extinct), elephants, hippopotami, walruses, warthogs, sperm and killer whales, and narwhals. Elephant ivory is the most highly valued of all ivories and describes the material comprising the tusks of Asian male elephants and African male and female elephants, as well as that from their relative, the mammoth. Although they share the taxonomic family Elephantidae, African elephants (*Loxodonta africana*) and Asian elephants (*Elephas maximus*) are different species.

The tusks of elephants, although differing in function, are directly related anatomically and compositionally to the teeth of other mammals. Elephant tusks correspond to incisors. Tusks can grow to 3.5 m in length (some African males) and weigh up to 90 kg (165 lb.) each. Like teeth, tusks have a pulp cavity where the root and soft tissue attach it to the jaw of the animal. The pulp cavity extends for approximately two-thirds of the tusk; its presence or absence on a carved ivory artifact can indicate the part of the tusk that was used and the original length of the tusk. Also like teeth, tusks are composed of dentine and cementum; however, teeth also have a hard outer layer of enamel, which is found only at the tip of tusks. Like living bone and dental tissues, ivory tusks are composed primarily of an inorganic component, calcium hydroxyapatite (approximately 60%), and an organic component, collagen (approximately 40%).

Visual examination under low magnification (fig. 11) remains one of the most useful methods to identify ivory, particularly if diagnostic features are present. It can be difficult to discern structures on worked ivory artifacts, especially if they are deteriorated or small in section (as for inlays). It is important to compare the object in question against reference materials and good detail images of elephant ivory, ivory from other mammals, and ivory substitutes (for diagnostic images, see Penniman [1984], Krzyszkowska [1990], Espinoza and Mann [1992], Hornbeck [2010/16], US Fish and Wildlife Service [2010], and Mann and Marts [2013]).

The characteristic visual identifier of elephant ivory is the presence of a pattern of intersecting arcs sometimes called *engine turnings*, *cross-hatching*, or *Schreger lines* (named after the German anatomist Bernhard Gottlob Schreger, who first described them in 1800) visible in cross section.

This intersecting arc pattern is present only on mammoth and elephant ivory; acute arc angles on mammoth ivory (fig. 12) distinguish it from elephant ivory (figs. 13, 14), which has obtuse arc angles. No other mammal ivories have the pattern, nor do natural material substitutes. The pattern can be viewed with the naked eye or under low magnification. However, the absence of the pattern does not absolutely negate a material, as working/cutting the ivory from different angles, especially tangential, may yield sections that do not show the pattern.

Fig. 11. An inexpensive simple adaptor lens can be fitted to the camera lens of a smartphone or media device to turn it into a microscope. This adaptor can zoom in to magnify, and one can view the feature in real time, take photos, and share them. Here, Stephanie Hornbeck uses a smartphone microscope adaptor to examine Nimrud ivory objects. (Courtesy of Stephanie Hornbeck)

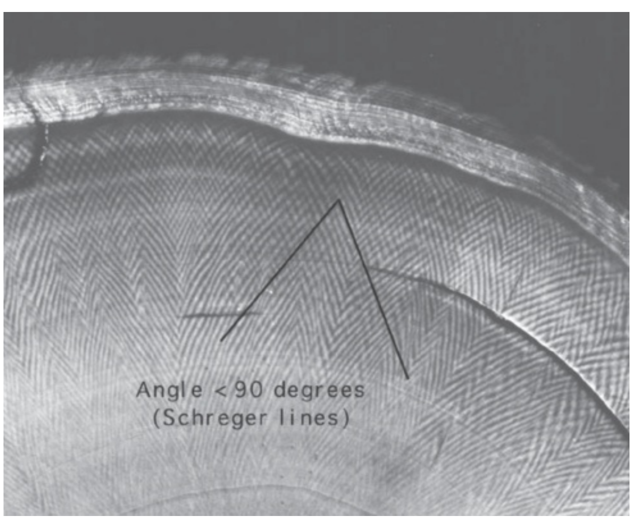

Fig. 12. Note acute angles of intersecting arcs (Schreger lines) on cross section of mammoth ivory. (Courtesy of US Fish and Wildlife Service and the World Wildlife Fund)

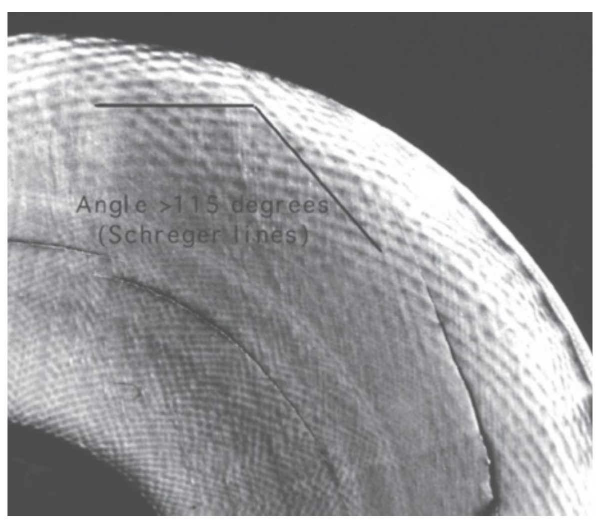

Fig. 13. Note obtuse angles of intersecting arcs (Schreger lines) on cross section of elephant ivory. (Courtesy of US Fish and Wildlife Service and the World Wildlife Fund)

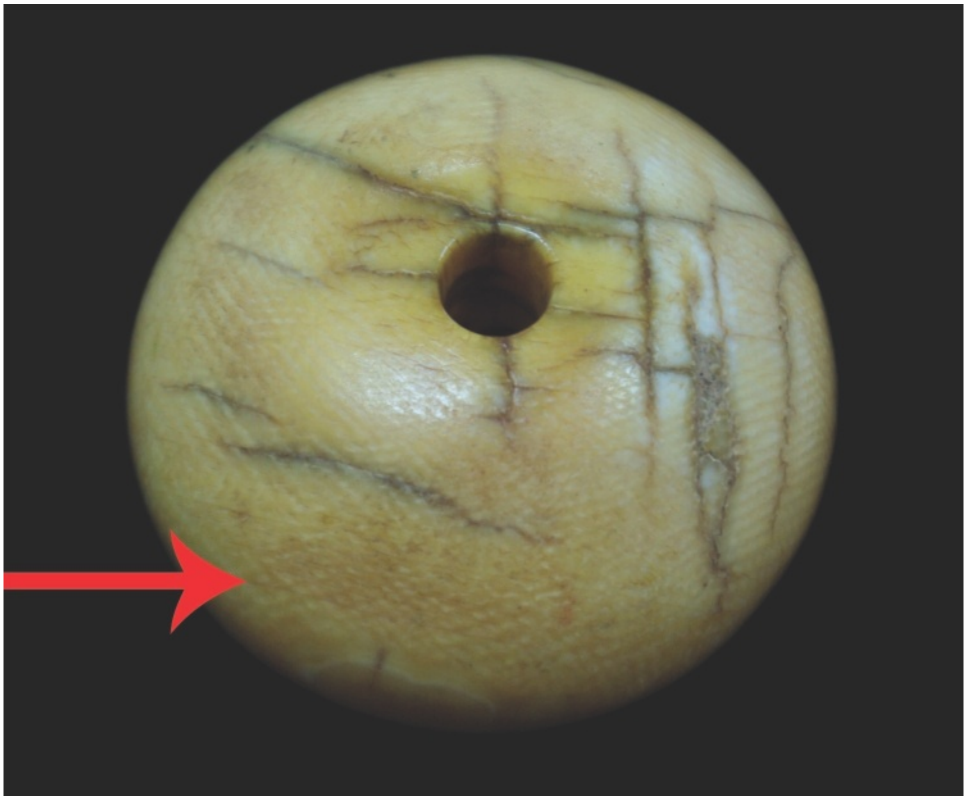

Fig. 14. Note the presence of intersecting arcs (Schreger lines) on the object. Turkana peoples, Kenya, *Labret*, mid-20th century, ivory, 5.0 × 5.5 × 3.3 cm. National Museum of African Art, 2004-9-3. Gift of Eileen Sobeck (Courtesy of Stephanie Hornbeck)

6.1 ELEPHANT IVORY SUBSTITUTES

As with other natural materials of high value, several substitute materials, including other mammal ivories and natural and synthetic materials, have been used to emulate elephant ivory. Now with the increased regulation of elephant ivory commerce, art vendors are increasingly identifying their objects as mammoth ivory or another substitute to circumvent the regulations, even if the material is actually elephant ivory. Thus, it is helpful to recognize the characteristics of these substitute materials as well.

Other animal ivories include mammoth tusk, mastodon tusk, hippopotamus teeth, sperm whale and killer whale teeth, narwhal tusk, walrus teeth and tusk, and warthog tusk.

Other natural materials include bone (historically the most often substituted material for ivory, characterized by the Haversian system of elongated holes from blood vessels), antler (outgrowths of bone), horn (keratin-based composition), shell, and vegetable ivory (also known as tagua or "ivory nuts").

Synthetic materials include various composite mixtures, such as ivory dust and casein, ivory dust and styrene resin, calcium carbonate and adhesive, casein and hardener, and plastics, typically celluloid. Celluloid is a proprietary plastic composed of cellulose nitrate and camphor developed in the 19th century. One of its primary uses was as an ivory substitute.

The provenance and age of an ivory artifact may shed light on the geographic origin of the material, which can narrow down the possibilities for identification. For example, elephants are not indigenous to North and South America, so prior to the establishment of international trade routes in the mid-16th century, elephant ivory could not have been used in these regions. If the ivory object was fabricated in the northern-most regions of Europe, Asia, and North America, it is as likely to be mammoth or walrus ivory as elephant. If the artifact was fabricated after the mid-19th century, it could be plastic.

The size of the artifact can indicate the source of its material. Elephant tusks from adults are much longer than other mammal ivories, most bones, vegetable ivory, and shells. Hence, a long, uninterrupted section may be indicative of elephant ivory. Similarly, because vegetable ivory derives from palm nuts that grow up to 5 cm in diameter, only whole artifacts that are small in size (i.e., miniatures, snuff boxes, cane heads) could be fabricated from this material. The weight of the object can also be a telling qualifier. Ivory and bone are heavier than shell, horn, composite mixtures, and plastics, which are all lightweight materials.

6.2 AGED ELEPHANT IVORY

As ivory desiccates, it loses its surface luster and becomes harder. With the passage of time, these changes can make visual identification more difficult. Indeed, ancient ivory, bone, and wood (as from archaeological contexts) can appear quite similar, sometimes requiring the use of analytical testing for identification. Thus, it is useful to know what aged ivory looks like. The deterioration of ivory is directly related to its composition and formation. Unlike the teeth of living mammals, the dentine layers of tusks are produced annually, somewhat similar to tree rings in cross section (Uno et al. 2013). Once these mammals are no longer living, the organic components of ivory deteriorate over time. Low humidity levels can result in separation or delamination of the layers of dentine (fig. 15), visible in cross section as a

Fig. 15. Directional cracking can yield delamination of ivory layers. Yoruba peoples, Nigeria, *Tusk* (detail), 19th century, ivory, 130 × 12.2 × 10.4 cm. National Museum of African Art, 79-16-47. Bequest of Samuel Rubin (Courtesy of Stephanie Hornbeck)

cone-within-a-cone pattern. Checks and cracks occur in longitudinal and radial planes in locations related to gaps in formation. Radial cracks form in the manner that wood splits along the grain. Cracks in the transverse plane follow the formation of dentine. In combination, directional cracking patterns can cause the ivory to exfoliate in curved rectangles. (For detail images of different types of deterioration, see Hornbeck [2010/16].)

6.3 TESTING/ANALYTICAL METHODS

More recent stringent regulations for elephant ivory will likely involve an increased necessity for testing to precisely identify elephant species and ivory age. Unfortunately, such precise requirements can only be served by destructive methods. It would be a very worthwhile endeavor for a conservation scientist to focus on development of a micro-analytical method that requires only a tiny sample. A review of the known methods to characterize elephant ivory is useful. The latter three methods are forensic techniques more appropriate for raw ivory than worked ivory artifacts.

Examination under longwave ultraviolet radiation can be diagnostic. Ivory fluoresces a bluish-white color, as do bone and shell. However, vegetable ivory fluoresces slightly orange and plastics absorb light, giving them a dull, matte appearance.

An older diagnostic test involves touching a small, obscure area of the object (i.e., the bottom) with a hot needle to indicate the presence of plastic or horn. Plastics will typically soften and emit a chemical odor (camphor in the case of celluloid), and horn will soften and smell like burned hair, whereas true ivory will not soften, although it may eventually char. This method may leave a permanent mark on the object and is not recommended for worked ivory artifacts.

If a more precise quantitative characterization is required, a sample may be submitted to analytical testing with Fourier transform infrared spectroscopy (FTIR). FTIR can differentiate ivory from its imitators, with the exception of bone, which is very similar in chemical composition.

DNA analysis has emerged as a precise method of identification and geographic sourcing (Wasser et al. 2004). The method utilizes a sample of ivory from which mitochondrial and microsatellite DNA can be isolated for comparison against data sets. This analytical method can differentiate between African (*Loxodonta africana*) and Asian *(Elephas maximus*) elephant species, and within a species it can distinguish forest from savannah dwellers. Furthermore, genetic variation within a geographic region indicates that ivory could be traced back to specific countries, and within those countries, even to specific forests. If enough organic material remains in aged samples, it is possible to extract DNA data from them as well. This method is promising for sourcing ivory confiscated from illegal trade, potentially enabling greater surveillance of specific geographic regions suspected of poaching.

Stable isotope analysis can trace origins and migration of wildlife source areas (Ziegler et al. 2013). Isotope markers, such as strontium-90, which substitutes for calcium in the minerals of skeletal tissue, can serve as a geochemical signature to source ancient and recent bone and ivory to a specific geologic area. Stable isotope ratios are based on stable isotope signatures in animal tissues that reflect local food sources and geology, and they can be used for tracing the origin or migration of wildlife. This principle has also been applied to determine the source of ivory; samples of at least 30 mg are needed.

Bomb curve radiocarbon analysis can accurately date ivory during and after the period of 1952–62, the “bomb curve” (Uno et al. 2013). The dramatic increase from 1952 to 1962 and subsequent decline of carbon-14 in the atmosphere relates to the testing of nuclear weapons. The technique uses accelerator mass spectrometry applied to the carbon contained in both collagen and the mineral apatite within ivory to provide an age of death of the animal from which the ivory originated. Bomb-curve radiocarbon analysis can provide a date within 2 years for samples dating after 1952. Such analysis is a potentially useful wildlife forensic method for recent ivories, although the sample size of at least 25 to 50 mg of collagen or 150 mg of apatite is not insignificant for many small ivory artifacts.

7. AIC POSITION PAPER ON AFRICAN ELEPHANT IVORY

In light of the complexities related to the new regulations for African elephant ivory, the AIC recently published the position paper "The Preservation of Cultural Property with Respect to U.S. Government Regulation of African Elephant Ivory" (AIC 2015). Conservators Nina Owczarek, Terry Drayman-Weisser, Jean Portell, and I prepared the paper for AIC, which aims to present a balanced approach that supports elephant conservation efforts and respects laws that halt illegal trafficking of new raw and worked ivory while also advocating for protecting permitted (pre-Convention, CITES, and ESA documented) worked ivories of documented provenance from unnecessary destruction, destructive testing, and possible confiscation. It is our hope that the AIC can collaborate with the FWS, the American Alliance of Museums, the Association of Art Museum Directors, the Archaeological Institute of America, and other allied organizations to differentiate between legal and illegal elephant ivory artifacts. Certainly all conservators are encouraged to respect state, national, and international laws and regulations that apply to elephant ivory (and all endangered species generally) by stipulating that objects that need conservation have proper legal documentation (see US Fish and Wildlife Service 2016a, c). Some well-considered guidelines aiming to preserve legally documented ancient and antique worked ivories need not be in opposition to the efforts of federal regulatory agencies to staunch the current flow of new raw and worked ivory from Africa's rapidly diminishing elephant populations.

8. CONCLUSIONS

As elephant ivory is a highly valued material in many Asian countries, particularly China, an increased Chinese industrial and business presence in Africa has seen a recent corresponding increase in the ivory trade. Because both male and female African elephants have tusks, they are targeted by poachers. As both males and females are at risk, the future of the entire species is at risk. New regulations banning African elephant ivory commerce also affect the transit of worked ivories of any age and also impact artifacts with small inlays or ivory repairs. Conservators can inform themselves of current regulations and also assist curators, collection managers, and collectors in abiding by CITES and new US federal and state laws related to artifacts that incorporate animal parts, notably elephant ivory. An understanding of ivory features and identification methods and knowledge of ivory substitute materials inform the conservator's examination of these objects.

Some American museums have implemented a moratorium/ban on the purchase of elephant ivory, and some have implemented educational/outreach programs. Since 2009, the Smithsonian Institution's Museum Conservation Institute has co-organized and hosted an important recurring program to train US Immigration and Customs Enforcement agents about cultural heritage in transit. This program aims to assist in stemming the illicit trade of antiquities, art, and artifacts, including those made of regulated plant and animal parts, like elephant ivory.

Some museums have begun to contextualize elephant ivory artifacts by providing information about elephant species conservation. The Metropolitan Museum of Art included this text panel in their 2014 exhibition *Assyria to Iberia at the Dawn of the Classical Age*:

> The rise in ivory collecting during the Iron Age was catastrophic for Syrian elephants. By the end of the eighth century B.C., they had been hunted to extinction. Today, nearly three thousand years later, the desire for carved ivories and trinkets made from modern elephant ivory once again threaten the future of elephants. In some countries, African elephants are the target of poachers who sell modern ivory to be used in such carvings. It is crucial to conserve and to protect African elephants from suffering the same fate as the Iron Age elephants of Syria.

Art vendors are adapting in opposite ways; for its May 2015 sale of African, Pre-Columbian, and Oceanic Art, Sotheby's identifies African Lega and Luba objects as bone or hippo ivory; yet traditionally, these types of objects are often carved of elephant ivory. The stakes are high and clearly the path complicated, as it winds among elephant conservation laws and regulations, illegal trade and transit, and preservation of legal worked ivory art and artifacts.

ACKNOWLEDGMENTS

I greatly appreciate the insights and knowledgeable contributions of the following colleagues to my own ivory research and to this subject in general: Bryna Freyer, Curator, Smithsonian Institution National Museum of African Art; Terry Drayman-Weisser, formerly Director of Conservation and Technical Research, The Walters Art Museum; Nina Owczarek, Conservator, University of Pennsylvania Museum of Archaeology and Anthropology; Catharine Hawks, Conservator, Smithsonian Institution National Museum of Natural History; Ellen Chase, Conservator, Smithsonian Institution Freer/Sackler Galleries; and Jean Portell, Conservator, Brooklyn, New York.

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ONE SMALL STEP FOR MAN, ONE GIANT LEAP FOR CONSERVATION

PAUL MARDIKIAN, CLAUDIA CHEMELLO, AND JERRAD ALEXANDER

This article describes the technical challenges of stabilizing and conserving 25,000 lb. (12.5 tons) of Apollo-era (1969–1972) *Saturn V* rocket engine parts that were recovered off the coast of Florida in 2013. After more than 40 years on the floor of the Atlantic Ocean, the engines had suffered extreme levels of deterioration and corrosion. Treatment was accomplished by taking a deliberate, archaeological object–based treatment approach for these composite objects that are both modern technological marvels and marine archaeological artifacts. The article describes the archaeological treatment approach adopted and the results of selected analytical work undertaken to understand the materials of construction and the deterioration processes.

KEYWORDS: Conservation, Marine, Archaeology, Aerospace heritage, NASA Apollo 11, Superalloys, Characterization, Corrosion, Stabilization, Composite materials, Corrosion inhibitors

1. INTRODUCTION

In March 2013, 25,000 lb. (12.5 tons) of Apollo-era (1969–1972) *Saturn V* rocket engine parts from several Apollo missions were recovered off the coast of Florida after more than 40 years on the floor of the Atlantic Ocean. With the support of the National Aeronautics and Space Administration (NASA), Jeff Bezos, Amazon's founder and chief executive, sponsored the expedition with the objective of finding the engines from Apollo 11. The engine parts were recovered from a debris field of 300 mi.^{2} at a depth of approximately 14,000 ft. (4,300 m) using deep-sea sonar and remotely operated vehicles (ROVs). After recovery, the artifacts were transported to the Kansas Cosmosphere and Space Center in Hutchinson, Kansas, to undergo excavation, identification, documentation, and conservation in a custom-designed facility. The recovery initiated exceptional press coverage and launched an unprecedented conservation project to preserve the most powerful, yet disposable, liquid-fueled engines that were ever made.

One of the chief difficulties of the project was planning conservation strategies for modern marine artifacts whose size, composition, and state of preservation were virtually unknown prior to their arrival in the lab. These oversize, complex artifacts are made from a combination of superalloys and other modern materials, many of which are unfamiliar to conservators. A superalloy is a high-performance alloy that exhibits several critical characteristics at high temperature, including outstanding corrosion resistance, high strength, excellent surface stability, and resistance to creep (Reed 2006). Identifying what materials were present was surprisingly difficult due to a scarcity of information about the composition of the engines and a veil of secrecy that still prevails after half a century.

The size and weight of the engine parts presented additional practical challenges for treatment, as did the extraordinary levels of deformation and corrosion alongside almost completely pristine metal. Addressing immediate stabilization concerns, such as keeping the artifacts wet at all times to prevent deterioration, added to the complexity and required a creative and flexible workspace and conservation approach.

Developing stabilization treatments that were compatible with multimetal artifacts propelled the general principles applicable to the conservation of marine archaeological artifacts to a completely different level. The decision to separate the different components for treatment or adopt a more holistic preservation philosophy was decided on a case-by-case basis. A successful multidisciplinary dialogue ensued and prompted an effective integration of conservation theory and practice to understand the level of deterioration of the engines and to determine how to best preserve the collection.

2. BACKGROUND AND HISTORY

2.1 THE APOLLO PROGRAM 1969–1972.

The Apollo program was NASA's third human spaceflight program, with the explicit goal of a manned lunar landing. Six of the missions (Apollo 11, 12, 14, 15, 16, and 17) achieved this goal. The Apollo missions began in 1961 and concluded in 1972, with a total of 12 missions flown. The lunar missions continued until Apollo 17 in 1972. The Apollo missions used the *Saturn V* rocket, an enormous multistage vehicle with its first stage powered by five F-1 engines as launch vehicles. The launch of Skylab in May 1973 marked the final flight of the gigantic *Saturn V* rocket and its F-1 engines. By the end of the Apollo program, a total of 65 F-1 engines were flown and lost at sea.

2.2 THE F-1 ENGINE

The development of the F-1 began with the United States Air Force in 1955 using materials and methods that were cutting-edge at the time. Once the Apollo program was under way, the F-1 was selected to power the first stage, the S1-C, of the *Saturn V* rockets that would carry mankind to the moon. The first test flight of the engines came in 1967 on the unmanned Apollo 4 mission. Two years later, on July 16, 1969, Apollo 11 lifted off, powered by five F-1 engines reaching an altitude of 65 km and speeds in excess of Mach 7 (8,643 kph) in less than two and a half minutes. Explosive bolts then fired, separating the first stage from the rest of the rocket, which plunged into the Atlantic Ocean.

The F-1 engines are a marvel of modern engineering and ingenuity. More than four decades after they were last used, they still hold the title of the most powerful liquid-fueled engines ever created. Each engine essentially consisted of a thrust chamber, exhaust nozzle, turbopump, injector assembly, turbine, and heat exchanger. A fully assembled F-1 was nearly 6 m tall, 4 m wide, and weighed more than 8,000 kg (fig. 1). Each engine generated a staggering 700,000 kg of thrust, consuming a mixture of 976 L of highly

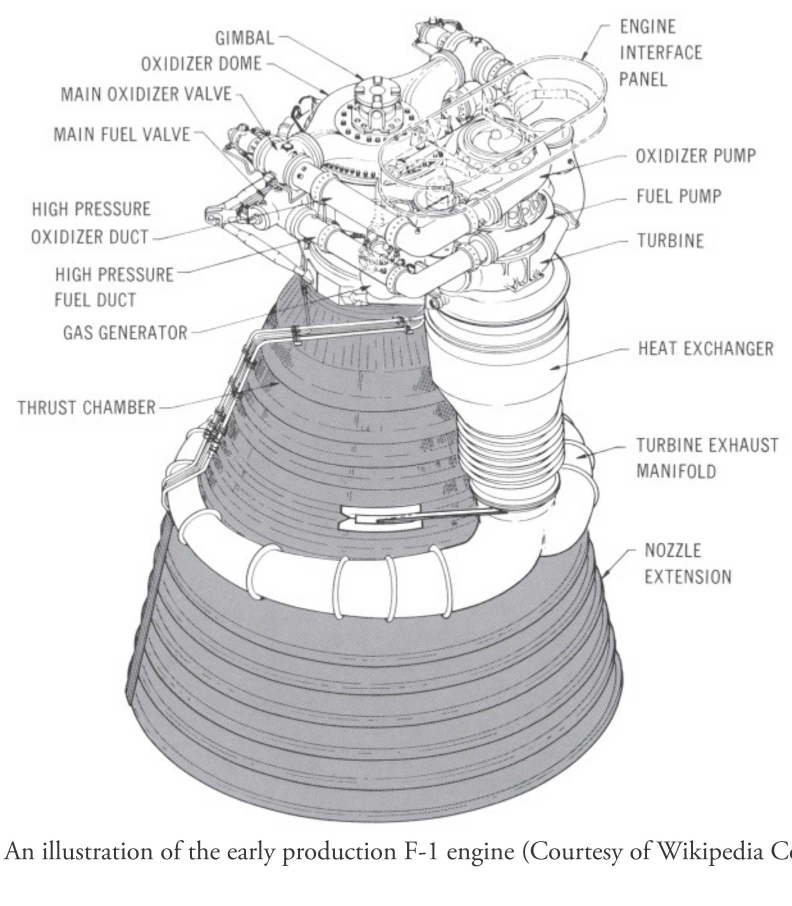

Fig. 1. An illustration of the early production F-1 engine (Courtesy of Wikipedia Commons)

refined kerosene and 1,565 L of liquid oxygen per second. By comparison, the space shuttle's three main engines collectively generated 544,000 kg of thrust. The thrust chamber and exhaust nozzle were constructed of a nickel-based superalloy called *Inconel X-750* to withstand the 3,300°C temperatures generated by the combustion process. The fuel and liquid oxygen were supplied via a turbopump driven by a 53,000-horsepower turbine. The fuels were kept separated until they reached the injector, which meters the mixture ratio and pressure to the thrust chamber. The heat exchanger acts as a sort of radiator, cooling exhaust gases from the turbine before they are introduced into the main exhaust nozzle.

2.3 RECOVERY

In March 2011, Jeff Bezos announced plans to find and recover the engines from Apollo 11, the historical mission that took man to the moon in 1969. The first step was to locate 5 engines out of 65 launched on *Saturn V* during the Apollo era from 1969 to 1972, 14,000 ft. (4,300 m) below sea level. A survey mission was planned with a 200-ft. vessel, the *Ocean Stalwart*, outfitted with specialized navigation and computer systems, and a 6-ton towfish containing state-of-the-art Synthetic Aperture Sonar capable of capturing high-resolution details at distances of more than 1,000 m.

Storms in the Atlantic caused difficulties and delays on the survey mission. Additionally, NASA's calculated trajectories for the S-1C stages did not account for the rockets breaking up on impact with the ocean surface and subsequent drifting on their decent to the seafloor. An initial 100 mi.^{2} search area turned in to nearly 200 mi.^{2} with hundreds of pieces of debris strewn across vast areas rather than the highly localized groupings the team expected (Capone 2013, 2014).

The recovery itself required its own set of specialized crew and technologically advanced equipment. The recovery mission employed the *Seabed Worker*, a six story tall, 300 ft. long recovery ship that utilizes sophisticated station-keeping and GPS systems to maintain precise positioning on the ocean surface. It carried two ROVs capable of working at depths of 5,000 m to video, photograph, dredge, and attach recovery slings and cables to the artifacts (fig. 2). A massive winch was used to hoist the recovered

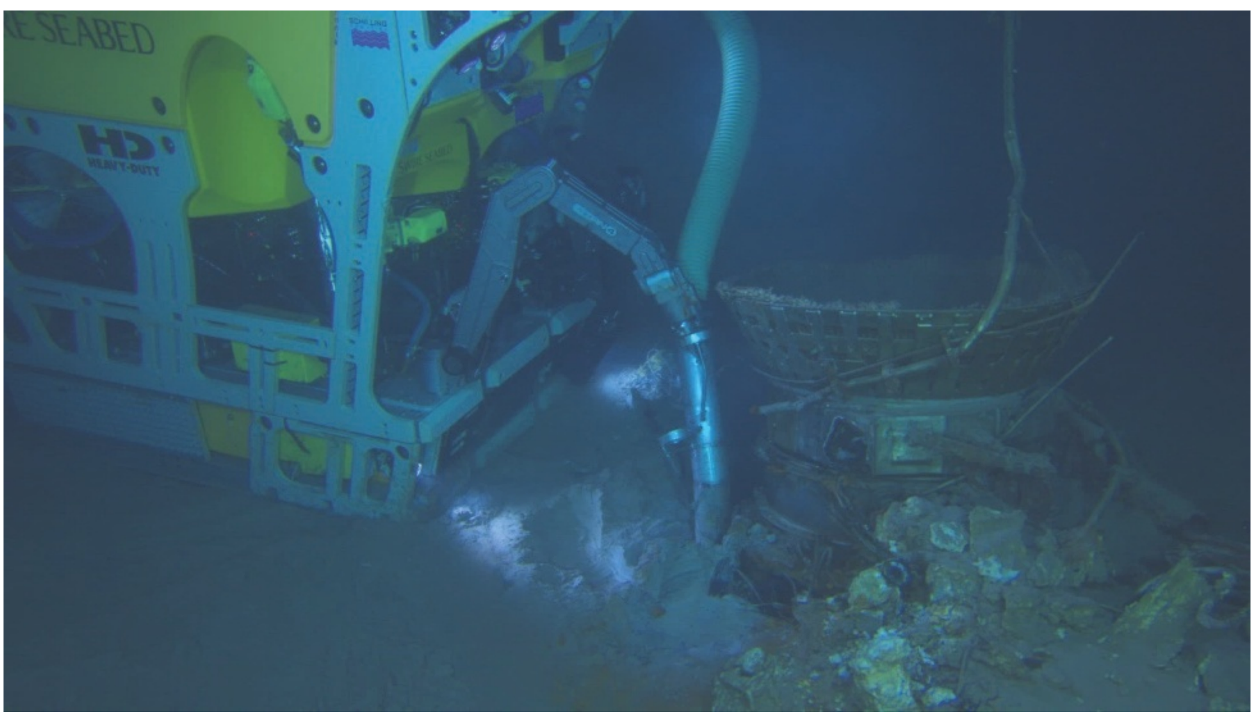

Fig. 2. ROV during the excavation of a thrust chamber (still of video capture) (Courtesy of Bezos 2014)

engine components, safely contained in large recovery cradles, to the surface, often requiring lifting tensions in excess of 9 tons.

Nearly 25,000 lb. of engine components were recovered in approximately three weeks and brought safely to shore at Cape Canaveral, Florida, close to where they had originally been launched. While aboard the ship, the engine components were rinsed intermittently with fresh water. Recovered artifacts included five thrust chambers, three liquid oxygen (LOX) domes, three injector assemblies, two turbopumps, one exhaust nozzle, two heat exchangers, four turbines, three turbine manifolds, and one gas generator from various Apollo missions. Once offloaded from the ship, the engine parts were cocooned in moistened cotton towels and shrink-wrapped before being transferred to flatbed trailers for their journey to the Kansas Cosmosphere and Space Center.

3. PLANNING FOR THE ARRIVAL OF THE ENGINES

3.1 TREATMENT FACILITY

One of the main challenges faced by conservators as the project began to unfold was the initial lack of information about the number of engines that would be recovered and their state of preservation. Due to an estimated speed between 400 and 500 mph (644–805 kph) at the time they hit the surface of the water, partial or complete breakage was anticipated. In contrast, expectations of the recovery team suggested that complete engines might be recovered. A contingency plan to accommodate whole engines measuring 18.5 ft. in height and 12.2 ft. in diameter, and weighing 18,500 lb. (8,400 kg), had to be in place at the time of recovery—particularly to address the size of the recovery baskets to be constructed and the lab space needed to accommodate them.

Identifying a suitable facility that could adequately accommodate the conservation of an unknown number of engines in whatever conditions they were received, whole or disarticulated, was critical to the success of the project. Fortunately, the Kansas Cosmosphere and Space Center had a 5,000 $ft.^2$ building available. The building was retrofitted from an artifact storage space to a turnkey conservation lab in less than two months. The building had several important key features, such as large overhead doors allowing access for large trucks or forklifts, a ceiling height of 35 ft., and a flat continuous concrete floor slab throughout, allowing the use of a mobile 5-ton gantry crane, pallet jacks, and forklifts. The building was equipped with a powerful HVAC system, deionized water filtration system, eye wash station, compressed air, a powerful light system, Internet access, 24/7 security access, and surveillance.

The concrete slab extended outside the lab to a large fenced area where wet treatment and cleaning could be carried out. In addition, an observation gallery independent from the lab space was constructed to allow access to visitors without interfering with the conservation work. The conservation facility was also adjacent to a large and fully equipped workshop where supports, lifting devices, and other custom-made tools could be produced as needed by the metal fabricators on staff.

Keeping the entire collection wet while conservation plans were developed was achieved with a "showering system" installed around two 16 ft. × 23 ft. × 25 in. shallow custom-fabricated basins lined with a waterproof membrane covered with thick rubber pads to avoid puncture. The showering system used city water, and the artifacts were manually sprayed once per day with a 0.1% solution of FlashCorr, an anionic surfactant and multimetal corrosion inhibitor made by Cortec Corporation. Sump pumps were used for filtration and recirculation inside the basins. This flexible system was chosen for initial receipt of the engine parts in lieu of individual tanks due to the unknown size and shape of the objects. The objects remained in the showering system for up to five months, until they were ready for individual treatment. During that time, they were easily accessible for initial cataloguing, documentation, examination, and cleaning (figs. 3a, 3b). For subsequent treatment of individual engine parts, custom-made fiberglass tanks, as used in the oil industry, replaced the two large basins.

Fig. 3a. View of the lab with recently recovered artifacts in custom-fabricated basins; 3b. Detailed view of basin #1 with turbopumps in the foreground (Courtesy of Terra Mare Conservation LLC)

3.2 DEVELOPING A CONSERVATION STRATEGY

The challenge presented by the conservation of the Apollo engines was immediately apparent: how to comprehend and preserve a large collection of 20th century aerospace heritage after burial in an aggressive marine environment? It was obvious to the authors that a treatment strategy for these modern materials, many of which are unknown in the conservation sphere, would require a plan that was guided by archaeological conservation standards to ensure a logical work plan that respected the context of the objects, as well as their unique materials, and ensured long-term preservation.

Conservators of archaeological materials face difficult and unique challenges in the preservation of objects from buried contexts whether wet or dry, particularly for metal and composite objects. Among these challenges is the often rapid and irreversible deterioration that can result from recovery and exposure to air, particularly for objects from a marine or wet environment. Acute fragility or structural collapse upon excavation, extreme deterioration due to corrosion and burial position, particularly if chloride ions are present in the burial context, accumulated dirt, and sediment or concretions overlying the original surface obscuring detail and rendering the object illegible are typical issues faced by conservators of archaeological materials.

An additional requirement when dealing with archaeological material is to retain as much contextual information as possible, particularly from the objects' use and history. Archaeological objects are often transformed by their environment, creating difficulties of interpretation. Evidence of the firing of the F-1 engines had left subtle surface traces, some of which were ephemeral. Preserving evidence of use was critical and one of the most important components of the archaeological approach adopted for treatment (figs. 4a, 4b, 5).

Fig. 4a. Example of a stenciled number on a thrust chamber only visible due to the presence of rust surrounding the numbers (Courtesy of Terra Mare Conservation LLC)

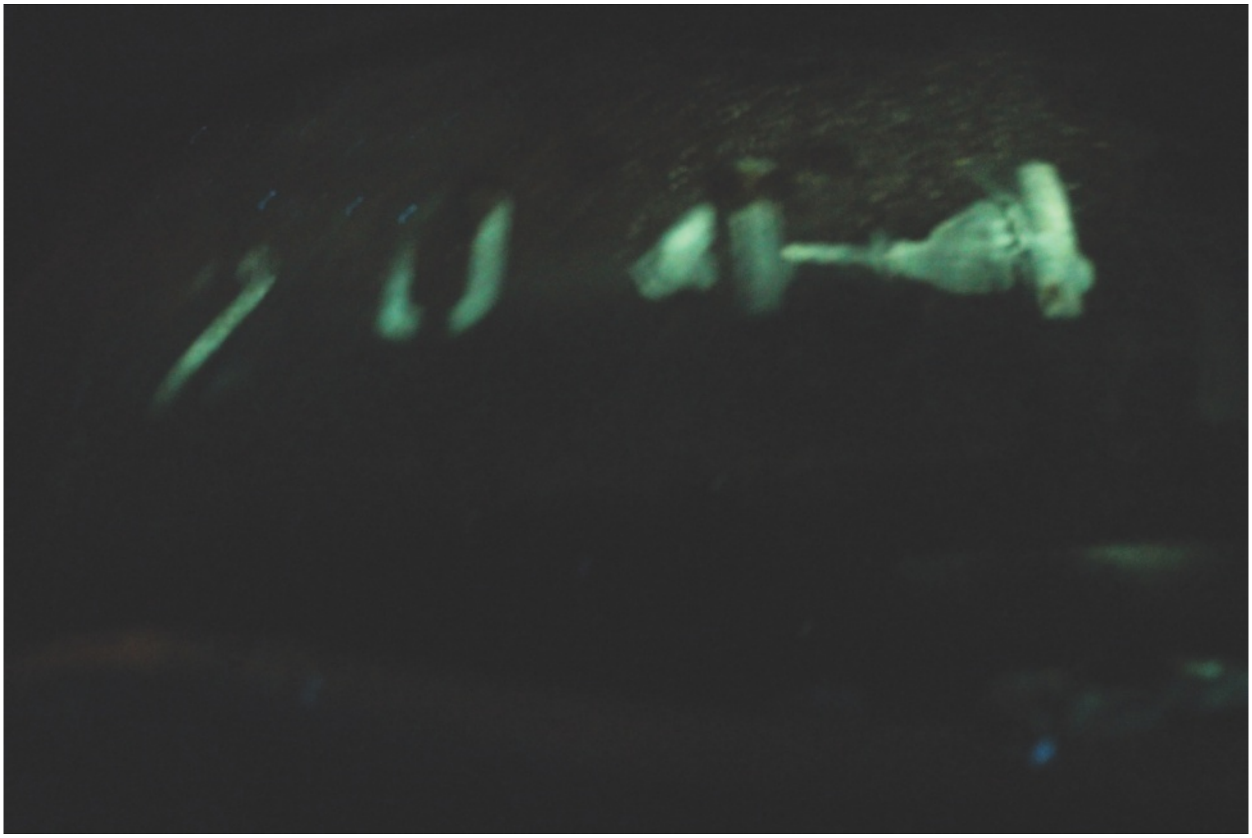

Fig. 4b. Original unit number on Apollo 11 thrust chamber only visible under ultraviolet light (Courtesy of Kansas Cosmosphere and Space Center)

The deformation of the engines upon impact with the ocean also formed an important part of each object's history and needed to be preserved. The level of deformation was quite extensive in some cases, as shown on thrust chamber F1-2013-0005 from Apollo 11 (fig. 6).

The engines' short life history, followed by burial for more than four decades on the bottom of the ocean, left us wondering what kind of information, if any, would be preserved, and how we would reveal and preserve that information for objects that had a fairly secretive life history, followed by a life span of only a few minutes. The following sequential approach was taken in response to these difficult questions:

1. Document and assess the collection as rapidly as possible while keeping the objects wet at all times.
2. Initial cleaning to remove compacted sediment, followed by rinsing and daily tracking of chloride levels, conductivity, pH, and other metals in solution, particularly copper.
3. Separate engine components when feasible and document the process.
4. Rotate the objects when possible and continue systematic cleaning to remove accumulated sediment and corrosion products.
5. Fabricate engine mounts to support the most fragile artifacts or modify their angle to facilitate stabilization.
6. Mission identification.
7. Transfer each artifact into individual tanks for stabilization treatment—chemical cleaning and chloride removal.

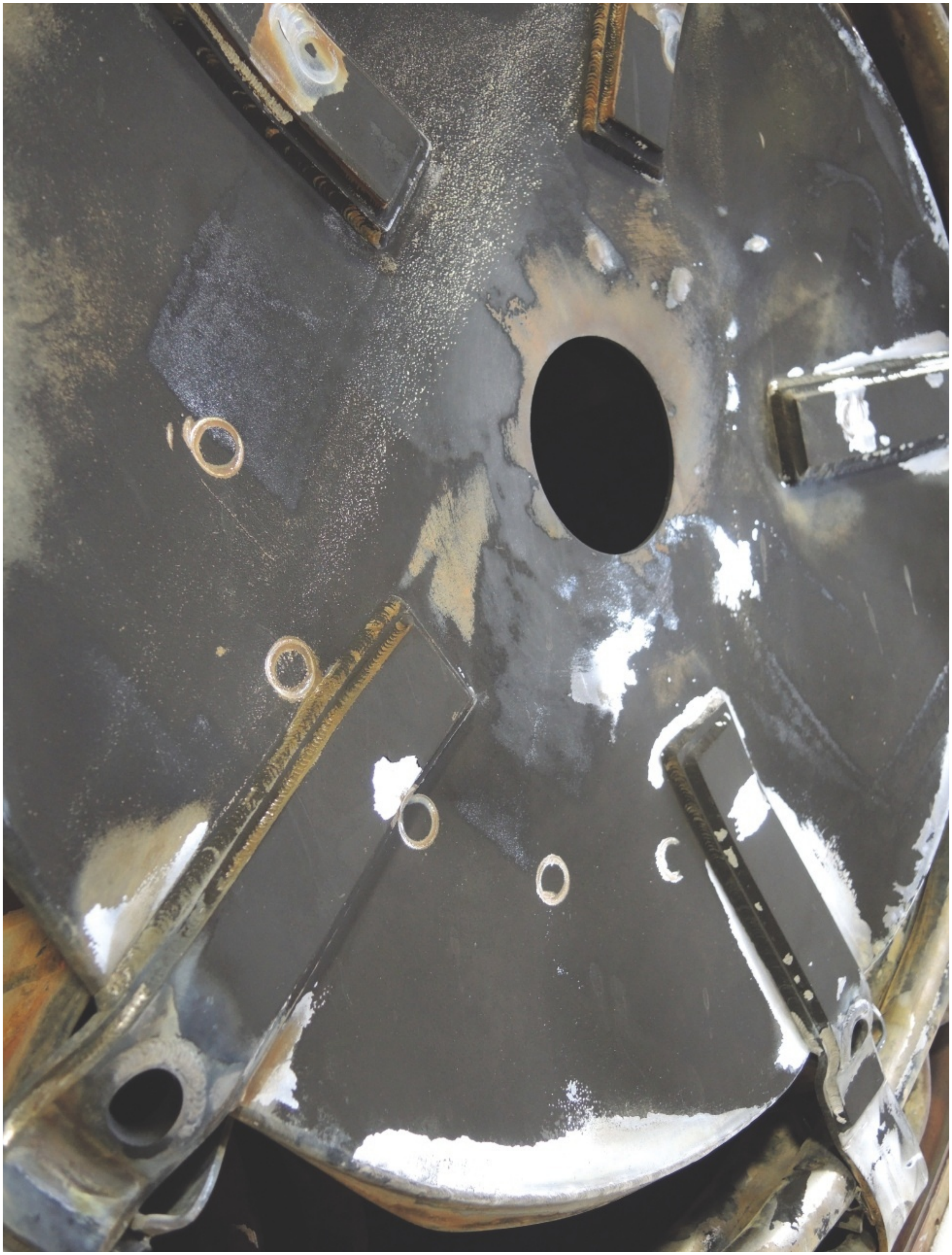

Fig. 5. Soot deposition on the interior of the heat exchanger F1-2013-0015 from Apollo 11 (Courtesy of Terra Mare Conservation LLC)

Fig. 6. Ruptured jacket from a thrust chamber belonging to engine #5 from Apollo 11 (Courtesy of Terra Mare Conservation LLC)

8. Extended rinsing to remove treatment chemicals in warmed deionized water.
9. Mechanical cleaning as required in conjunction with pressure washing.
10. Apply a suitable corrosion inhibitor for multimetal objects.
11. Dry the objects both internally and externally with compressed air or molecular sieve.
12. Final finishing and coating, if needed.

4. DOCUMENTATION

Initial documentation of the artifacts upon their arrival in the lab was based on the archaeological numbers assigned during the survey and recovery operations at sea. Smaller objects and those removed for treatment were numbered with an expanding alphanumerical system based on these target designations. This facilitated the tracking of each major component to its original recovery position, as well as tracking each sub-component to its parent during dismantling and treatment.

Each object was also given individual treatment tracking documents that were created based on a standard United States Air Force aircraft maintenance form, AF Form 791A. Parameters such as weight, dimensions, treatment protocols, and actions taken could be readily documented and included the initials of the person responsible. These details were then transcribed into a custom computer database built using FileMaker Pro 12. The database entries included materials identification along with technical descriptions, condition reports, identifying markings, and photographs.

5. MISSION IDENTIFICATION

Matching the engine components to the specific mission on which they flew would prove to be one of the most difficult tasks of the project for several reasons. First, the recovery area was vast, and the engines were heavily damaged, corroded, embedded in sediment, and covered with stains and layers of corrosion products, all of which obscured the markings necessary to identify the components. Second, detailed documentation including individual part and serial numbers was not available. Rocketdyne, the company that produced the engines, did have a knowledge-retention program in place at the time of the F-1's development. However, due to the proprietary nature of the documents, four decades of corporate leadership changes, and government classification, much of the hard copy data has been lost or is not readily retrievable. In addition, Rocketdyne, while still in operation, was purchased and sold several times by various parent corporations during the decades since the Apollo missions, which has led to the loss of much of the original documentation. Evidence of part swapping and the reallocation of components were also discovered while researching the available data, supported by the discovery that some of the components had multiple serial numbers. It is also worth noting that the atmosphere in general during the Apollo era was one of "hurry up and get it done" (Clarke, pers. comm.). Finally, some of the methods of serializing the components, such as the painted stencils, rarely survived burial on the ocean floor. Others, such as stamped or etched numbering on the metal surface, proved to be an ideal location for corrosion to form, altering the markings.

To decisively establish the provenance of each object, conservators looked for specific identifying marks, called *unit numbers*, which were placed on several of the major engine components by various means in different locations with no discernible standardization. These unit numbers were assigned upon the completion of each engine and are only four digits, with the first two digits ("20") being identical for each. Thus, the only means by which to identify a specific mission were the final two digits, making the task much more difficult. Fortunately, through several means including visual inspection, mold casting, and using ultraviolet light in conjunction with digital photography, components from the Apollo 11, 12, 14, and 16 missions were positively identified. An example of a stenciled area revealed under ultraviolet light on a thrust chamber belonging to engine #5 from Apollo 11 is given in figure 4b.

6. MATERIALS IDENTIFICATION

Prior to the objects arriving in the lab, research was undertaken to develop a list of metals and other materials likely to be found on the F-1 engines. Several original Rocketdyne documents were obtained, including a familiarization manual and an illustrated parts breakdown, which proved to be invaluable resources containing detailed schematics and diagrams (Rocketdyne 1970, 1972). However, they did not provide a precise bill of materials. Prior published research in the book *Saturn V* by Alan Lawrie (2005) provided an additional means of materials identification through manufacturing records. Later on, this book would prove helpful in identifying on which specific Apollo mission each component flew, as well as offer further insight into the difficulty of mission identification.

As the project progressed, the need to more precisely determine the alloys used on the F-1 engines became critical for several reasons: to elaborate a suitable conservation plan based on the materials present; to understand the corrosion processes affecting the most fragile and unstable objects, particularly galvanic corrosion; and to identify possible harmful materials that may have caused health issues for the conservators, particularly asbestos and beryllium.

Analysis was performed in several phases to assist conservators in implementing a treatment plan specific to each type of material present, and to help clarify specific questions concerning corrosion products and more precisely undertake materials and metallurgical investigation as the project developed.

The following analytical program was carried out:

- X-ray fluorescence (XRF) was performed by Bruce Kaiser of Bruker Elemental, Tim Foecke and Adam Creuziger of the National Institute of Standards and Technology (NIST), and Gregory Dale Smith of the Indianapolis Museum of Art.
- Scanning electron microscopy with energy dispersive spectroscopy (SEM/EDS) was undertaken at NIST.
- Raman spectroscopy and Fourier transform infrared spectroscopy (FTIR) were performed by Greg Smith.
- X-ray diffraction was carried out by Joe Swider of McCrone Associates Inc.
- X-radiography was carried out by Chris Watters and Mike Alton at Newco Inc.
- Metallurgical investigation of the corroded turbine blades was performed by NIST (not reported here)

Detailed results and discussion of the analytical results will be presented elsewhere. The following summary briefly describes analyses and results that were helpful to the conservators during treatment of the engines.

6.1 MATERIALS AND METHODS OF MATERIALS IDENTIFICATION

Samples for analyses were removed mechanically from discreet areas on specific objects or were obtained from loose debris not attached to, but associated with, the particular object.

The initial XRF survey was performed in situ on 73 discreet areas on the surface of 12 objects using a Bruker Tracer III SD handheld XRF. Nine samples were obtained and further analyzed with XRF by NIST, using a portable XRF analyzer (model Olympic DS-4000-CC). Six samples were analyzed by Greg Smith using a Bruker Tracer III-V handheld XRF with rhodium tube, silicon-pin detector, and polymer window (~3 × 5 mm oval spot).

In tandem with the XRF analysis undertaken by NIST, six samples were obtained from four objects for more detailed compositional analysis using SEM/EDS. Three of these samples were analyzed by XRF, and three were measured with compositional mapping to show the spatial distribution of elements. Two different scanning electron microscopes (SEMs) with energy dispersive spectroscopy (EDS) detectors were used to analyze the samples. The first SEM was a JEOL 6400 with an Evex SiLi EDS detector and Revolution analysis software. Beam energy of 20 keV was used, and the current was chosen such that the detector dead time was between 20% and 35%. Energy spectra were recorded over a section of the sample magnified at 200X (approximately 500 μm × 400 μm, or 0.2 mm^2).

The second SEM system used was a JEOL 7100 with an 80 mm^2 X-max^N SDD detector with Oxford AZtec analysis software. Beam energy of 20 keV was used, and the current was chosen such that the detector deadtime was approximately 50%.

Six samples from four objects were characterized by Raman spectroscopy for phase identification, including copper corrosion products from one of the injector assemblies. Raman spectra were acquired using a Bruker Senterra microspectrometer on a Z-axis gantry. The spectrometer utilizes three selectable excitation lasers (532, 633, and 785 nm), an AndorPeltier-cooled CCD detector, and a 50-mm confocal pinhole. Laser power at the sample was generally below 3 mW. The spectra are the result of 10-second integrations with 20 to 30 coadditions. A 50X ultra-long working distance objective was used to focus on select particles. The analysis spot size was on the order of 1 mm, and the spectral resolution was in the range of 9 to 18 cm^{-1}. OPUS software allowed for automated cosmic spike removal, peak shape correction, and spectral calibration.

Six samples were analyzed using FTIR spectroscopy using a SpectraTech Smart Orbit diamond ATR attachment coupled to a Nicolet 6700 spectrometer with a mid-IR DTGS detector. The instrument was purged with dry, CO_2-free air. The spectra are the sum of 64 coadditions at 4 cm^{-1} spectral resolution. Sample identification was performed using the Infrared and Raman Users Group (IRUG) reference spectral library.

Eight corrosion samples from six objects were obtained for phase identification by x-ray diffraction. The XRD instrument is a Rigaku RAPID x-ray diffraction system operated at 40 kV and 20 mA. Particles are typically run for 15 minutes and processed using Rigaku imaging software and MDI JADE software for data analysis. The resulting patterns were compared to references in the International Centre for Diffraction Data (ICDD) database of more than 300,000 references.

6.1.1 Results and Discussion of Materials Analysis

The XRF and EDS analyses revealed that the common materials present were alloys of nickel, aluminum (cast and wrought), and iron (various grades of stainless steel), as well as copper, brass, carbon steel, chrome and nickel plating, and other materials like polyurethane foam. The common nickel-chromium-ferrous alloys contain major quantities of nickel and chromium, and they could most readily be differentiated by the presence of alloying elements molybdenum, tungsten, niobium, and/or titanium (Creuziger and Foecke 2014). However, the often small or trace amounts of certain elements detected with XRF and EDS made precise identification difficult. The nickel-based alloys are most likely Hastelloy C-276, Inconel alloy X-750, Inconel 625, Inconel 718, Haynes 556, Rene 41, and Incoloy A-286. The results likely characterize a 6xxx wrought aluminum alloy and possibly a 6061 alloy. Investigation via compositional mapping further suggested that a 40x.x or 41x.x aluminum alloy was present, specifically on the turbopumps. The stainless steel alloys identified are made of 3xx series stainless steel based on the major iron-chromium-nickel signals from XRF and EDS. The trace amounts of niobium and titanium make distinguishing between 3xx series alloys difficult.

Of the samples analyzed, many deviated from the known composition of that alloy, raising the possibility that a non-standard alloy was used. This may help explain why some of the objects, such as the turbine blades, presented advanced levels of deterioration.

The Raman and FTIR spectra results identified solid matches for paratacamite on one of the fuel injectors, a corrosion mineral suspected from visual examination of all three injectors. This result was supported by the results of XRD analysis, which identified clinoatacamite, atacamite, and paratacamite, and copper chloride hydroxide as major, minor, and trace phases, in addition to cuprite and malachite. The presence of this problematic chloride-containing mineral species directly influenced the treatment protocol chosen for the three fuel injectors described further in section 7.4.

6.2 X-RADIOGRAPHY

Seven turbine blades were imaged with radiography to determine the extent of corrosion that was visible on the blades, and noted by their loss of weight. A selection of four extremely corroded and lightweight turbine blades, two from stage 1 and two from stage 2, were imaged in the first group. In a subsequent group, three additional blades were imaged to compare results to group 1. The second set of blades were heavier in weight than the first, and it was presumed that this meant that the blades were in better condition with more metal remaining. The blades were imaged by Newco Inc. with a General Electric DXR250w Direct Radiography panel at 130 kV and 1.0 mA for 3.2 seconds.

The images from both groups confirmed the severe corrosion, most of which was not visible to the eye, with a more acute result noted in group 1 blades (not pictured here) that appeared to have lost the greatest density, judging by their weight. Images from group 2 revealed that these blades were also extremely corroded, although possibly the corrosion was not quite as advanced as that seen on the first set of blades, supported by the heavier weight of these blades (fig. 7). The x-ray images reveal that

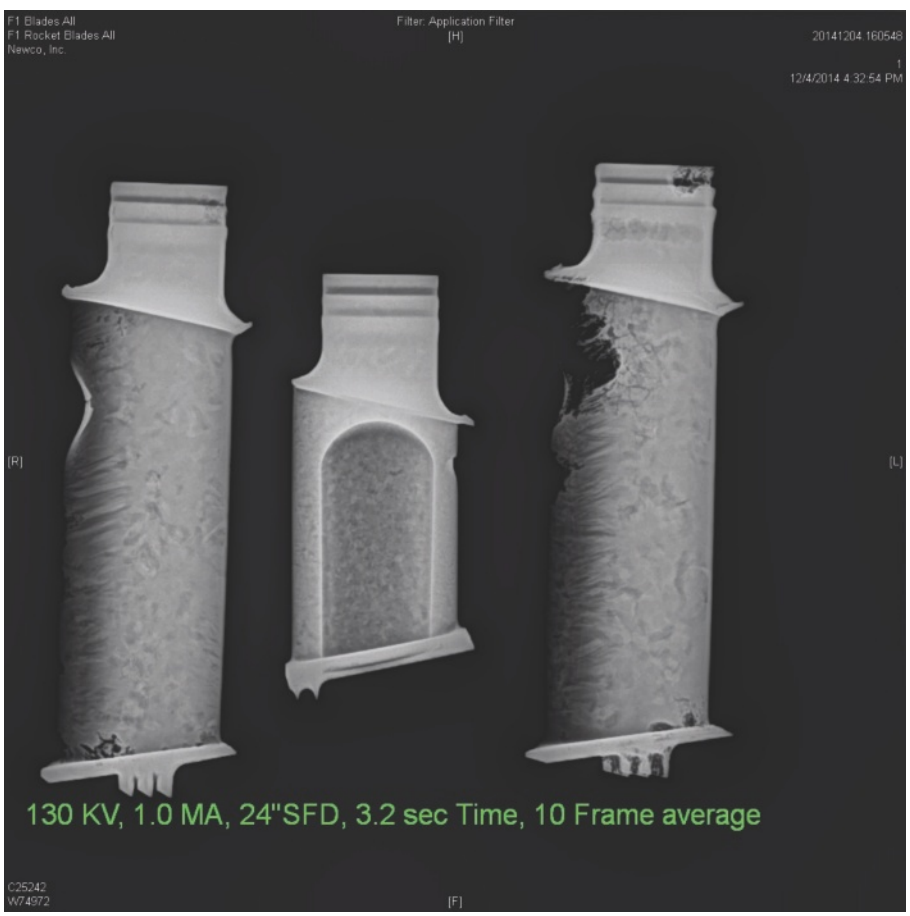

Fig. 7. X-radiograph of a corroded stage-2 turbine blade (Courtesy of Christopher Watters, Newco Inc.)

corrosion had penetrated the blade surface from small pits, most probably initiated by the stagnant conditions on the seafloor. This information proved valuable when a metallographic investigation was undertaken on samples of the turbine blades, and the full extent of the corrosion was revealed. It was also critical in deciding that consolidation of all detached turbine blades was needed to provide structural stability.

7. TREATMENT

The engine components were treated in several phases, following the strategy previously outlined. These stages often overlapped, and the progress of the treatment was far from linear. Many of the most problematic objects went through multiple phases of the same treatment stage, as issues arose concerning access to all parts of the object.

7.1 MOVING THE OBJECTS

One of the biggest obstacles we faced during treatment was moving heavy, fragile, wet, and unstable objects weighing up to 3,000 lb. (1.3 tons). Moving the objects in and out of the treatment tanks, changing their position, or temporarily bracing, raising, or suspending them for examination or treatment had to be done in a careful and methodical manner to ensure safety for both the object and the team. Each move was thoroughly researched and planned by the team to ensure that the center of gravity was correctly located to accurately balance the object during moving. The combined experience of the team, encompassing engineering and technical knowledge, was invaluable at this time. Use of an overhead 5-ton gantry mobile along with a forklift and several pallet jacks allowed ease of movement. Lifting required innovative and customized modifications to allow the engines themselves to be picked up or maneuvered. Several methods were used for moving the engines. Where possible, engines were rigged with synthetic slings and lifted by their strongest component. Many of the heaviest parts were rigged and lifted with reinforced plastic pallets attached to evenly distribute the weight and avoid point load as much as possible. For some objects, the original rigging points were preserved, and, where feasible, these were fitted with new, custom lifting devices, spreader bars, connecting devices, and adaptors from which the part could then be rigged and safely lifted (fig. 8).

7.2 INITIAL TREATMENT: REMOVAL OF SEDIMENT AND IRON STAINING

Most of the artifacts were caked with very compacted grey sediment and massive corrosion products, in some cases totally obscuring the surface. Some of the worst-affected objects were the aluminum turbopumps (see fig. 3b) and the stainless steel fuel manifolds. The electric components and wire bundles still attached to some of the thrust chambers were held in place, embedded in hard sediment and iron corrosion products.

Complete removal of all sediment was necessary to enable access to the metal surface for stabilization (particularly inside the engines), to fully reveal surface details, and to improve the aesthetic appearance of the metal. The sediment, often mixed in with gelatinous corrosion products, was present in every possible cavity (even the tiniest cavities), inside the numerous instrumentation control lines, and within the cooling tubes that line the interior of the thrust chambers. The sediment was extremely stubborn, did not easily dissolve in water or other liquids, and had to be manually removed by a combination of hand cleaning and pressure washing. Multiple campaigns of cleaning were necessary, as most of the objects had extremely complex geometry that impeded access. As all sides of the objects

Fig. 8. The team examining turbopump F1-2013-0045 (Courtesy of Terra Mare Conservation LLC)

were gradually accessed, new pockets of sediment were revealed, which allowed for more in-depth cleaning (fig. 9).

Many of the objects were heavily stained with iron corrosion products from steel components that had preferentially corroded or completely disintegrated, causing widespread rust-colored stains. In some cases, the stains gave us valuable information about the steel components that had disappeared and clues about the position of the objects in the burial sediment. The objects worst affected by stains were the thrust chambers, the LOX domes, and the heat exchangers. The steel outriggers, originally welded to the exterior of the thrust chambers, and steel gimbals, the original attachment point of each engine to the rocket, were the cause of most, if not all, of the staining. None of the outriggers were recovered, and only one partial gimbal survived still attached to its LOX dome. The gimbal was identified as belonging to Apollo 11 and is shown in figure 10 before and after treatment.

The most severe rust stains were reduced or eliminated by immersion of the objects in recirculated deionized water with a 0.1% solution of FlashCorr, an anionic surfactant and multi-metal corrosion inhibitor made by Cortec Corporation. It was also observed that the chloride extraction process using this family of surface-active molecules was enhanced compared to that of deionized water, particularly on aluminum alloys. This was assessed by measuring the chloride levels of the treatment tanks on a weekly basis. This may be due to the ability of this type of anionic compound to displace adsorbed chloride ions from the metal (Monticelli et al. 1991; Malik 2011; Balbo et al. 2013). This treatment was

Fig. 9. Conservator Claudia Chemello working on heat exchanger F1-2013-0046 from Apollo 16 (Courtesy of Terra Mare Conservation LLC)

combined with periodic pressure washing and manual brushing of the surface. The treatment time varied depending on the extent of the staining and took up to two months for certain objects.

After removal of sediment and surface staining, hard, white deposits were still visible on certain parts of the engines. These were assumed to be calcium carbonate from the burial environment. These deposits were tenacious, generally unaffected by the chelating properties of FlashCorr, and were reduced or eliminated with dry ice cleaning after stabilization.

7.3 PRESERVING EPHEMERAL INFORMATION

The firing of the engines left numerous traces and marks on the surface of the objects. Preserving evidence of use was critical and one of the most important goals of the archaeological approach adopted for treatment. Indications of engine use included layers of soot from the burning of the propellants and bluing of the metal due to extreme heat. Examples of ephemeral traces include partial stenciled numbers that were identified on some of the thrust chambers using visible or ultraviolet light, adhesive remains that had secured a data plate to a thrust chambers with legible numbers visible in the adhesive, and a paper identification label adhered to a hypergol manifold. All treatments involving mechanical action avoided areas where ephemeral traces remained on the surface. In some instances, areas were specifically protected with physical barriers during activities such as chemical cleaning, pressure washing, or dry ice cleaning. For chemical treatments, the painted stencils were protected with cyclododecane during treatment.

Fig. 10a. Lead Technician Jerrad Alexander (left) and Conservator Paul Mardikian (right) removing the steel gimbal from Apollo 11's LOX dome F1-2013-0005-1 for conservation; 10b. The same LOX dome and gimbal after conservation (Courtesy of Terra Mare Conservation LLC)

7.4 CHEMICAL STABILIZATION

After several decades on the bottom of the Atlantic Ocean, salts (or more specifically, the chloride ions from these salts) had caused severe corrosion problems on some of the objects. Chloride ions permeate metals during burial and can cause active corrosion after recovery. The main goal of the stabilization phase was to ensure that entrapped chloride ions were reduced to the lowest achievable level to enhance long-term stability.

The chloride release from all objects was tracked from the beginning of the project, from the time rinsing first began in the basins. Chloride detection was carried out with various methods according to the stage of the project: QuanTab test strips for chloride, titration using the argentometric method (Rice 2015), and a chloride-specific electrode. Following the removal of sediment and staining, it was clear that a more interventive approach was necessary to further reduce chloride levels in certain objects.
A stabilization strategy was designed for each type of object based on its materials and degree of corrosion. Some objects, such as the Inconel thrust chambers and turbine assemblies, required less stabilization, as the chloride levels had already been drastically reduced in successive baths of deionized water and a short immersion in FlashCorr for rust stain removal. The presence of stencils on the thrust chambers also meant that the use of more aggressive chemicals was too risky.

Some artifacts were extremely unstable and required a custom stabilization treatment, including the turbopumps and the fuel injectors. The turbopumps were constructed from at least 10 different alloys. One of the turbopumps was relatively intact, whereas the other had suffered extensive corrosion with major loss to its outer aluminum casing, as shown in figure 11. The presence of a nickel-plated steel

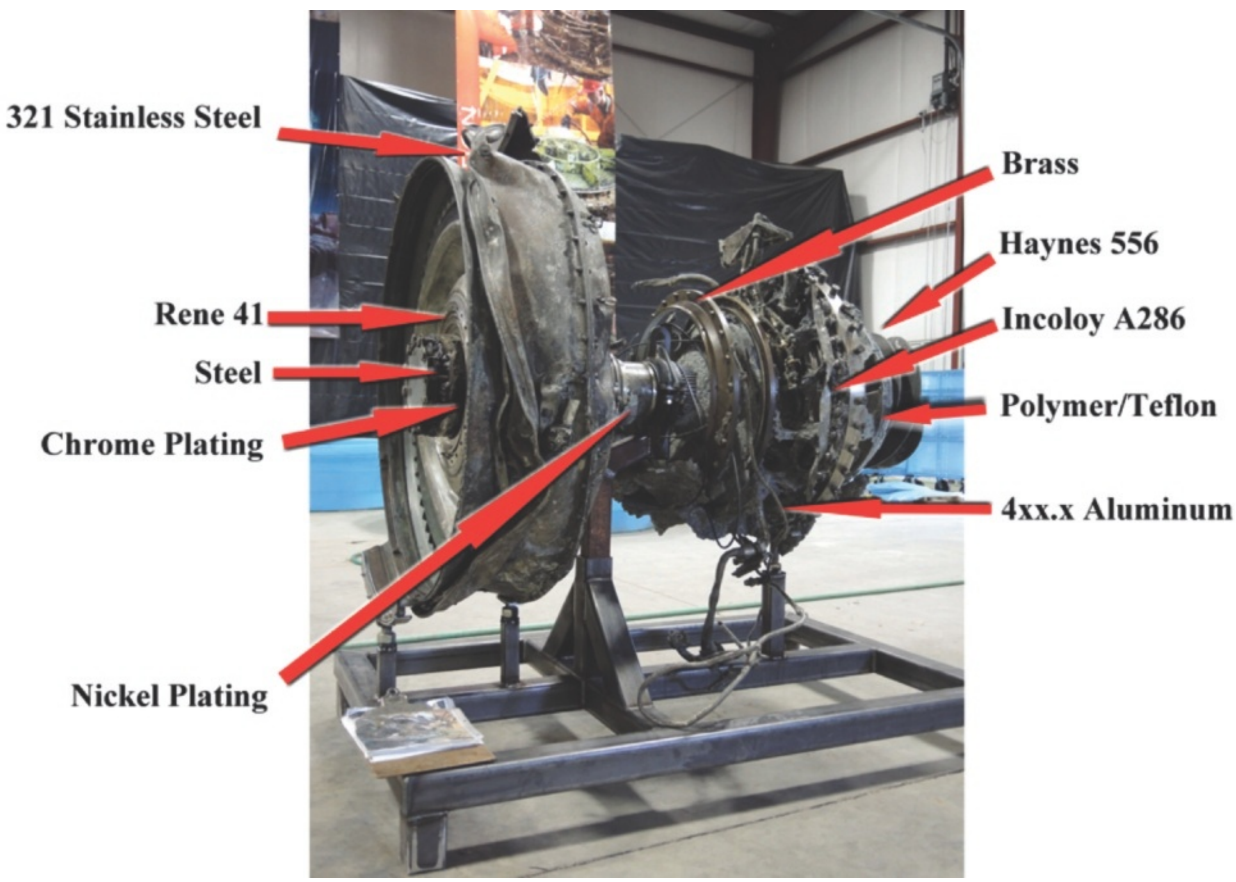

Fig. 11. Deteriorated turbopump F1-2013-0012 after conservation showing some of the different alloys present on this object (Courtesy of Terra Mare Conservation LLC)

drive shaft, steel bearings, and a deteriorated aluminum casing, in addition to numerous other metals in contact with each other, had created extremely complex corrosion issues. Dismantling of the turbopumps was briefly considered but deemed too unsafe for the objects. The high precision with which these objects were assembled and the difficulty of achieving a precise and accurate reassembly meant that certain objects could not be taken apart.

Active corrosion was visible on the drive shaft, particularly where the nickel plating was missing, and on the steel bearings. Stabilizing the steel components of the turbopumps was the main focus of the treatment. The treatment was complicated further because the treatment solution had to be alkaline enough to stabilize the steel without corroding the aluminum, which is highly susceptible to corrosion in an alkaline environment.

Stabilization was achieved using a 0.5% solution of sodium metasilicate in deionized water, a corrosion inhibitor used in industry for inhibition of aluminum, and successfully employed for the treatment of artifacts made from aluminum and steel recovered from freshwater sites (Degrigny 1995). The object was placed under electrolysis to facilitate chloride extraction at a cathodic potential of −1 V versus Ag/$AgCl_2$ reference electrode (−0.8 V vs. standard hydrogen electrode). Chloride extraction was tracked on a weekly basis and required six months to achieve a consistent chloride reading under 2.5 ppm in solution. The solution was then renewed and the object was maintained in treatment for an additional two months. During treatment, more detailed cleaning occurred, particularly to the heavily corroded shaft bearings. Conserved turbopumps are shown in figures 11 and 12.

Fig. 12a. Turbopump F1-2013-0045 after conservation (Courtesy Terra Mare Conservation LLC); 12b. Original photo showing a similar turbopump on the assembly line (Courtesy Rocketdyne Harold C. Hall Collection)

The three fuel injectors, made primarily from copper alloy and 3xx series stainless steel, most likely 304, were found in their original position, sandwiched between an Inconel LOX dome and Inconel thrust chamber. The copper alloy side of the injector was heavily corroded, with bright green corrosion covering the surface, almost certainly due to severe galvanic corrosion. The stainless steel side was also heavily corroded and pitted. The choice of stabilization treatment had to be compatible with both materials, as the object was constructed as one unit and could not be dismantled.

The fuel injectors were initially stabilized in a recirculated solution of 1% sodium sesquicarbonate in deionized water to begin chloride extraction, whereas analysis with Raman spectroscopy and x-ray diffraction was undertaken to determine what corrosion products were present. The copper chloride species atacamite and paratacamite were identified, confirming the need for a more interventive treatment to arrest corrosion and stabilize the objects. This was accomplished using a modified version of alkaline Rochelle salts, a treatment familiar to conservators treating archaeological copper alloys. A 0.1M solution (3.9 g/L of sodium hydroxide and 28.2 g/L of sodium potassium tartrate) in 200 L of deionized water was used, and the chloride and copper levels were tracked in the treatment solution. Once the green corrosion products were reduced, the fuel injectors were thoroughly rinsed with a pressure washer, mechanically cleaned to remove corrosion inside the fuel holes, and returned to a 1% solution of sodium sesquicarbonate for final chloride removal. When the chloride levels remained consistently under 2.5 ppm for two months, the rinsing process began. Fuel injector F1-2013-0005-2 is shown before and after conservation in figure 13.

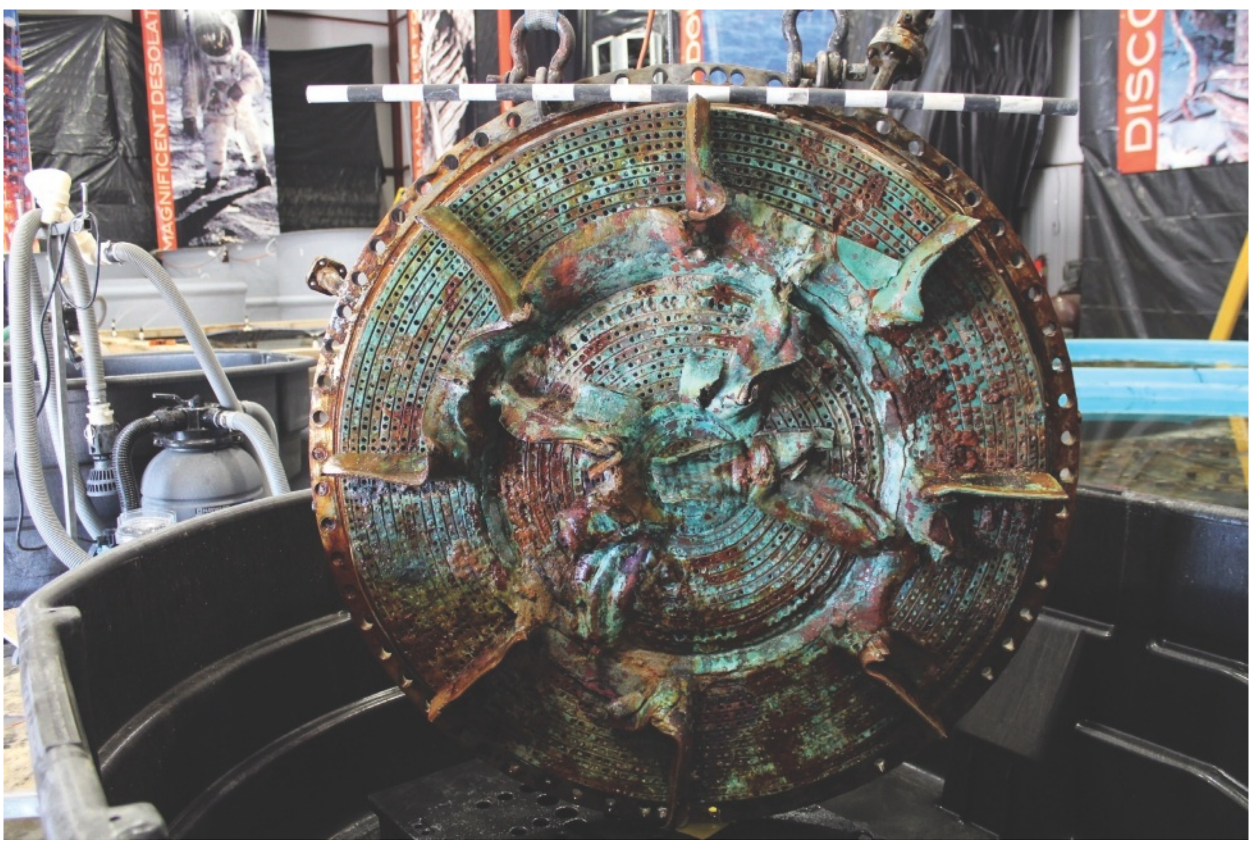

Fig. 13a. View of the fuel injector F1-2013-0005-2 from Apollo 11 before conservation

Fig. 13b. The fuel injector after conservation (Courtesy of Terra Mare Conservation LLC)

7.5 RINSING

After chemical stabilization was complete, an extended period of rinsing, often lasting several months, commenced to remove traces of the chemicals used during stabilization. Rinsing was carried out with recirculated deionized water at a temperature of approximately 40°C. The pH and conductivity of the water was monitored until it reached that of the deionized water. The turbopumps treated with sodium metasilicate were rinsed under cathodic protection to avoid flash rusting of the steel components.

7.6 CORROSION INHIBITION

The complex materials of the engines, particularly their intricate internal geometry, prompted a decision to apply a corrosion inhibitor to the most problematic and unstable objects in the collection, namely the fuel injectors and the turbopumps. These objects had been through an extensive treatment regime for active corrosion and had numerous and complex internal cavities, posing a risk for long-term stability. However, the long-term environmental conditions that will prevail for these objects are unknown at the time of writing.

Several tests were undertaken to assess VpCI-377 and VpCI-316, vapor phase corrosion inhibitors made by Cortec Corporation, designed for indoor protection. Both are water-based multimetal corrosion inhibitors. Tests were performed on metal coupons at 2.5%, 5%, and 10% concentrations in deionized water, assessing the inhibitors' visual appearance, tackiness, viscosity, and corrosion protection. Inhibitor 377 at 2.5% proved to be a better choice, was easy to apply by dipping, and was almost invisible. However, the long-term behavior and protectiveness of vapor phase corrosion inhibitors is not totally understood on cultural heritage materials, and more research and evaluation are needed. It is our hope to be able to follow their long-term effect on this collection.

7.7 FINAL SURFACE FINISHING

Final surface cleaning was performed using dry ice blasting with a KG30 machine supplied by Continental Carbonic (fig. 14). This method was far superior at removing unwanted surface accretions and hard calcium deposits that simply could not be removed by any other method. Overall surface cleaning of the majority of the objects was accomplished using 35 to 45 pounds per hour (pph) of dry ice at a pressure of 25 to 50 psi with a medium-size splitter and a 2 in. wide nozzle attachment. This broad cleaning allowed for the identification of those areas in need of more aggressive treatment. For these areas, the wide nozzle was replaced with the 7-mm "standard" nozzle. This somewhat shorter, smaller attachment gave a greater degree of access to areas of the object that were difficult to reach, as well as a much more targeted cleaning. Machine settings for areas on objects requiring the removal of denser accretions and hard deposits were between 45 and 55 pph and 50 and 75 psi. Areas with the thickest encrustations of what appeared to be calcium deposits required the most aggressive settings, 60 to 65 pph and 75 to 100 psi, using the smallest (5-mm) nozzle. Working distance and dwell time were adjusted according to what was necessary to achieve the desired cleaning level at each phase (fig.14). A view of the lab at the end of the project is shown in figure 15.

7.8 ARTIFACT DISPOSITION

Several museums expressed interest in acquiring objects from this collection, in agreement with NASA, who had oversight for the objects' disposition. These institutions included the Smithsonian National Air and Space Museum, who will receive the Apollo 11 objects; the Museum of Flight in Seattle, Washington; the US Space and Rocket Center in Huntsville, Alabama; the Kansas Cosmosphere and Space Center; and the Space Museum in Bonne Terre, Missouri. It is unclear whether the objects will be placed immediately on display; however, we believe that the intention of the receiving institutions is to

Fig. 14. Conservator Claudia Chemello cleans turbopump F1-2013-0012 with dry ice (Courtesy of Terra Mare Conservation LLC)

organize new exhibits around the engine components. The remainder of the collection is currently housed at the Kansas Cosmosphere and Space Center in the climate-controlled lab where they were treated but are not accessible to the public.

8. CONCLUSIONS

The conservation of Apollo-era F-1 engines provided an extraordinary opportunity to conserve objects made of materials that are rarely encountered in the conservation community. To add to the challenge of conserving a group of objects of such significance, the engines had been buried in the ocean for more than four decades and exhibited extreme levels of corrosion and alteration. Treatment was accomplished by taking a deliberate, archaeological object–based approach for these modern archaeological artifacts. Given the importance and irreplaceable nature of these objects, this approach has proved to be successful. The project was completed in two and a half years, a tour de force in the world of large-scale maritime conservation projects. The key steps to its success include the collaborative structure of the project, bridging the world of conservation, aerospace engineering, fabrication, restoration, and materials science together; advanced planning and logistical support; and a holistic approach to preserving the context and history behind these objects as much as the materials themselves.

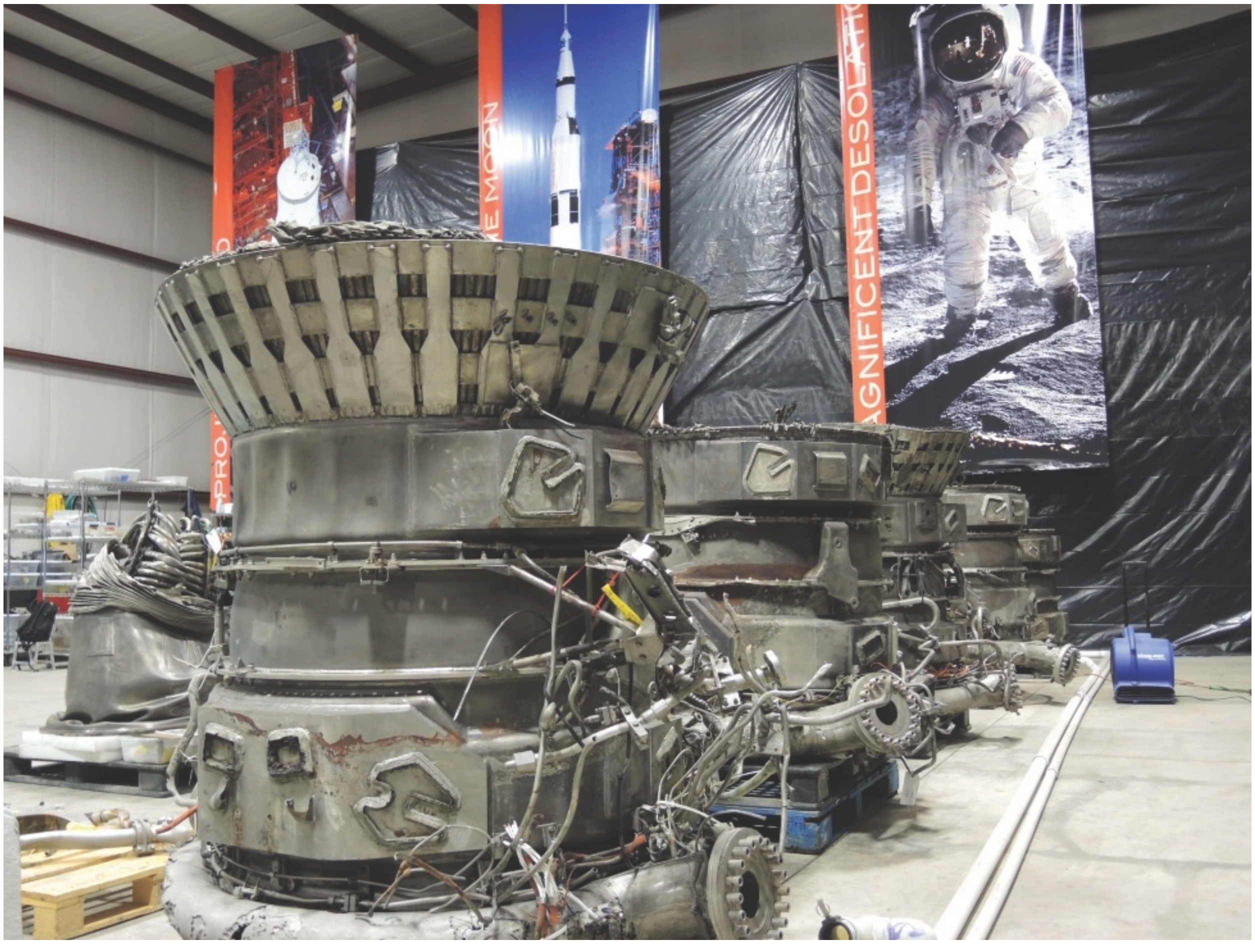

Fig. 15. General view of the lab with some of the artifacts after conservation (Courtesy of Terra Mare Conservation LLC)

ACKNOWLEDGMENTS

Jeff Bezos; Jim Remar and Dick Hollowell, Kansas Cosmosphere and Space Center; Larry Goodwin, Dale Capps, and Don Aich, Space Works; John Broadwater, Spritsail Enterprises; Tim Foecke and Adam Creuzinger, National Institute of Standards and Technology (NIST); Gregory Dale Smith, Indianapolis Museum of Art; Caitlyn Phipps, former graduate intern at the Indianapolis Museum of Art; Joseph Swider, McCrone Associates Inc.; Chris Watters, Mike Alton, and Bill Williams, Newco Inc.; Bruce Kaiser, Bruker Elemental; Lyndsie Selwyn, Canadian Conservation Institute; Ian MacLeod, Western Australian Maritime Museum; and Casey Heurung, Cortec Corporation.

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SOURCES OF MATERIALS

Sodium Metasilicate (Cat. No. 191382) and Sodium Potassium Tartrate Tetrahydrate (Cat. No. 150156)
MP Biomedical LLC
29525 Fountain Parkway
Solon, OH 44139
800-854-0530

FlashCorr, VpCI-377, and VpCI-316
Packnet Limited
2950 Lexington Ave. S
Eagan, MN 55122
952-944-9124

Double Junction Reference Electrode
Thermo Scientific
166 Cummings Center
Beverly, MA 01915
978-232-6000

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SILVER OR GOLD? SURPRISING CHALLENGES IN CLEANING A 19TH-CENTURY PERSIAN WATER PIPE

ARIEL O'CONNOR, MEG CRAFT, GLENN GATES, AND JULIE LAUFFENBURGER

A heavily tarnished 19th-century Persian water pipe, or *nargile*, made of gilded silver decorated with gemstones required cleaning for exhibition at the Walters Art Museum. X-ray fluorescence spectrographic analysis indicated an alloy of silver with copper, gold, and lead. Standard methods for mechanical tarnish reduction were tested, but all produced a silver-colored surface. Further x-ray fluorescence spectrographic analysis revealed that even the gentlest mechanical method—solvent cleaning with a cosmetic sponge—removed gold from the surface. Chemical test cleaning with acidified thiourea, or "silver dip," removed tarnish and preserved gold, but research has shown problems with this method, including potential leaching of copper, microetching, residual surface complexes, and increased light reactivity. Pros and cons of each method were considered, and thiourea was selected as least harmful. Methods for the safe use of thiourea in this context are discussed, and a new approach with non-woven cotton pads is introduced for cleaning.

KEYWORDS: Silver, Silver Cleaning, Gilding, Erasers, Thiourea, Silver Dip, Cleaning, Polishing

1. BACKGROUND

During the summer of 1903, Walters Art Museum founders William and Henry Walters traveled to Constantinople and purchased a group of 13 elaborately decorated objects made of precious metals and stones. Among these objects was a spectacular *nargile* (WAM 49.2199), or Persian tobacco water pipe, commonly called a *hookah*, stylistically dated to the mid-19th century (fig. 1).

Since 1934, when the nargile was bequeathed to the Walters Art Museum, no museum records were created, and it is unlikely the object has been cleaned or studied at the museum. The object was brought to the conservation lab in 2014 in preparation for exhibition. The conservation goal was established jointly with the curatorial department and included stabilization, surface cleaning, and materials and technology identification that could help inform treatment and elucidate the manufacture of this complicated object.

This article will only focus on the cleaning and tarnish reduction of the metal alloy components on the object, as the other components received standard conservation treatments.

2. MATERIALS, CONSTRUCTION, AND CONDITION

The nargile is an elaborately constructed and striking object that stands more than two feet tall and is composed of silver alloy, Chinese porcelain, and Persian enamel, and studded with rubies, emeralds, and turquoise.

The nargile was in stable condition but significantly altered by layers of tarnish. Interpretation of the object was difficult due to the variability of the appearance of the component metal parts. The repoussé metal components on the nargile not covered in tarnish were golden in appearance, but the smooth undecorated metal areas without tarnish had a silvery tone. The object is constructed from the sections shown in figure 2.

The lower third of the object functions as the water jar and unscrews from the top so that water can be added. The water jar is made from the bottom of a Chinese blue and white porcelain vessel, possibly from the 1720s.[1] The ceramic is set into a tarnished silver alloy metal mount with eight vertical ribs, each pinned at the top and soldered at the base.

Fig. 1. Overall view of the nargile before treatment. Artist unknown, *Nargile*, mid-19th century, ceramic vessel ca. 1720, gilded silver and copper alloy, porcelain, enamels, rubies (spinels), emeralds (beryls), dimensions with lid: 66.5 × 17.5 × 16 cm. The Walters Art Museum, 49.2199 (Courtesy of the Walters Art Museum)

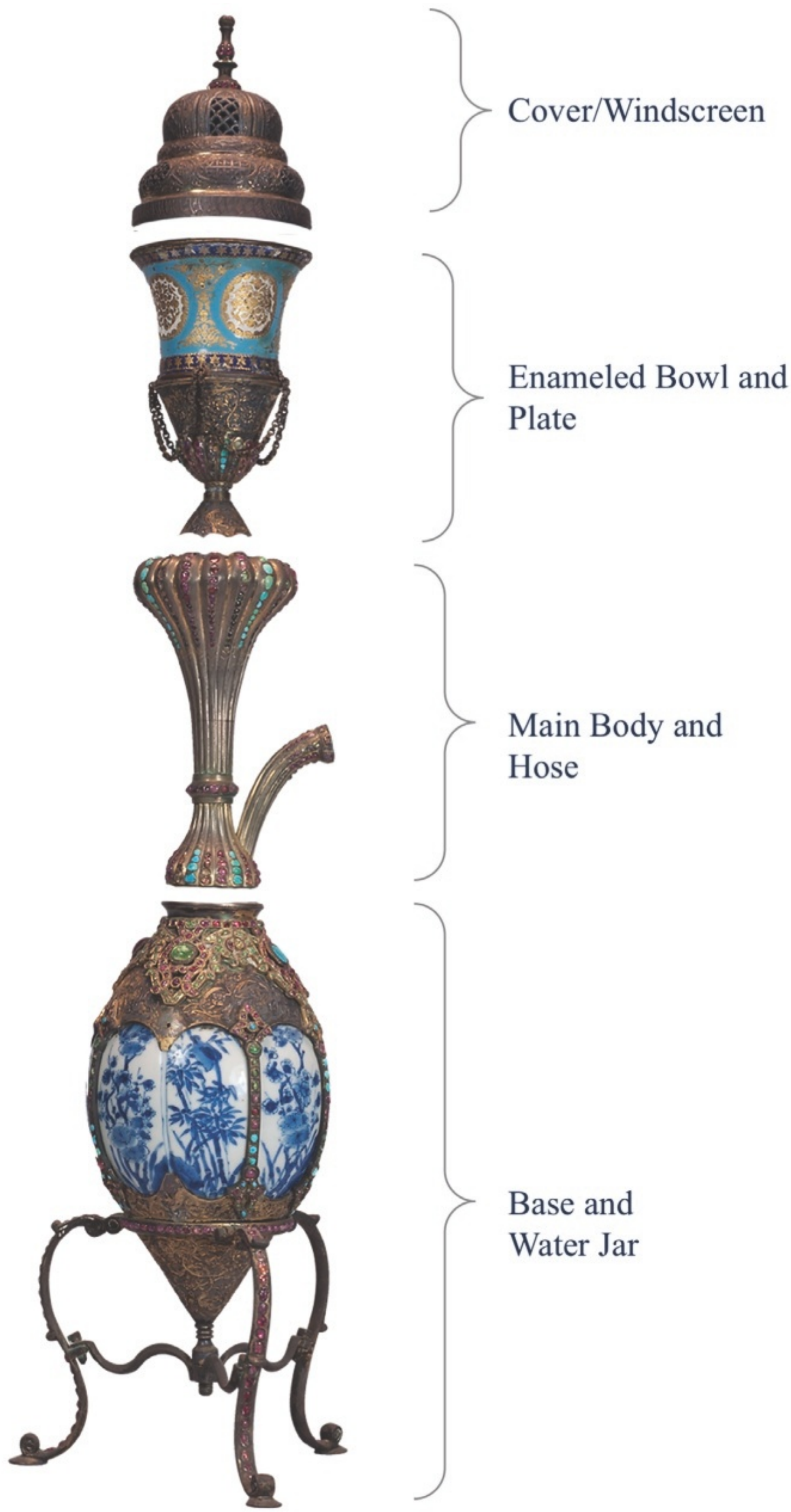

Fig. 2. Diagram of the nargile's primary sections (Courtesy of the Walters Art Museum)

Fig. 3. Detail of metal mount before treatment, highlighting engraved and stamped designs (Courtesy of the Walters Art Museum)

The tarnished metal mount is ornamented with repoussé and engraved floral designs (fig. 3), and the metal ribs are set with rows of cabochon gemstones (fig. 4). The bottom of the mount terminates in a cone-shaped point and is screwed into a cast tripod base with an equally tarnished surface. The tripod base is composed of five parts attached with modern screws. The metal and porcelain are held together with a black resin-like adhesive and cannot be separated.

Sitting directly above the water jar, the main body is a smooth silver-colored metal alloy with vertical fluted ridges. Two vertical halves were constructed by hammering, and vertical solder seams join the two sections. The smooth undecorated metal surface of this section stands in contrast to the elaborately textured patterns of the nargile's other metal components. This section is more "silvery" in tone and color than the rest of the object. The ridges are set with rows of cabochon rubies, emeralds, and turquoise. The hose is missing.

Above the body sits an inverted metal cone with a repoussé floral design, which acts as a decorative support for a fluted metal cup inlayed with cabochon gemstones and a scalloped upper ridge. This fluted cup sits at the base of a Persian-style enameled bowl. Inside, a perforated metal plate originally held the tobacco.

The cover, which sits at the top of the nargile, functions as a windscreen to prevent wind from increasing the burn rate and temperature of the coal. This very thin cover is made from a silver alloy base

Fig. 4. Varied gemstones pictured from all surfaces. A missing ruby reveals the silvered sheet and red dye underneath, indicated with a white arrow (Courtesy of the Walters Art Museum)

metal, hammered and raised from a single sheet of metal. Small air holes were punched or cut from the outside, inward. The surface was decorated with repoussé and chasing. A modern screw is soldered upside down on the top. A decorative finial sits loosely over the screw and is turned from a solid piece of metal and decorated with cabochon rubies and emeralds.

The gemstones used to decorate the surfaces are cabochon rubies, emeralds, and turquoise (fig. 4). The rubies and emeralds vary in color and clarity. To set the stones, individually cut holes were made in the metal specific to the outline of each stone. Each stone is backed with a tiny square piece of thin metal foil (fig. 4). Visual evidence suggests that this sheet is a copper alloy with a silvered surface. The silver-colored side of the sheet reflects light. To homogenize the unevenly colored stones, a colored dye in a gum-like medium was applied to the metal foil.

3. XRF ANALYSIS[2]

Prior to cleaning, analysis of the metal surface with XRF was undertaken to help characterize the complex metal components because of extreme variation in the object's current appearance. We hoped to understand the original coloration of the surface under the black tarnish, as some areas appeared silver and others gold. An understanding of the materials would help inform the methods selected for the cleaning tests.

The XRF survey of the metal components indicated a silver alloy with an enriched or gold-plated surface in most areas, with individual parts of the nargile having slightly different constituents and alloying ratios.

Although absolute quantification was not possible, a rough estimation of the alloy used for the water jar was obtained by comparison to silver metal standards; this indicated an alloy of approximately 85% to 90% silver, with approximately 5% copper, 5% gold, and 1% lead. No zinc or mercury were detected. The height of the low energy M-line peak for gold, relative to the standards, provided an indication that there was gold at the surface (fig. 5). No mercury was detected, so we did not have an amalgam gilding layer. XRF also identified strong sulfur peaks in the black tarnished areas. The finial and middle have the same silver, copper, gold, and lead elements, but in slightly different proportions than the water jar. The lid and tripod base both contain zinc, and very little gold was detected.

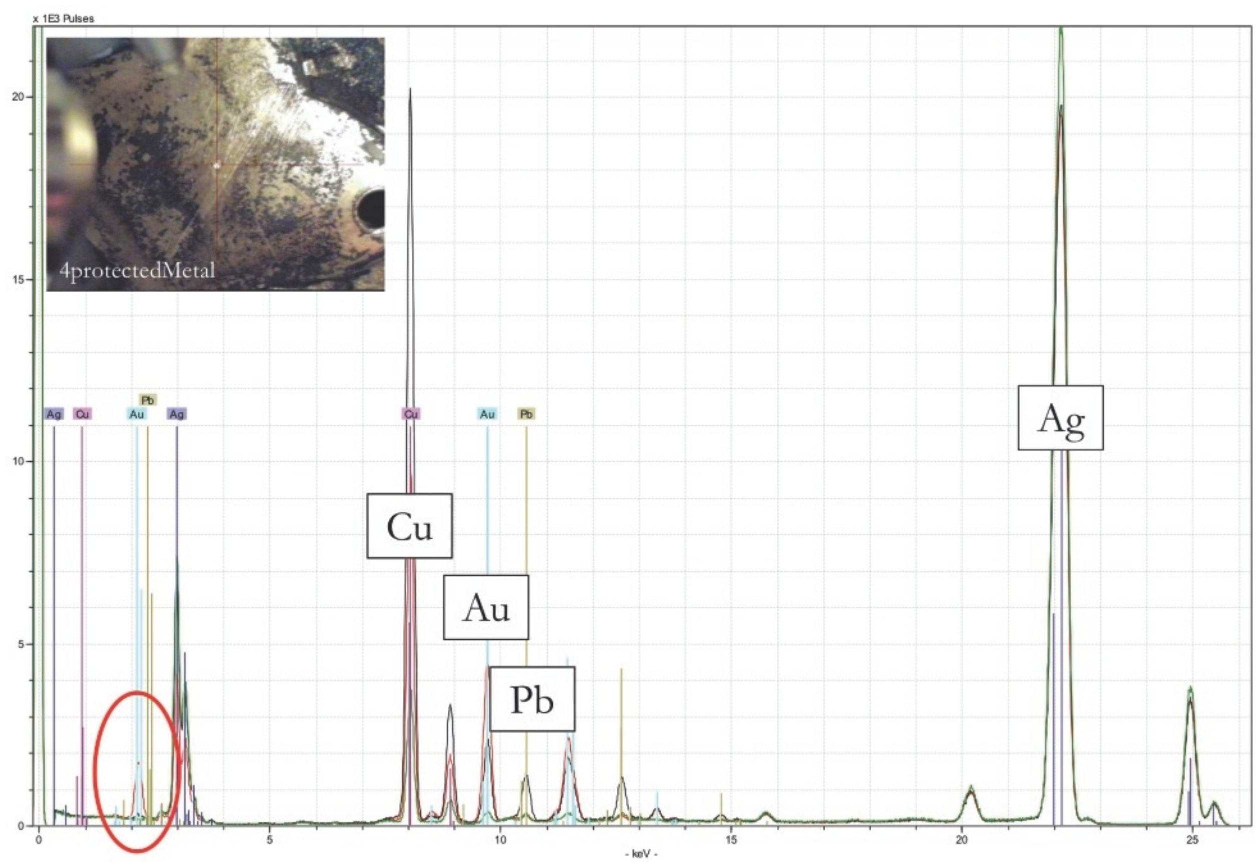

Fig. 5. XRF spectrum before cleaning of metal surface in a protected and untarnished area under a rib in section B. XRF shows the surface of the object to be mostly silver, with a small amount of copper, gold, and lead. This spectrum is overlaid with two standard samples for a rough estimation of ratio. The red circle highlights the M-line peak for gold (Courtesy of the Walters Art Museum)

All alloys display extensive silver sulfide corrosion with a variable surface appearance. Although questions still remained as to the original intention of the metals' appearances and whether or not there was a gilding layer, we decided to move forward with cleaning tests. It was our hope that these tests, combined with XRF information, could uncover the original surface treatment and intention.

4. MECHANICAL CLEANING TESTS

Following surface analysis, small cleaning tests were performed on each section of the nargile. While selecting a cleaning methodology, two problems posed the largest concern: rinsing the intricately textured metal surfaces and the dye under the gemstones.

The textured surface of the metal could easily trap traditional polish materials and chemical cleaning solutions, making rinsing and clearing difficult. In addition, the fragile gemstones were backed with a dye and gel-like medium that are highly soluble in most solvents, especially ethanol.

Because of these concerns, initial cleaning focused on mechanical silver-cleaning methods that would leave minimal to no residue. These methods included solvents on cotton swabs, cosmetic sponges, calcium carbonate, commercial polishes, and vinyl erasers. The cleaning tests were evaluated visually and deemed effective if they reduced the tarnish, worked effectively in tight spaces, and left a minimal residue (table 1).

Table 1. Mechanical Cleaning Tests

Material	Notes	Effective?
Stoddard's solvent, cosmetic sponge	Picked up dark tarnish on sponge, but no visible change in thickest tarnish areas.	No
Stoddard's solvent, cotton swab	Picked up light tarnish on swab, and some visual change on the object, but no visible difference in thick tarnish areas.	No
Goddard's Long Shine Silver Cloth	Picked up tarnish, but difficult to use in tight, small spaces.	No
Precipitated $CaCO_3$ in distilled H_2O, cotton swab	Effective, but slow. Left an unacceptable residue that was difficult to remove from textured surface.	No
Duraglit commercial silver polish, cotton swab	Aluminum oxide abrasive. Very effective at removing thick tarnish; no loose residue to remove. Good option for flat metal areas without gemstones. Clearing required.	Yes
Staedtler Mars plastic erasers (no. 526-52)	Most effective of all options tried with regard to both speed and ease of use. Erasers could be cut to size and rubbed on the tarnished areas, quickly removing tarnish. When dipped in water or mineral spirits, this process was faster than other methods.	Yes

Fig. 6. Cleaning window on base with Staedtler Mars plastic erasers dipped in deionized water. Note the silvery tone of the cleaned area compared to the untarnished golden-toned highlights on the adjacent uncleaned area (Courtesy of the Walters Art Museum)

Despite the compositional differences revealed earlier with XRF and indications of a gold enriched surface, all mechanical cleaning methods and materials consistently revealed a bright silver surface underneath. Erasers were selected as the most efficient method of cleaning, as they did not leave a residue on the textured surface and were safe to use around the perimeter of the stones without affecting the dye or swelling the carrier material. The erasers would be used dry around gemstones. On areas of metal without gemstones, the erasers would be dipped in distilled water or mineral spirits.

After the initial cleaning tests, a 1 × 1 in. cleaning window was opened on the base with Staedtler Mars erasers (fig. 6). The erasers removed the silver sulfide tarnish from the surface evenly, did not leave a residue, and could be used safely around the gemstones. Similar to the small tests mentioned earlier, this cleaning window had a silvery tone.

Given that XRF indicated the possibility of a gilding layer at the surface, we were surprised to see how silvery the surface appeared after cleaning compared to the small untarnished areas elsewhere that had a golden tone. Surprisingly, all methods of mechanical cleaning, even soft cosmetic sponges, yielded a bright silver surface. This visual discrepancy initiated discussions: was the original gold surface extensively worn from use or pre-1934 restoration so the surface now appeared silvery, or was our cleaning technique damaging the surviving gold surface?

5. CHEMICAL CLEANING TESTS

To understand the connection between mechanical cleaning and the silver appearance, we explored a chemical cleaning method. In the past, the Walters conservation lab used "silver dip," a traditional silver cleaning method using acidified thiourea. This methodology works as the acidic component dissolves the tarnish layer and the thiourea complexes the silver ions, allowing both to be rinsed away with water. However, this practice had fallen out of favor in recent decades, as research uncovered that thiourea could remove gold, complex with copper and trace minerals, and etch the microstructure of the silver surface (Barger et al. 1982; Selwyn 1990; Contreras-Vargas et al. 2013; van Santen 2014).

The traditional recipe in the Walters lab files used 5 ml sulfuric acid, 8 g thiourea, and 100 ml distilled water. We also tested solutions made with citric acid, but these were too slow and required multiple applications.

A comparative test was done on the metal rib detached from section A in an area with thick black sulfide corrosion (fig. 7). Silver dip was applied with a cotton swab, rolled on a 1 cm^2 area for 10 seconds, then cleared with deionized water on a cotton swab rolled gently across the surface. Two passes were sufficient to remove the sulfide and reveal a golden tone underneath. This gold-colored test area is seen on the far right side of figure 9, highlighted in yellow.

A second cleaning test was conducted in an adjacent area with similar sulfide corrosion. This area was cleaned mechanically using the softest of the mechanical methods tested—a cosmetic sponge with mineral spirits. The sponge picked up tarnish but could not remove all of the sulfide corrosion. The metal revealed through the tarnish had a silvery tone. This test spot is seen at the far left side of figure 6, highlighted in white.

Finally, a third cleaning test was done in the middle, first with silver dip to remove the sulfide, followed by half of the area cleaned with a cosmetic sponge and mineral spirits. The silver dip pass removed the sulfide corrosion and left a golden surface. After a few light passes with the sponge on half of the test area, the surface color changed from gold to silver.

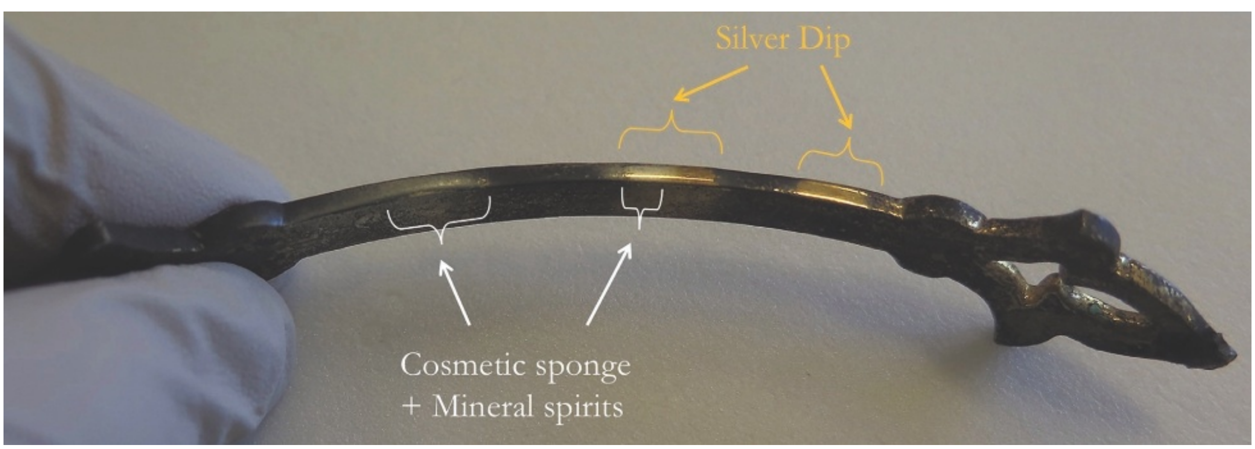

Fig. 7. Comparative mechanical and chemical cleaning tests on detached rib edge with thick sulfide corrosion. Note the silver tone of the cosmetic sponge areas and the golden tone of the silver dip areas (Courtesy of the Walters Art Museum)

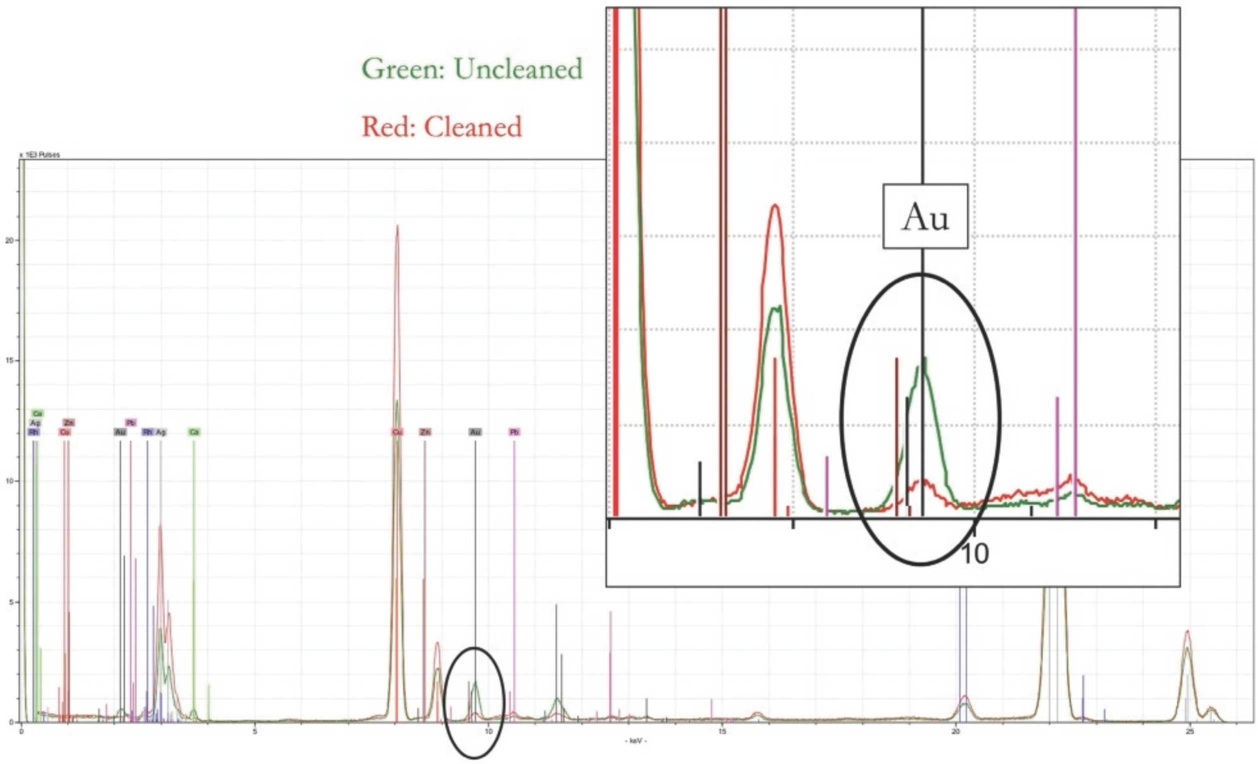

Fig. 8. XRF spectra of the cleaning tests on the rib before and after cleaning with a cosmetic sponge. The uncleaned surface shows a strong gold peak, whereas the cleaned surface shows much less surviving gold (Courtesy of the Walters Art Museum)

XRF was used to compare the mechanical and chemical cleaning methods. The area cleaned with a cosmetic sponge and mineral spirits showed a significant reduction in gold and a visual change to silver (fig. 8). We were surprised to discover that the soft cosmetic sponges were abrasive enough to remove the incredibly thin gilding layer. XRF of the dirty eraser crumbs from the earlier mechanical cleaning tests revealed that they contained gold.

6. DECISION

Conservation was left with a difficult decision between a mechanical cleaning that reduced surface gilding and a chemical cleaning with unknown aging properties in proximity to solvent-soluble dyes. An ideal conservation approach might postpone treatment until a later date when another cleaning method might be determined. However, the exhibition schedule required treatment to be completed quickly. The final decision was an informed compromise.

Other cleaning options, such as electrolytic cleaning, gels, or lasers, required further lengthy testing and research.

7. TREATMENT

Silver dip seemed to be the safest option for the artifact in our current situation. To ensure that we were using thiourea in the safest practical manner, we consulted with other conservators who had surveyed the literature (Pouliot and Nichols 2015) and have extensive practical experience using silver dip (Meighan and Lins 2015). After consultation, we believed that the silver dip could be used safely on this object by following the proper precautions, which are listed as follows. The silver dip should be left on the surface for less than 60 seconds—the amount of time it is safe before the solution could potentially attack different phases of the metal alloy (Meighan and Lins 2015). Since we could not immerse this object in any type of alkaline wash afterward because of the gemstones, it was stressed that we needed to rinse the area very well with distilled water (Meighan and Lins 2015). During cleaning, no swabs should be double-dipped into the silver dip, as this risks redepositing metal ions from the corrosion onto the object's surface. For the health and safety of the conservator and lab, the work must be carried out in a fume hood, as hydrogen sulfide gas is produced during the cleaning. With these precautions and steps in place, the treatment moved forward using silver dip as the sulfide cleaning methodology.

The goal of this treatment approach was an efficient and minimally abrasive reduction of the black sulfide tarnish layer. A simple cotton poultice application was developed that would keep the silver dip in contact with the surface without unnecessary abrasion (fig. 9). A large area could be covered with less abrasion using cotton Webril Handi-Pads cut to the size of the desired cleaning area. A 1 in. × 1 in. pad ended up being an optimal size for most areas, but it varied as the surface texture and shape changed.

Once the cotton pad was in place on the object, a plastic dropper was used to add silver dip to the surface until saturated but not dripping. This was left in place for approximately 20 seconds; a gloved finger was used to gently press the wet cotton against the surface. This proved useful in minimizing applications on textured areas.

The cotton pad was removed and thrown away, and the area was wiped thoroughly and immediately with a new cotton pad pre-dipped in distilled water. If needed, the process was repeated until the tarnish was removed. Most areas required only two passes. By using the cotton pads, abrasion to the fragile gilded surface was kept to a minimum.

The biggest challenge was cleaning the metal surface in areas adjacent to stones, which covered the majority of the artifact's surface. In these areas, the silver dip was added to the cotton before applying to the surface to prevent excess liquid near the stones. Thin cotton strips were cut for the rib sides adjacent to gemstones. If a particular area was too dry when applied, more silver dip could be added carefully with the dropper. If a cotton pad could not fit in recesses or undercuts, swabs were used gently.

After tarnish reduction, it was decided not to apply a coating, as the surface cannot withstand the abrasion needed to remove the coating in the future. Passive methods must be used to prevent retarnishing. The exhibition case was fitted with Pacific Silvercloth covering the air intake openings to filter the air before it reached the case. For storage, the object is wrapped with tissue, then silver cloth, and stored in a sealed polyethylene bag.

Fig. 9. Before, during, and after a thiourea application on the base with a pre-cut Webril cotton pad (Courtesy of the Walters Art Museum)

7.1 SILVER-TONED ERASER TEST CLEANING AREA

The eraser-cleaned test area had a silver tone and was brighter than the gold tone of the adjacent areas cleaned with silver dip. Several ideas were discussed to inpaint this aesthetic discrepancy, including a toned lacquer coating, thin acrylic wash, or even a new gold displacement application. In a case study where silver coins were cleaned with thiourea, a slight gold-colored tone was observed on the silver after cleaning (Contreras-Vargas et al. 2013). This phenomenon is due to hydrogen sulfide gas produced during cleaning, which can induce the formation of sulfides on the surface, giving a slight golden tone (Contreras-Vargas et al. 2013).

The slight color shift was not perceptible on the nargile's thiourea-cleaned areas with surviving gilding, but a test on the eraser-cleaned area of our object confirmed that the silver looked more golden after thiourea treatment. Ultimately, it was decided to re-clean this test area with the silver dip. The golden tone was achieved, and the entire object was treated with the same solution and methodology. The surfaces will age in a similar manner without an application of selectively placed coatings.

Fig. 10. Views of base before and after treatment (Courtesy of the Walters Art Museum)

Fig. 11. View of reassembled object after treatment (Courtesy of the Walters Art Museum)

8. CONCLUSIONS

This complex object still conceals mysteries about its manufacture and original appearance, but some conclusions were reached from this analysis and treatment. The nargile was constructed from separate pieces, each with a different silver alloy containing varying levels of silver, copper, lead, zinc, and gold. The surface color was unified with an overall gilding layer. The method of gilding can be inferred through process of elimination: no mercury detected and thus not amalgam gilt, not enough gold present in the alloy for depletion gilding or tombaga (La Niece and Craddock 1993, 188), and not a cold application of gold leaf and binder because of the surface texture and detail. Two likely options remain: electroplating or diffusion gilding (Philadelphia Museum of Art 2015). The extreme fragility of the gilded surface suggests diffusion gilding.

This treatment epitomized the theme of the conference, "making it work," because this, like many projects in the real world, presented a problem with no straightforward solution. It was a surprise to us to identify a gilding layer so thin that a soft cosmetic sponge could abrade it away. Aesthetically, we are pleased with the outcome after treatment. We were able to clean the surface without disturbing the fragile gilding while also protecting the solvent-sensitive resin carrying the dyes in the foil-backed gemstones. We feel as good as we can about our methodology, but we understand that cleaning with silver dip leaves a complex on the surface that is not well understood, and it will likely present a visual shift in the future. It is an unfavorable method in the current conservation lexicon but was the least harmful solution for this object and situation. We thought it was important to bring forward our findings and share them with the conservation community who might encounter similarly fragile gilding layers, and encourage others to investigate similar surfaces on their collections.

ACKNOWLEDGMENTS

The authors would like to acknowledge the following people for their contributions to this project and for generously sharing their extensive experience and knowledge. At the Walters Art Museum, we thank Terry Drayman-Weisser, retired Director of Conservation; Robert Mintz, Chief Curator and Curator of Asian Art; Jo Briggs, Assistant Curator of 18th and 19th Century Art; Amy Landau, Walters Associate Curator of Manuscripts and Islamic Art; and Aubrey Quasney, Islamic Curatorial Intern. At the Philadelphia Museum of Art, we thank Conservators Melissa Meighan and Andrew Lins. At the Winterthur/University of Delaware Program in Art Conservation, we thank Professor Bruno Pouliot and students Alexandra Nichols and Emily Brown, as well as the Conservators, Fellows, and Interns in the Walters Art Museum Conservation Department, especially Gregory Bailey, Geneva Griswold, Stephanie Hulman, Meaghan Monaghan, Megan Berkey, and Megan Salazar-Walsh.

NOTES

1. A stylistic attribution made by Robert Mintz, Chief Curator and Curator of Asian Art at the Walters Art Museum.

2. XRF analysis was performed with a Bruker AXS Artax equipped with a rhodium tube collimated to 1.5 mm diameter at 50 kV and 200 µA for 120 seconds without a filter.

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SOURCES OF MATERIALS

Cosmetic sponges, latex free polyurethane white triangular makeup sponge 20147
Qosmedix
2002-Q Orville Dr. North
Ronkonkoma, NY 11779
631-242-3270
http://www.qosmedix.com/pages/product/117/20147/36-Piece-Sponge-Block-White.aspx

Cotton swabs, Solon Care 56225
Careforde
233 S. Wacker Dr.
Suite 8400
Chicago, IL 60606
800-830-4050
http://careforde.com/solon-applicators-56225-cotton-tipped-applicator-6-x-1-12-wood-stick-tapered-tip-100-bg-10-bg-bx-10-bx-cs/

Duraglit Wadding Polish, now called Silvo Wadding Polish
Conservation Support Systems
PO Box 91746
Santa Barbara, CA 93190-1746
800-482-6299
http://www.conservationsupportsystems.com/product/show/duraglit-wadding-polish/polishing-materials

Mylar polyester film roll, 2 mil.
Talas
330 Morgan Ave.
Brooklyn NY 11211
212-219-0770
http://talasonline.com

Northern Lab-Goddards 707684 Goddard's Long Shine Silver Care Cloth (17.5 in. × 13 in.); Pacific Silvercloth
Amazon
1200 12th Ave. South
Suite 1200
Seattle, WA 98144
888-280-3321
http://www.amazon.com

Precipitated calcium carbonate, CAS NO: 471-34-1, USP/NF, .04 micron
Sciencelab.com Inc.
14025 Smith Rd.
Houston, TX 77396
800-901-7247
www.sciencelab.com

Staedtler Mars plastic erasers
Office Depot
800-463-3768
http://www.officedepot.com/a/products/120451/Staedtler-Mars-Plastic-Erasers-Pack-Of/?cm_mmc=PLA-_-Bing-_-Drafting-_-120451_

Stoddard solvent; Sulfuric acid, ACS reagent
Thermo Fisher Scientific
81 Wyman St.
Waltham, MA 02451
800-766-7000
http://www.fishersci.com

Thiourea, ACS reagent
Sigma-Aldrich
3050 Spruce St.
St. Louis, MO 63103
800-325-3010
http://www.sigmaaldrich.com/catalog/product/sial/t8656?lang=en&region=US

Webril Handi-Pads, 4 in. × 4 in.
Uline
12575 Uline Dr.
Pleasant Prairie, WI 53158
800-295-5510
http://www.uline.com/Product/Detail/S-20682/Wipers/Webril-Handi-Pads?pricode=WY233&utm_source=Bing&utm_medium=pla&utm_term=S-20682&utm_campaign=Janitorial%2BSupplies

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WORKING WITH A COLLECTION OF RADIOACTIVE AIRCRAFT INSTRUMENTS

SHARON NORQUEST, AMELIA KILE, AND DAVID PETERS

The Smithsonian National Air and Space Museum holds approximately 5,500 instruments that pertain to flight management, navigation, and engine and system performance. In fall 2013, a project was undertaken to outfit a large display case at the Steven F. Udvar-Hazy Center with 86 instruments from the collection. The display illustrates how the technology of instrumentation has advanced over the past 100 years as we progressed from the analog to the digital age.

Included in this collection are both unique prototypes and mass-produced gauges from civilian and military aircraft. Although the collection is vast, many of the instruments contain one common hazardous feature: radium paint. This glow-in-the-dark paint allowed pilots to fly at night and read the instruments while maintaining their night vision in a low-lit cockpit. Even though the paint no longer glows in the dark, the radium continues to emit measurable radiation. This paint presents the challenge of conserving, storing, and displaying a collection of radioactive objects in a museum.

Questions that arose and were addressed during the project included the following. What, if any, ideals must be compromised when dealing with a large collection that poses health hazards to the public and to staff? Is the workflow altered because of additional outside regulation, institution-wide requirements, and safety and health concerns?

A safe working environment for the staff and a safe display case for the public were established. As the Smithsonian National Air and Space Museum has a large collection of radioactive objects, the collection is licensed by the United States Nuclear Regulatory Commission. In addition to conservation work for the display, tasks were completed to meet the requirements of the Nuclear Regulatory Commission license. These tasks will be discussed and an explanation of equipment used to record radiation levels will be provided, as we developed a practical system for working with a radioactive collection.

KEYWORDS: Radioactive, Radium, Aircraft, Instruments, Health, Safety, NRC

1. INTRODUCTION

A vast collection of aircraft instruments are housed at the Smithsonian National Air and Space Museum (NASM). The term *aircraft instrument* pertains to many different devices. These devices aid with flight management, assist with navigational purposes, and indicate engine and system performance. This collection includes single instruments and entire panels of instruments that were removed from the cockpits of airplanes, helicopters, gliders, and airships. In fall 2013, a project was undertaken to outfit a large display case at the Steven F. Udvar-Hazy Center with 86 instruments from the collection. These objects were previously in storage, making this a great opportunity to share unseen objects with the public.

The display illustrates how the technology of instrumentation has advanced over the past 100 years, and NASM is fortunate to have unique prototypes of early models. World War I put new demands on aircraft, and now pilots were flying in adverse conditions out of necessity. These adverse conditions generated a scenario of flying at night or in inclement weather where previous methods of flying by sight were no longer possible. As flying at night became more routine, new methods of lighting a cockpit were developed, which included application of radium paint onto dials and switches. The use of radium paint decreased significantly after World War II.

Paint containing radium is a type of luminescent paint. This glow-in-the-dark paint allowed pilots to the read the instruments while maintaining their night vision in a low-lit cockpit (fig. 1). Approximately two-thirds of the instruments displayed in the case at NASM contain radium paint. Even though the paint no longer glows in the dark, the radium continues to emit measurable radiation. This paint presents the challenge of conserving, storing, and displaying a collection of radioactive objects in a museum. In preparation for and over the course of the project, procedures were established to provide a safe working environment for the staff and a safe display case for the public.

Fig. 1. This Mach meter is an instrument in the display case that contains radium paint. NASM, A19490053000. (Courtesy of Sharon Norquest)

2. RADIUM PAINT

Radium paint is composed of the radium isotope Ra-226, usually in the form of a radium salt such as radium sulfate, radium bromide, or radium chloride (Lind 1925). Radium sulfate was usually preferred, as it is less soluble than the other salts (Frame 2007). This radium salt is combined with a luminescent material and a paint binder. Historically the luminescent material was zinc sulfide (Jones and Day 1945). The energy from the radium interacts with the luminescent materials, causing the material to glow. In the case of zinc sulfide the radiation causes it to glow green. One recipe from 1945 lists 70 micrograms of radium sulfate to 1 g of zinc sulfide (Jones and Day 1945). There are historic accounts of the binder being gum arabic (Jones and Day 1945); another account lists the binder as linseed oil (Frame 2007). Other radioactive sources, such as thorium and tritium, have been used in the fabrication of luminescent paint; however, this article will focus solely on paints derived from radium isotopes. Paints were made with the minimum amount of binder possible, as there was concern that the binder would interfere with the radiation energy and intensity of the glow. One reason the paint is so fragile today is because the radium is breaking down the binder material and the paint may have been underbound. Radium paint that currently does not glow is due to a breakdown of the luminescent material (Warren 2010). Radium is present in some nonglowing paint; thus any suspicious paint should be checked for radiation, as there may be no visual clues that the material is radioactive. Due to the long half-life of radium, it would take 1,600 years for the radium to break down and not be present in the paint.

On two instruments with an exposed face that was not fully covered in glass, a portable Bruker Tracer III-SD XRF instrument was used to provide elemental analysis of the radium paint. A high level of zinc was found in this paint, but not in any of the surrounding black painted surface. The analysis also revealed the presence of sulfur. Although the paint analysis was very limited, preliminary elemental analysis indicates that the paint is composed of both zinc and sulfur. This is in agreement with historic recipes. Due to the health hazards and license restrictions, samples of paint could not be removed from the object for analysis. Paint covered by glass could not be analyzed due to the distance and obstruction of the glass.

3. HEALTH HAZARDS

Radium paint emits alpha and some gamma radiation. Radium decay also produces beta radiation and radon gas. Alpha particles have low penetrating power. Beta particles have a range of energy, but they are easily stopped with common shielding materials such as wood or plastic. Gamma rays travel the farthest and can penetrate many materials, including human tissue (United States Environmental Protection Agency 2015). The radium paint on the instruments in the NASM collection have a relatively low level of radioactivity. With this low radioactivity level, the primary health hazard shifts from the focus of gamma ray exposure to the danger of ingesting radioactive particles in the form of dust or paint flakes. The potential of being inhaled or ingested creates an internal hazard, which is greater than that of an external hazard of the same quantity of material. Inhaled or ingested radium increases the risk of developing bone cancer and other diseases, such as lymphoma and leukemia (United States Environmental Protection Agency 2015). Radium paint was used on instrument dials until adverse health effects were discovered. The working conditions and unfortunate health consequences of dial painters in a factory in New Jersey is well documented in books, poems, and movies about the "Radium Girls." In 1945 an article was published by the *British Journal of Industrial Medicine* that describes the protective gear worn by their radium painters in response to the conditions in the New Jersey factory (Jones and Day 1945). This was the beginning of recognizing the health hazards of radium paint. By the late 1960s radium paint was generally no longer applied to instrument dials.

The buildup of radon gas is another health hazard that needs to be considered; it is produced from the decay of radium, and exposure can lead to cancer. Large collections containing radium should be stored in a well-ventilated area to reduce radon accumulation. For storage rooms where radon accumulation is a concern, a process for monitoring the concentration of radon should be implemented.

4. MEASURING AND RECORDING RADIATION LEVELS

Monitoring and tracking exposure for people working around radioactive collections is part of a comprehensive health and safety program. For monitoring personal exposure to gamma, beta, and x-rays, using a dosimeter that is worn on the body or an extremity is appropriate. Depending on the intended use, instant readings or exposure over time can be measured, the latter of which enables data tracking. Various types of dosimeters exist, including photographic film, thermoluminescent dosimeters, pencil dosimeters, and electronic dosimeters. A subscription service typically is purchased from a certified laboratory for a relatively low cost to provide dosimeters and dose reports. Systems may be purchased to read the dosimeters on-site, which is usually practical for larger numbers of users. Pencil and electronic dosimeters are reusable direct reading instruments. These will provide a measure of dose that can be read by the user throughout a monitoring period. Exposure dose results are typically in units of millirem (mrem) per monitoring period, such as an hour, week, month, quarter, or year. The United States Nuclear Regulatory Commission (NRC) has established an annual cumulative exposure limit of 5,000 mrem for employees exposed to radioactive material.

Radiation detection instruments come in a variety of types, from nonportable stand-alone or countertop instruments to handheld detectors such as Geiger counters. All instruments have their strengths and weaknesses, so it is important to use an instrument appropriate to the purpose (type of decay and energy) and calibrated for the type of survey intended. It is common for the calibration method to be noted on the side of the instrument. If not, consult the person or company who provided the meter.

For the purpose of this discussion, we will briefly highlight several instruments most commonly used for surveys: wipe counters for detecting removable contamination and dosimeters used to document personal exposure. The simplest and perhaps most fundamental of all instruments are handheld survey meters, which comprise the meter body and the detector. Sometimes the survey meter is a separate instrument body with a detector attached by a cable. Other models may have the detector built into the body of the instrument. One of the most typical types of detectors is the Geiger-Müller, or GM detector, often termed the *Geiger counter*. The GM detector is a very good general-purpose detector capable of detecting alpha and beta particles as well as photons of x-rays or gamma rays. It can be used for the detection of radium, but for some isotopes with very low energy, the efficiency of the GM detector declines. If the energy is low enough it may not even be detected. Such is the case for low-energy beta-emitters such as tritium or low-energy gamma-emitters such as iodine-125. Properly calibrated, such instruments will detect the alpha and gamma energy of radium-226, commonly found in watches, clocks, instruments and gauges, or dials. These instruments are typically calibrated as rate meters, with the meter results provided in units of counts per minute; however, they also may be calibrated for exposure rate in units of milliroentgen per hour (mR/hr). A GM detector is highly energy dependent, so depending on the purpose of the survey, correction factors may need to be considered. NASM has access to a wide variety of survey instrumentation, and we typically use Ludlum Model 3 handheld survey meters, with either a Model 44-9 alpha-beta-gamma detector or a Model 44-7 beta-gamma detector. These are calibrated on a yearly schedule by a qualified technician (in our case, a contracted company called RSO, Inc.). Using the back of the 44-9 pancake detector allows recording of the gamma levels in the NASM Collections Information System (The Museum System database). The front of the pancake detector can also be used as a tool to identify the presence of alpha particles emitted from radium-226.

The scintillator detector is another practical detector used for general scanning to identify whether or not radioactive material is present. Scintillation detectors can be used to detect radioactive material at much lower levels than that of a handheld instrument. These detectors come in various types and can be connected to a survey meter. A liquid scintillator detector is used at NASM. To operate this detector a cotton swab or paper disk (also called a *wipe*) is touched to the surface of an object with care not to touch exposed or friable paint, as shown in figure 2.

Any radiation "leaks" or removable surface contamination are picked up by the paper or swab. The swab is then placed in a vial of scintillation cocktail, which is a solvent that contains scintillators and surfactants. The vials are run through the scintillation detector and radiation on the swab is recorded. The unit can run many samples at one time. Depending on the type, they may be suited to low-energy gamma, higher-energy gamma, or beta and gamma energy. An alpha-beta counter can also be used to record the radiation level on a cotton swab or paper disk.

Ion chambers, microR meters, and energy-compensated detectors are grouped together because they are typically calibrated for exposure rate in units of milliroentgen per hour or microroentgen per hour (µR/hr). These instruments provide a measure of ionization in air; for x-rays and gamma rays, the measured results are comparable to the dose rate. Ion chambers may be useful for gamma and x-rays when the exposure rate is greater than a few milliroentgen per hour. Energy-compensated detectors help to flatten the energy response curve and are capable of measuring gamma and x-rays approximately 10–100 times below 1 mR/hr with background radiation in the range of 0.01–0.05 mR/hr. A microR meter, as the name suggests, will typically detect energy 1,000 times less than a typical ion chamber or about 3–10 µR/hr for background. All of these detectors tend to have a relatively flat energy response as

Fig. 2. Taking a wipe from the exterior surface of an instrument face (Courtesy of Amelia Kile)

opposed to GM and scintillation detectors. Any meter appropriate for the type of decay and energy response may provide useful information if the calibration and measurement technique are known. Typically, some form of exposure rate measurement is useful for providing a measure of dose to ensure compliance with exposure limits for staff and the general public.

A simple combination of these tools, selected by purpose and need, will enable individuals to evaluate and monitor personal exposure to the staff and the public, as well as proper management of collections containing radioactive material. The documented results will provide reasonable records of exposures and contamination control, which are key elements in a radiation safety program.
GM detectors may be purchased and used with relative ease. In addition, outside laboratories and consultants may be useful in conducting surveys, calibrating instruments, or analyzing wipes for contamination detection.

5. WORKING WITH THE NUCLEAR REGULATORY COMMISSION

Because the Smithsonian Institution is a federal entity with a large collection of radioactive objects, these objects are licensed by the NRC. In addition to conservation work for display, tasks were completed to meet the requirements of the NRC license. Managing radioactive collections in storage and in preparation for display will be discussed in the context of developing a practical system for working with a radioactive collection.

Simply owning licensed radioactive collections objects, particularly individual aircraft instruments, is an extensive undertaking. It requires significant advance preparation and collaboration involving multiple parties and departments, because when more than 100 radioactive instruments are located in one place and not installed in an aircraft or vehicle, state regulators or the NRC may require the owner to either reduce the number of instruments they own or apply for a specific license that governs possession of those objects beyond more general laws and regulations. For example, as the Smithsonian Institution has more than 100 such objects, the NRC has issued a specific license that applies a greater degree of regulatory compliance. The license requires more frequent and extensive inventory than the museum's regular collection-wide cyclical inventory. Inventory and disposal records must be made available for unannounced NRC inspections. Our license also requires "leak testing" radium-containing objects for removable contamination at regular intervals and before transport. Testing for removable contamination or leaks is done using a liquid scintillation counter. Radiation safety training for staff, routine surveys, survey instrument calibration, and adequate documentation are required elements of our license.

Preparing instruments for display requires additional health and safety policies and procedures to be in place. Records must be kept documenting that proper procedures are followed and tests performed to keep work areas from becoming contaminated. Up-to-date signage needs to be posted, possibly including NRC Form 3. Maintaining radioactive objects on display also requires regular inventories and leak testing. The NRC treats individual instruments much differently than those installed in aircraft. Typically for NASM, there is not public access to aircraft cockpits and leak tests are not required. Leak testing for individual gauges on display must be performed by licensed personnel. Staff with access to display cases containing radioactive objects are informed of their locations and properties so that they can take proper precautions when accessing those cases.

Obtaining training for handling radioactive artifacts can be challenging. For scenarios in which multiple people will encounter radioactive objects in a collection, having an outside resource brought in to address training for specific needs and uses is likely the best route. In addition, being knowledgeable about the level of training required by local or federal regulators is strongly advised, whether for routine handling or conservation treatment. The Smithsonian Institution is fortunate to have a safety office with resources to address health and safety concerns. Independent services and labs are available as well. We work closely with the radiation safety officer (RSO) and followed his guidance for this display. The RSO continues to work as a point of contact with the NRC to increase understanding of how possession and use of radioactive materials in museums is unique from other industries. This dialogue could influence how regulations are applied at NASM. Any changes that could come about for the application of regulations could serve as a precedent at the state level for cultural institutions and historic artifacts. NASM's institutional knowledge about managing the instrument collection has developed markedly as a result of working more closely with the NRC and health and safety experts, and our procedures have evolved and improved accordingly.

6. STORAGE AND SHIPMENT OF OBJECTS WITH RADIUM PAINT

Several issues are prominent in storing radium-painted instruments properly for long-term preservation, regulatory compliance, and health and safety concerns. These issues include radon gas emissions, protective housing to prevent dial face breakage, physical security, and contamination control.

Proper ventilation is essential for storing even a small number of radium-containing objects, as radium decay can cause an accumulation of radon gas at levels inappropriate for both residential and occupational exposure. This means that storage and display areas may need to be tested for radon and ventilation for those areas may need to be evaluated. A procedure for venting cabinets may be sufficient, or a dedicated ventilation system may be necessary. NASM has come to the conclusion in more than one situation that open shelving is preferable to ventilated cabinets for long-term storage at our facilities, because the cabinets do not significantly contribute to already multilayered security and they are cost-inefficient. Additionally, dedicated cabinet ventilation systems are more complex and may be prone to maintenance issues.

Several organizations recommend housing radium-painted instruments in bags (Ashton 1993). Although housing instruments in bags and additional handling containers may be prudent to reduce the risk of contamination, we have concluded that polyethylene bags do not have the added benefit of significantly reducing radon accumulation. Polyethylene is a cost-effective and easy-to-implement choice of material for bags to contain potential particulate contamination such as paint flakes. The diffusion coefficient for radon through polyethylene is lower than the radon diffusion coefficient through air or water (Leung et al. 2007). This means that radon will move slower through polyethylene than it will through air or air with a moisture vapor barrier. As the radon is moving at a slow rate through polyethylene, some radon will remain contained within the enclosure; therefore, the bag should be opened in a well-ventilated area or in a fume hood. Considering that the primary purpose of the bag is to contain paint particles and not trap radon gas, the thickness of the bag can be varied. Variations in the thickness of the polyethylene bag or additional layers of bag will affect the diffusion of radon. The method of bag closure is not critical to contain radon, as the radon can escape through the polyethylene. Since the NASM instrument collection is routinely accessed to meet criteria for the NRC license, objects were placed in polyethylene bags with a zipper-style seal and housed in archival corrugated board boxes to provide easier access to the collection. Bags made of other material (e.g., Marvelseal) pose several problems, such as difficulty in quickly and effectively resealing the bag as well as relatively high cost. For a situation where the object does not need to be accessed for long periods of time, material like Marvelseal may be a good option but requires future research.

Storage shelves should be periodically wipe tested if objects or containers are found to be contaminated with radium paint particles. These wipes will determine the level of radon daughter product. Radon daughters, or radon decay products (e.g., polonium-218 or lead-210), are solids and can adhere to surfaces and dust, unlike radon gas. If the wipe analysis shows elevated levels of radiation, the shelves can be decontaminated and resampled to ensure that levels are acceptable. Contamination by radon daughter products can be differentiated from radium contamination by allowing the wipe to decay, since radon daughter products decay much faster than radium.

Information about packaging, labeling, and documenting transportation of radioactive material for those with an NRC license is contained in Title 10 of the Code of Federal Regulations, Part 71. Many of the packaging requirements for objects like radium-painted dials are no greater than the standard or best practices for cultural institutions; however, they are more specific. For safe handling and hazard communication at NASM, particularly for instruments in storage, we have adopted some labeling and packaging similar to that required for transporting radioactive materials, including markings with exposure rates, dates, isotope, and standardized radioactive labels on multiple sides of the container that houses the object. A removable tag is also placed on the object. Each record in the collections database has a hazardous materials flag that appears at the top of the record, which is specific to radiation. Survey meter results and results from tests for removable contamination are recorded in the database for each instrument tested, along with the date, storage location, names of staff, instrument calibration information, and specific locations tested on the object.

Several companies provide training either with distance-learning courses or by an in-person instructor for a group for people who may need to ship objects containing radioactive materials. This training is particularly helpful for collections managers and registrars, to be aware of the requirements imposed by the U.S. Department of Transportation and the International Air Transport Association, even though a contracted company would typically be the carrier. Training is mandatory for anyone preparing a package of hazardous material or dangerous goods, which includes radioactive material, for shipment by a commercial carrier such as FedEx or UPS.

7. SETTING UP A DESIGNATED WORK SPACE AND PERSONAL SAFETY EQUIPMENT

Space at two facilities of NASM was established to conduct work on radioactive objects. A small side room in the Emil Buehler conservation lab at the Udvar-Hazy Center was set aside for this work, as it had the advantage of being in a clearly separate work space within a room with a closeable door. Being behind a closed secured door during public tours was desired to limit public access, exposure, and concern about radioactive material. The main conservation lab and side room are labeled with NRC-required signs (Form 3) informing all individuals that materials in these spaces may be radioactive. In each work space a portable high-efficiency particulate air (HEPA)-filtered fume hood designated for radioactive material was utilized. These fume hoods were labeled and inspected routinely by the Smithsonian Office of Safety, Health and Environmental Management. The work surfaces of the fume hood, tables, carts, and storage shelves were lined with a material called Benchkote. This liner and similar products are commonly used in research and production laboratories in the biology, medical, and chemical industries. One side is a textured cellulose that can trap dust particles, and the other side is a thick layer of polyethylene that prevents the transfer of liquids.

At NASM's Paul E. Garber storage facility in Suitland, Maryland, a similar workspace was equipped with a HEPA-filtered, radioactive-materials–only fume hood and a dedicated vacuum with a HEPA filter. Since work tables and carts were not used exclusively for radioactive materials, they were lined with Benchkote when work with the instruments was being performed. At the end of each work period when the table or cart was no longer being used for the instruments, the Benchkote was removed. The work surfaces were surveyed for removable contamination, and the results were recorded and posted. Contamination was not an issue for this project, but equipment, training, and supplies to properly clean up and dispose of possible contamination were available.

Protective gloves, masks for dust particles, and protective or disposable clothing (e.g., a lab coat) were also used. All tools were retained in the designated work space and were marked with a radioactive label until the project was complete and/or the tool was tested and found not to harbor surface contamination. A lead-free apron was worn when desired to protect workers from radiation. To keep exposure as low as reasonably achievable (ALARA), it may be advisable to use shielding when, for example, working for longer periods of time in a location where close proximity to gauges and/or radium-painted toggle switches is unavoidable. Aprons and/or lead shields are generally not required for this application, but a dosimetry program would provide the information to make this determination.

8. TREATMENT PROCEDURES FOR RADIOACTIVE OBJECTS

Conservation treatment steps were adapted to provide the best care for the object while working safely with a hazardous material and meeting the NRC requirements. This included working in the designated work space and using Benchkote on all work surfaces. To minimize the risk of contaminating the background paper used for photography of nonradioactive objects, a system was devised in which radioactive objects were placed on a cart covered in Benchkote. The cart was then rolled into the photography area *in front of* the background paper. This had two advantages: the cart itself was moved to photograph all sides, preventing direct handling of the object, and the object was never in direct contact with the photo paper.

Treatment focused on the exterior of objects and on instruments with exposed paint. Due to limited access and a desire for limiting radiation exposure time, treatment of the radium paint was minimal. Radium paint was consolidated and coated with 5% (w/v) Paraloid B-72 in acetone, applied by brush where possible. The stock solution of Paraloid B-72 was labeled radioactive, and at the conclusion of the project the remaining B-72 was disposed of as radioactive waste. This acrylic resin and solvent carrier did not adversely interact with the radium paint. Two applications of Paraloid B-72 were sometimes necessary in situations where a thick topcoat of acrylic was desired to help block alpha radiation particles. The consolidant helped to reduce the risk of the spread of contamination and the health hazard of friable paint. The testing of other consolidants was not carried out, as mock ups of radium paint could not be fabricated. There is a precedent at NASM of using Paraloid B-72 on radium paint (e.g., on toggle switches manufactured with a dot of exposed paint), and we have found the acrylic resin to be a stable consolidant over time and in various storage conditions. The paint binder was not analyzed due to limited physical access to the radium paint and the fact that no radium paint samples could be removed from the object. It would have been desirable to test various consolidants and analyze the paint binder; however, because of the hazardous nature of the paint, these steps were not possible. Inpainting was carried out on the instrument face only if the face was accessible, it was deemed absolutely necessary, and if the time to inpaint could be kept to a minimum to limit exposure to radiation. It should be noted that disassembly of instruments containing radium paint is not allowed except by specific authorization with the NRC or an agreement state. Agreement states have some regulatory authority over radioactive materials, as they have signed agreements with the NRC.

Other treatment steps included cleaning and stabilizing the exterior surfaces, inpainting nonradium paint where necessary, and addressing metal corrosion. The work space and tools were monitored and tested with a survey instrument and/or wipe samples at the end of each day to identify contamination and determine appropriate disposal. Materials tested include gloves, lab coats, Benchkote, and packing material as shown in figure 3.

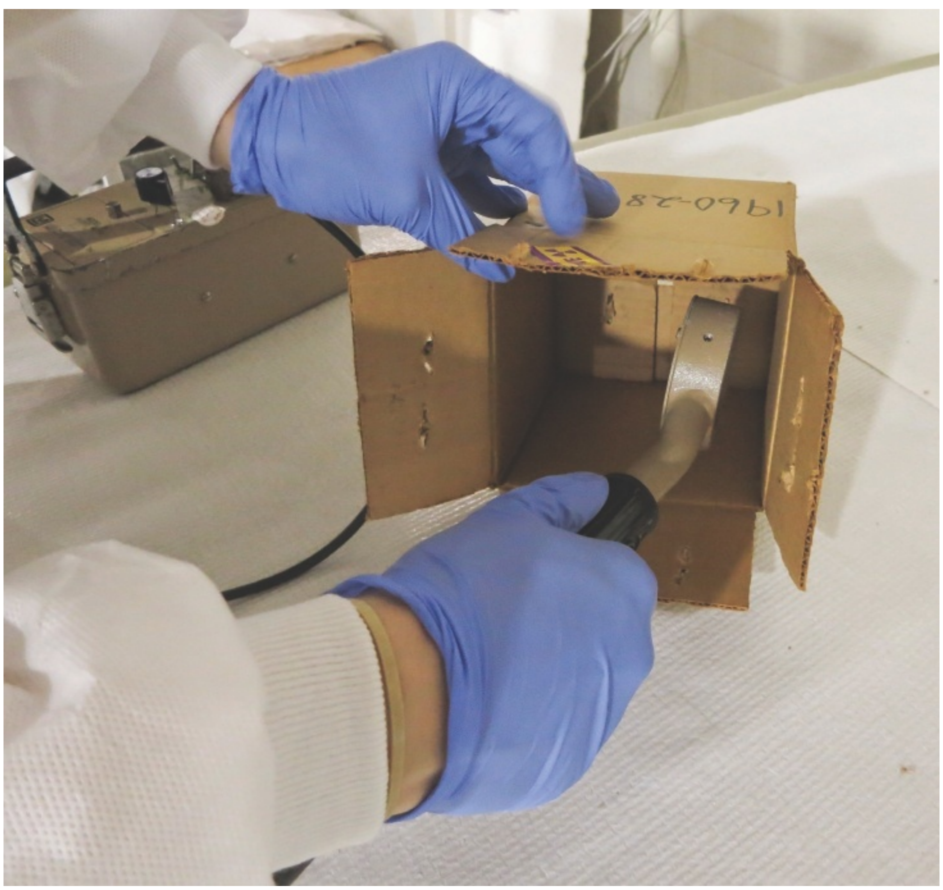

Fig. 3. Testing a box with a Geiger counter for radioactive paint flake contamination (Courtesy of Sharon Norquest)

Materials used for treatment, such as cotton swabs or Kimwipes, were disposed of as radioactive waste. At the end of a workday a wipe test was carried out on the workbench, floor, and fume hood. All results of these wipe tests were recorded in a binder that could be checked during NRC inspections.

For disposal of radioactive waste, material with a short half-life can usually be held on-site in proper storage for decay until only ambient or background levels of radioactivity remain. This is not an option for Ra-226, as its half-life is about 1,600 years. At NASM all radioactive waste is inventoried and placed in a specialized and labeled waste barrel in a secured area. It is then picked up by a licensed contractor who transports the material to Clive, Utah, for disposal.

9. DISPLAY CONCERNS

The primary concern with the display case was to determine if the public exposure was below the 2 mrem/hr requirement. The general public radiation limit established by the NRC is 100 mrem/yr (United States Nuclear Regulatory Commission 2014a). The public exposure limit at the outer surface of the case is 2 mrem/hr (United States Nuclear Regulatory Commission 2014b). With these guidelines a visitor can stand in front of a display at NASM for at least 50 hours. To test the potential level of exposure, instruments with the highest levels of radioactivity were temporarily placed in the case during the museum's closed hours. The exposure rates were recorded with a handheld survey meter at the outside surface of the clear acrylic vitrine. Even with many radioactive instruments in one large display case, the measured exposure rates for the public did not exceed the limit. The clear acrylic acts as a shield for the alpha particles. The distance between a radioactive instrument and the public was also considered, as the radiation exposure drops exponentially with an increase in distance. Two objects with higher radiation levels were placed at the back of the case farthest from the public. By moving these objects back, the levels of radioactivity just outside the case were kept as low as possible. No objects needed to be shielded or removed from the original layout.

The display case will only be opened by trained staff who are monitored through the dosimeter program. These staff will follow precautionary procedures each time the case is opened in the event of unexpected radon accumulation. The radon levels in the case will be monitored and the case ventilation will be retrofitted if it becomes necessary. The case has a security system that provides reasonable accountability and control, because all licensed radioactive material must be secured against unauthorized access. Concerns for light, temperature, and relative humidity were not out of the ordinary. A section of the case receives direct sunlight during certain times of day and year, so care was taken to display only the least sensitive objects in this section and UV film was installed.

Another challenge was to set up a display mock-up with the exhibits team to determine object placement within the case. To accomplish this task, tables were lined with Benchkote and objects were retained in their handling trays. Staff trained to work with radioactive objects handled the objects during this display mock-up while the curator and exhibit designers determined object layout in the display case. For the case, lining for the glass shelves was not necessary. If the exhibit is deinstalled, shelves would be checked for contamination and, if necessary, could be easily decontaminated. A large graphic label discussing the case contents mentions their radioactivity in a historical context.

10. CONCLUSION

By establishing and following procedures we were able to conserve and display approximately 60 radioactive objects. Fortunately, all instruments and panels the curator desired to exhibit could be situated in a large display case without excluding any objects from display. Additional shielding for the public was unnecessary as well. Certain analysis and treatment steps were curtailed by stringent health and safety requirements. However, the work was completed in a manner that provided a safe working environment for the staff and a display case that is safe for public visitors has been installed, all while also meeting the requirements of the NRC. This work could not have been completed without collaboration between the Smithsonian Office of Safety, Health and Environmental Management, the curator of the collection, collections processing, conservation, and exhibits staff. The final steps of installing the instruments into the case are being conducted. It is our hope that this article is useful to others who may be embarking on the treatment and display of radioactive artifacts.

ACKNOWLEDGMENTS

We would like to thank our many colleagues at NASM for their assistance and support during this project. Thank you to Roger Connor, the curator of the instrument collection, whose knowledge about the collection was imperative. We also extend a big thank you to David Peters, whose guidance made this project possible. This project would not have been possible without generous funding from Bruce Del Mar.

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SOURCES OF MATERIALS

Benchkote
Manufactured by Whatman
100 Results Way
Marlborough, MA 01752
1-800-526-3593
http://www.gelifesciences.com/webapp/wcs/stores/servlet/catalog/en/GELifeSciences-au/products/AlternativeProductStructure_17131/28418846

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THE USE OF COPYFLEX FOOD GRADE SILICONE RUBBER FOR MAKING IMPRESSIONS OF ARCHAEOLOGICAL OBJECTS

VANESSA MUROS, HEATHER WHITE, AND ÖZGE GENÇAY-ÜSTÜN

Conservators are always looking for stable and inert materials that are easy and safe to use on cultural objects. This is especially true when working in the field, where lab grade facilities and resources are limited, if not inaccessible. In the summer of 2014, conservators at the Ancient Methone Archaeological Project tested a food grade silicone rubber, CopyFlex, to make impressions of ceramic artifacts. The pilot application of CopyFlex in the field, combined with the results of Oddy testing, shows it to be a remarkably viable field tool that reproduces fine surface detail while being simple to prepare, easy to use, and safe for the artifact. This article will describe the material and highlight the advantages of its use in the field with the aim of adding another product to the conservator's tool kit.

KEYWORDS: Archaeological conservation, Silicone rubber, Mold, Food grade, Oddy test

1. INTRODUCTION

Conservators often need to make molds or take impressions of artifacts that are used as replicas to cast and recreate missing areas on an object, or in the case of archaeological conservators working on site, to make copies of artifacts or take impressions for research and publication. Silicone rubber is a material commonly used for molding artifacts and has been successfully used to copy fine details on archaeological objects.

The directors of the Ancient Methone Archaeological Project were interested in taking impressions of objects, such as coins, or possibly molding and casting small artifacts for study purposes since it is not possible to remove archaeological objects from Greece for research purposes. The conservators were tasked with finding a suitable molding material for these purposes. At the suggestion of a colleague, the conservators on the project tested CopyFlex, a two-part room temperature vulcanization (RTV) food grade silicone rubber, for its suitability as a molding material to take into the field. The low cost, ease in mixing, ability to copy fine detail, and low toxicity of CopyFlex made it an appealing alternative to more commonly used low-viscosity molding materials, such as Dow Silastic 3110 RTV silicone rubber, or dental impression materials.

2. COPYFLEX

CopyFlex is a two-part, RTV silicone rubber (organopolysiloxane based) manufactured by Make Your Own Molds. This silicone rubber is a food grade silicone rubber and can be used to make molds for creating food items, but it is also marketed for molding non-food items. The manufacturers describe the material as having a low viscosity, which makes it ideal for replicating fine details.

2.1 WHAT IS FOOD GRADE SILICONE RUBBER?

CopyFlex is described as a food grade silicone rubber and is safe to use to make food molds, such as those used for hard candy, chocolates, or other food items (fig. 1). The Material Safety Data Sheet (MSDS) (Make Your Own Molds 2015a) describes CopyFlex as having low toxicity and a low health hazard. But what exactly is meant by a silicone rubber being "food grade"?

Some other RTV silicone rubbers may contain hazardous ingredients and are not necessarily food grade ingredients as regulated by the US Food and Drug Administration (FDA). However, the ingredients used in CopyFlex comply with the FDA's regulations cited in 21CFR177.2600 (US Food and Drug

Fig. 1. CopyFlex is a food grade silicone rubber that can be used as a mold for different food items, such as the chocolates pictured here. The authors used the silicone rubber to mold a modern glass lion head to make a dark chocolate version of the glass plaque. (Courtesy of Vanessa Muros)

Administration 2014b). This document describes regulations set out for "Food for Human Consumption" and has a section on "Indirect Food Additives: Polymers" (Part 177), which discusses "rubber articles intended for repeated use," such as molds. To be considered food grade, both the elastomer and catalyst must be non-toxic in their uncured state. The silicone elastomer that comprises CopyFlex is on the list of approved materials contained in the regulation ("a silicone elastomer made with methyl and vinyl groups"). The catalyst in CopyFlex, platinum dicarbonyl dichloride, has been approved for use by the FDA as an indirect food additive as long as it does not exceed 150 ppm (or 0.015%) (US Food and Drug Administration 2014a). In CopyFlex, the catalyst makes up 0.01% of Part A (Make Your Own Molds 2015a).

In addition to complying with the preceding regulations, according to the manufacturer, CopyFlex has been subject to extraction testing performed by an FDA-approved and independent laboratory that specifically certifies its suitability for use with water-based foods and also foods that contain fat (Make Your Own Molds 2015b).

2.2 WORKING PROPERTIES

In researching CopyFlex as a potential mold-making material, there were several aspects that made it appealing for use in the field:

- *Easy mixing ratio*: CopyFlex comes in two parts, A and B, and is mixed using a 1:1 ratio of both parts by either weight or volume. This flexible mixing ratio makes it easy to prepare in the field because it does not require the use of a balance for weighing out the catalyst.
- *Shorter curing time*: Unlike other low-viscosity RTV silicone rubbers commonly used for mold making, CopyFlex has a shorter cure time. It cures in 4–5 hours at 70°F.
- *Low cost*: CopyFlex is fairly low in cost compared to other low-viscosity RTV silicone rubbers. A 1 lb. kit costs $25, and the price decreases when larger volumes are purchased. Excavations often run on tight budgets, so it is important to find good-quality and effective materials to use that are low in cost.
- *Low toxicity and low health hazard for user*: Conservation work on archaeological excavations often takes place in makeshift field labs without the proper health and safety controls that would be available in a standard lab. Although personal protective equipment can be used to protect the field conservator when working with toxic materials, ideally it would be best to work with materials that have no or low toxicity. The fact that CopyFlex has low toxicity and is a low health hazard according to the MSDS additionally made it of great interest for testing in a field situation.

2.3 BARRIER MATERIALS: PROTECTING THE SURFACE OF ARTIFACTS

Conservators have often found that the application of silicone rubber to porous materials can result in alteration of the surface. The silicone oils contained in the silicone rubber can leave stains that are difficult to impossible to remove (Larsen 1981; Maish 1994). Silicone rubber can also adhere to porous materials and result in some loss of the surface when the silicone rubber is removed. A surface sealant, release agent, or some kind of barrier layer is often applied to a porous surface prior to application of the molding material to ensure that no damage is caused to the artifact. Materials commonly used by conservators to seal surfaces prior to molding include methylcellulose, resins like Paraloid B-72, and more recently cyclododecane (Brückle et al. 1999; Maish and Risser 2002).

The technical information provided on the use of CopyFlex does not suggest the use of any kind of barrier layer or sealant in regard to this specific product (Make Your Own Molds 2015b). The manufacturers sell a product called *Seal-Dit*, made of a blend of food grade waxes, which is recommended to seal the surface of porous materials prior to the use of any of their molding products to ensure release of the material and no loss to the surface of the object to be molded (Make Your Own Molds 2015c). However, there is no mention of protection needed for possible staining due to silicone oils in the molding material.

2.3.1 Testing

Prior to using CopyFlex on any archeological artifact, the conservators decided to conduct some tests to see if the use of CopyFlex on an unsealed surface resulted in staining and whether CopyFlex would adhere to and remove material from a porous surface. Two resins available on the project were tested as potential surface sealants or barrier layers: Paraloid B-72 and B48-N. Low concentration solutions (3% and 5%) of each resin were tested to ensure that the barrier layer would be thin enough to not obscure any surface detail, but also that it would not darken the porous surface to which it was applied in case not all traces of the barrier layer could be removed after application of CopyFlex.

Table 1. Results of Testing Barrier Materials After Application of CopyFlex and Its Removal After Curing

	Flower Pot Dish	Terracotta Roof Tile	Removal/Damage of Surface
No Barrier	Stained	Stained	Only observed on terracotta roof tile
3% Paraloid B-72	Some staining	Some staining	None
5% Paraloid B-72	No staining	No staining	None
3% Paraloid B48-N	Some staining	Some staining	None
5% Paraloid B48-N	No staining	No staining	None

Staining tests were conducted on a terracotta flower pot dish and a terracotta roof tile. Rectangular areas were marked off on each terracotta object, and the surface was sealed in each area with two coats of each of the solutions, which were prepared in acetone. One area was left unsealed, which was used to test the effect of CopyFlex on the unsealed surface. Once the sealed surfaces dried, CopyFlex was prepared according to the manufacturer's instructions and applied to each test area. Once the CopyFlex cured, it was peeled off the test areas. Visual examination was used to determine if any staining had occurred, comparing unsealed areas and sealed areas before and after application of CopyFlex.

2.3.2 Results

The unsealed areas and the areas coated with the 3% B-72 and 3% B48-N solutions showed signs of staining (table 1). The unsealed areas appeared very dark and the surface was saturated after removal of CopyFlex. Although no testing was conducted to characterize the stains, they were thought to be due to presence of silicone oils in CopyFlex. The test areas sealed with the 3% solutions showed spots of some dark discoloration similar to what was observed on the unsealed areas. The test areas sealed with the 5% solutions showed no dark stains on the surface similar to what was observed on the other test areas and attributed to the silicone oils or silicone rubber residues (figs. 2a, 2b).

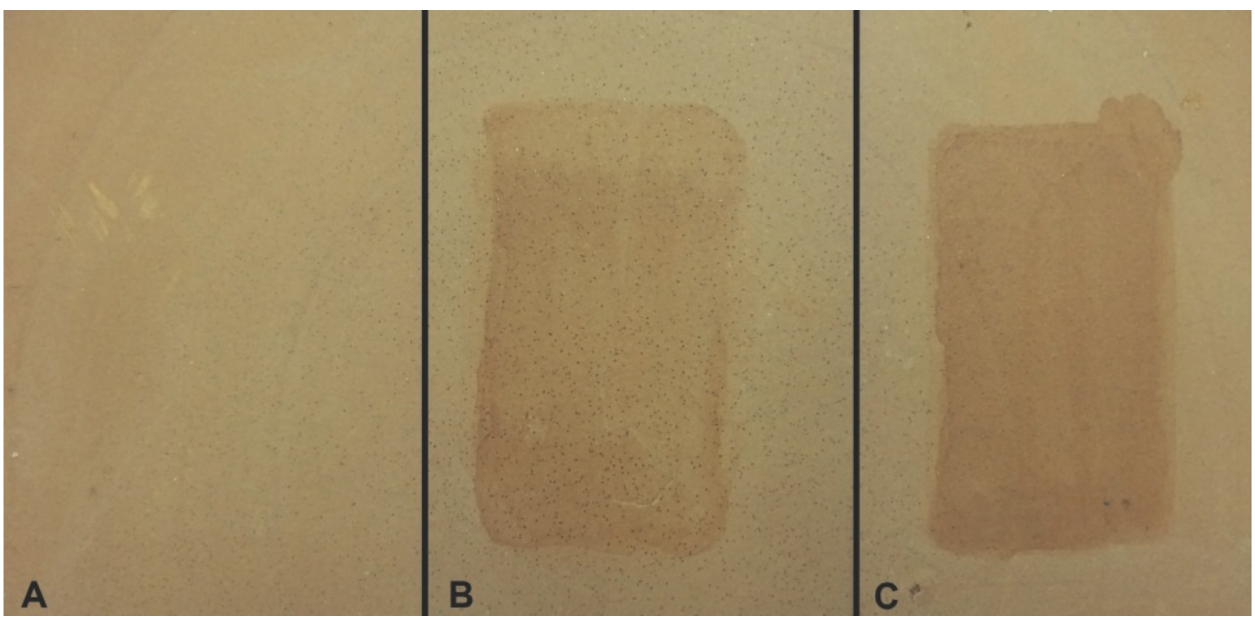

Fig. 2a. Example of one of the staining tests conducted. Here the test areas on a terracotta flower pot dish are documented after the application of a barrier and prior to the application of CopyFlex. Area A has no barrier applied, area B has two coats of 3% Paraloid B-72, and area C has two coats of 5% Paraloid B-72. (Courtesy of Vanessa Muros)

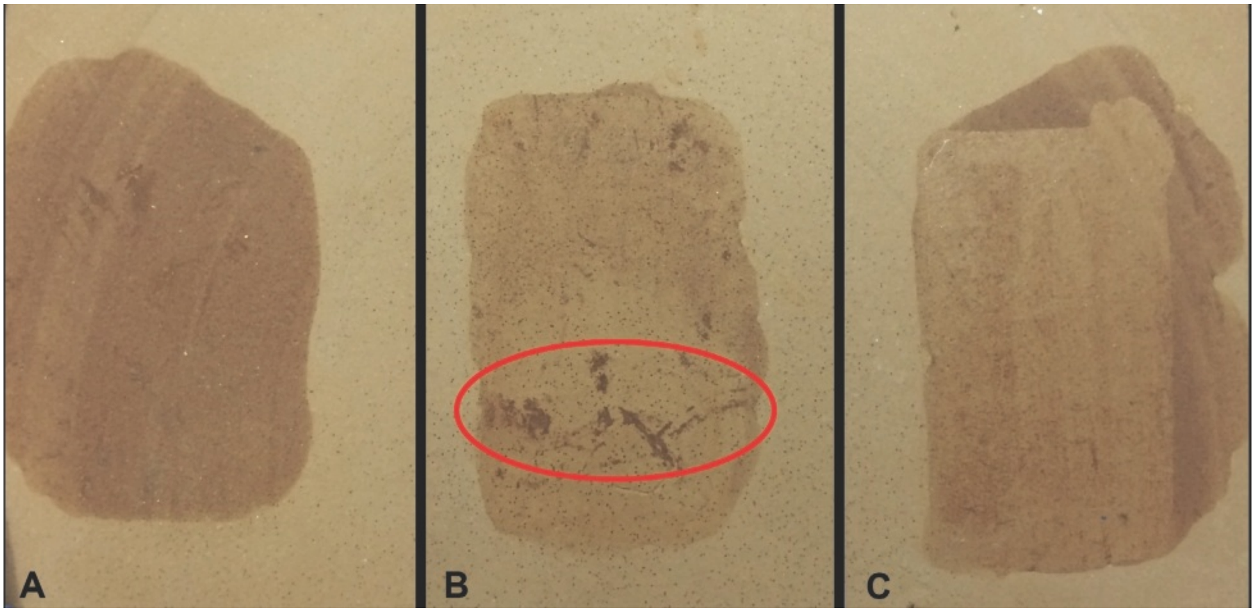

Fig. 2b. Test areas documented in figure 1a after the application of CopyFlex and its removal after curing. Area A (with no barrier) and area B (with a 3% Paraloid B-72 barrier) show some staining from what is likely oils in the silicone rubber. In area B, an example of this staining is marked in red. Area C (with a 5% Paraloid B-72 barrier) showed no signs of staining from the application of the silicone rubber except in the areas around the sealed rectangular section where the silicone rubber ran beyond the test area during curing. (Courtesy of Vanessa Muros)

Based on these observations, it appears that the 5% solution of B-72 and B48-N were both effective in sealing the surface and preventing any staining of the porous materials as a result of the application of CopyFlex.

Because the results of the staining tests relied on visual examination and determination of a color change, it was important to rule out any darkening that could have occurred due to the application of the resin barriers. The test areas that were coated with resin were swabbed with acetone to remove or reduce any of the resin applied. Since silicone oils would not dissolve in acetone, areas that did not change color after swabbing with acetone were assumed to be stained due to the application of CopyFlex and not due to the application of the resin. The areas with no barrier applied did not change color and stayed dark and saturated in appearance. The areas that had the 3% solutions applied had some sections that appeared lighter and others that stayed dark and saturated after application of the acetone. This was interpreted as evidence that some of the dark stains were likely due to staining by silicone oils. The test areas coated with the 5% solutions lightened considerably after swabbing with acetone, and by the same reasoning there did not seem to have been any staining or discoloration due to the silicone oils in those areas.

Test areas with CopyFlex applied were also examined to see if it damaged or pulled up any of the surface of the terracotta test materials (see table 1). Test areas where the surface was sealed, regardless of the concentration of the solution, showed no damage, and the silicone rubber could be removed easily without any observed loss of the surface under visual examination with low magnification. CopyFlex applied to an unsealed area of the flower pot dish peeled off cleanly. However, CopyFlex applied to an unsealed area of the roof tile pulled off some of the surface. The results of this examination show that it is best to seal the surface of porous materials to ensure that no damage or discoloration occurs to their surfaces.

3. CASE STUDY: USE OF COPYFLEX ON THE ANCIENT METHONE ARCHAEOLOGICAL PROJECT

CopyFlex was field tested in the summer of 2014 to make an impression of a rare ceramic figurine mold discovered during a field survey on the Ancient Methone Archaeological Project. The site of ancient Methone is located in northern Greece on the Thermaic Gulf at the delta of the Aliakmon River. It is situated near the modern-day town of Nea Agathopoli. The site shows evidence of occupation from the late Neolithic through the Archaic periods. The site was abandoned in 354 BCE when Philip II of Macedon, Alexander the Great's father, invaded Methone and moved all residents out of the site (Archibald 2012). Methone was never reoccupied, although a Macedonian garrison was built by Philip just north of it.

The object—METH 5582—was brought to the lab covered in concretions that initially disguised the presence of a face and likewise the object's identity as a mold (figs. 3a, 3b). Following treatment and removal of the concretions, the mold was found to be in excellent condition with

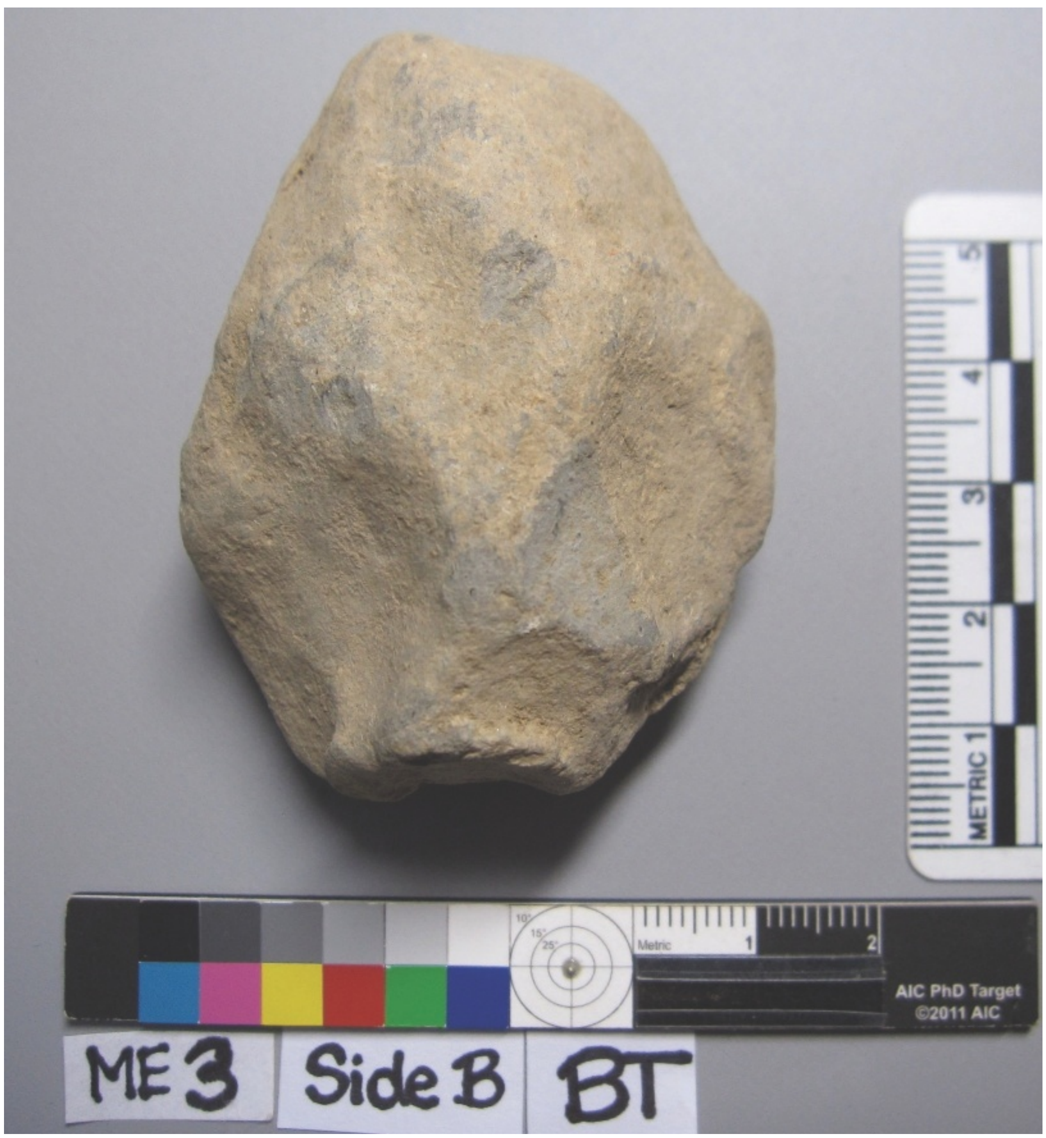

Fig. 3a. Before treatment image of exterior, *Figurine Mold*, ca. 6th–5th-century BCE, Ceramic, 5.1 × 4.2 × 3.1 cm, Ancient Methone Archaeological Project, METH 5582 (Courtesy of the Ancient Methone Archaeological Project)

Fig. 3b. Interior of ceramic figurine mold (METH 5582) before treatment. The extensive concretions obscured the recessed face. (Courtesy of the Ancient Methone Archaeological Project)

well-preserved details of the figure's face (figs. 4a, 4b). The discovery of the object as a figurine mold warranted a great deal of excitement, as it is the first Archaic period mold found at Methone. The site shows evidence of manufacturing and production (ceramics, bronze, iron, lead, bone/ivory working, and possibly glass) and contains evidence of extensive trade throughout the Mediterranean (Archibald 2012). The archaeologists and project directors were very interested in making an impression of the mold to compare its details, such as face and hairstyle, with ceramic female figurines found in the area to see if there was a connection between possible production at Methone and distribution of the finished product.

In preparation for making the impression using CopyFlex, the interior surface of the mold was brush coated with a barrier layer of 3% B-72 and 5% B48-N in acetone to mitigate any possible discoloration of the porous ceramic; the decision to add a layer of 5% B48-N was based on preliminary staining tests conducted on a roof tile (see Section 2.3.1). An initial layer of silicone rubber was applied to the sealed surface using a brush to ensure full contact with the recessed facial details (fig. 5).

Fig. 4a. Interior of ceramic figurine mold (METH 5582) after removal of concretions (Courtesy of the Ancient Methone Archaeological Project)

Fig. 4b. Detail of interior of ceramic figurine mold (METH 5582) after removal of concretions (Courtesy of the Ancient Methone Archaeological Project)

Fig. 5. Coating the interior of the mold with a thin layer of CopyFlex (Courtesy of the Ancient Methone Archaeological Project)

PRIMA Plastalina modeling clay (sulfur-free) walls were built around the mold over barriers of plastic wrap; these walls created a well that would contain the silicone rubber as it was poured (figs. 6, 7). CopyFlex was slowly poured into the mold until it reached the top of the clay walls. The following day,

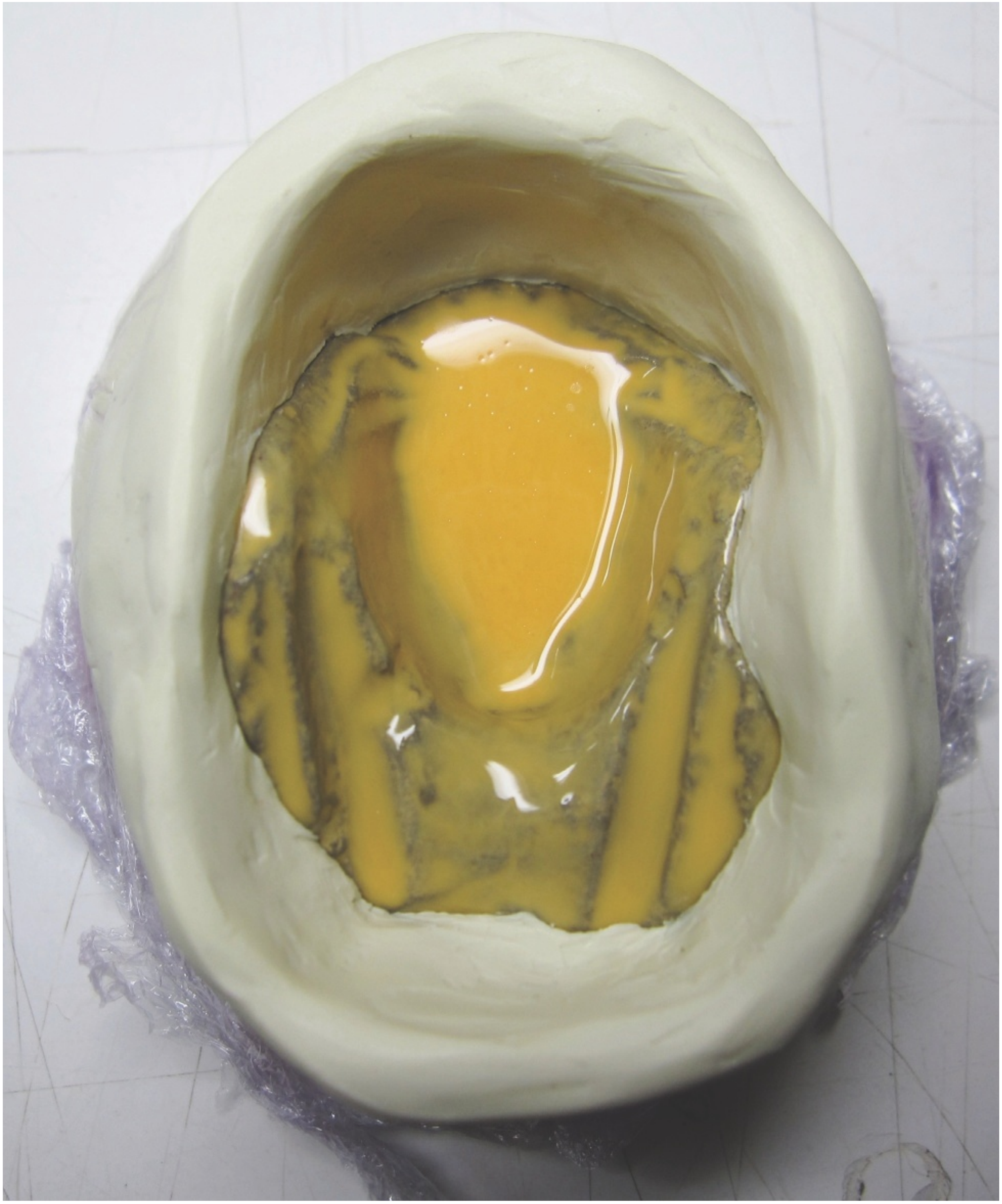

Fig. 6. Modeling clay walls were built around the figurine mold to contain the silicone rubber as it was poured. (Courtesy of the Ancient Methone Archaeological Project)

Fig. 7. Pouring the silicone rubber (Courtesy of the Ancient Methone Archaeological Project)

Fig. 8. After curing, the modeling clay walls were peeled away to reveal the cured CopyFlex, which was then easily removed from the figurine mold. (Courtesy of the Ancient Methone Archaeological Project)

approximately 24 hours after the material was poured, the cured silicone rubber impression was easily removed from the artifact without incident (fig. 8).

The impression accurately reproduced the fine details of the facial rendering, as well as details of the mold's surface condition (figs. 9–11).

Fig. 9. CopyFlex impression of the ceramic figurine mold (Courtesy of the Ancient Methone Archaeological Project)

Fig. 10. Subtle surface details, including losses and other features of the mold's condition on the proper left side of the figure's nose, were accurately represented. (Courtesy of the Ancient Methone Archaeological Project)

Fig. 11. CopyFlex impression and ceramic figurine mold (METH 5582) (Courtesy of the Ancient Methone Archaeological Project)

4. MATERIALS TESTING: ODDY TESTS

CopyFlex is described as a food grade silicone rubber, but it was not clear what this meant in terms of its interactions with artifacts. The natural assumption was that the silicone would not off-gas or cause any damage when in contact with or near archaeological artifacts because it was "food grade." However, at the end of the 2014 season on the Ancient Methone project, the conservators were faced with the question of how to store the silicone rubber impression. They wanted to keep the impression and artifact in the same storage bag but were unsure if any products would off-gas from the CopyFlex, which could be detrimental to the ceramic artifact in an enclosed environment. The conservators decided to isolate each component—the CopyFlex impression and the ceramic figurine mold—in a polyethylene bag for storage but took samples of the cured silicone rubber back with them to conduct Oddy tests on the silicone rubber.

The Oddy test is an accelerated aging test, usually conducted to look at volatile products that off-gas from the test material. In the case of testing CopyFlex, contact tests between the metal coupons and the silicone rubber, as well as testing for off-gassed materials, would be conducted. This would inform not only whether CopyFlex and artifacts could be stored in the same bag or container but also whether they could be in contact with each other.

4.1 ODDY TEST 1: AUTRY

The first Oddy test was conducted with a sample of cured CopyFlex that was the original material used to make the impression in the field. This sample was tested two months after curing. The Oddy test was performed using the test protocol of the Autry Museum of the American West. What follows is a description of how CopyFlex silicone rubber was tested in Autry's conservation laboratories using that protocol.

4.1.1 Coupons

Coupons of copper, silver, and lead, each of 99.98% purity, were prepared for testing. The coupons were cut with scissors to size. The lead and copper coupons were newly cut from their original sheet, but the silver was reused from past Oddy tests. The coupons were of thicknesses outlined in the published protocol (Üstün 2015), with the silver coupon slightly thinner than the published protocol because it had been used repeatedly for other Oddy tests.

Both sides of the copper and silver coupons were polished using fiberglass bristle brushes. The lead coupons were not polished. All coupons were submerged in acetone for five minutes. They were then left to air dry on Mylar film. Gloves were worn during the coupon preparation, as well as throughout the entire test preparation, such as washing the jars and handling the test material until the closed jars were put in the oven, to ensure that there was no contamination.

4.1.2 Glassware

Each piece of Kimax glassware that would be used for testing had already been cleaned after the previous Oddy test. However, before the current test, they were rewashed using Lipsol biodegradable liquid laboratory detergent. After washing, the coupons were rinsed with tap water, followed by an overall wash in distilled water. They were hung on a laboratory rack for air-drying.

4.1.3 Oddy Test 1: Preparation

All three coupons were inserted in a 1-g sample of the cured CopyFlex, which was then placed inside a 20-mL beaker. Half of each coupon was inserted into the silicone rubber so that half

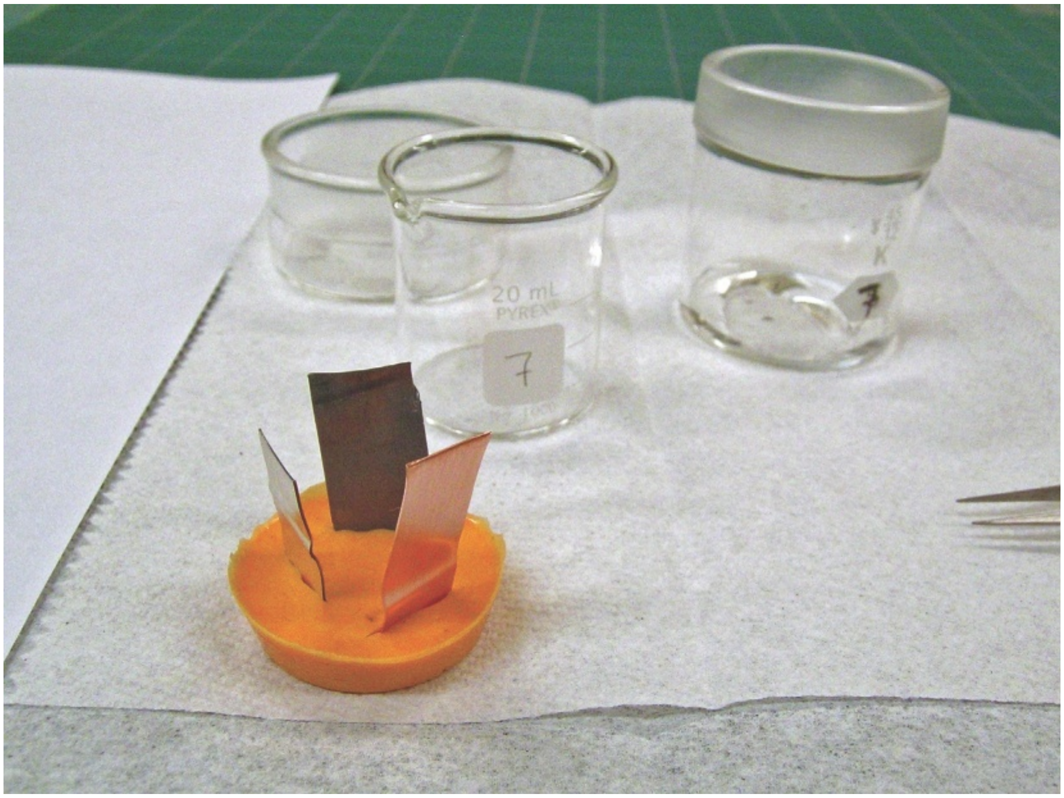

Fig. 12. Detail of the coupons tested with the cured CopyFlex (lower half in contact) before the Oddy test (Courtesy of Özge Gençay Üstün)

the coupon was in direct contact with the material during testing and the other half would maintain contact with any vapors that off-gassed (fig. 12). Kimax weighing jars were filled with 1 mL of distilled water that had a pH of 4.5–5. The beakers containing the samples were lowered inside the Kimax jars. For the control jar, the coupons were bent over the mouth of the 20-mL beaker. A thin layer of Dow Corning silicone vacuum grease was applied inside the lid (on the ground glass part) to tightly close the jars.

4.1.4 Testing Specifics

The test lasted for 28 days in an oven that maintains 60˚C within ±3˚C fluctuations. Inside each jar, 1 mL of water was added to maintain the 1:70 water to container volume ratio (Bamberger et al. 1999). This ensured that relative humidity (RH) was maintained at 100% inside the test jar for the duration of the test. If there was excess water inside the container, condensation did not build up on the coupons because the coupons had been inserted into the test material and stood vertically to prevent water from pooling on them (see fig. 12).

4.1.5 Assessing the Results

According to the Autry protocol, two conservators look at the coupons independently of each other and without knowing what material is being tested. Then they discuss their separately submitted Oddy test results about each material and compare them to each other. During this discussion, the material being tested, its use, and the duration of use are taken into consideration before the final results are agreed upon.

Fig. 13. Results of Oddy test 1 showing the test coupons and the control (Courtesy of Özge Gençay Üstün)

4.1.6 Oddy Test 1: Results

After completion of the accelerated aging, the jars were removed from the oven and test coupons were compared to the control coupons. The section of the coupons inserted into the cured CopyFlex showed similar corrosion patterns to the coupons exposed to vapors, as well as to the control (fig. 13). Based on the results observed, this sample of CopyFlex showed no alteration to the coupons in the contact or vapor testing. Two conservators independent of each other concurrently deemed CopyFlex suitable to be near or in contact with artifacts.

In addition, the pH of the water in the test jar and the control jar was remeasured (6 and 5.5−6, respectively) immediately after the test was concluded. This slight rise of the water pH in the control jar has been previously observed in many other past Oddy test control jars conducted on other materials. The pH of water inside the CopyFlex jar was no different from the one in the control jar in this instance.

4.2 ODDY TEST 2: GETTY VILLA

The second Oddy test was conducted at the UCLA/Getty Conservation training labs at the Getty Villa in Malibu, California, using the Getty Conservation Institute's Oddy testing protocol (Schiro 2015) with some modifications. The materials tested included Part A and Part B of the CopyFlex liquid silicone rubber, as well as a cured sample of the material freshly after mixing. The interest of this test was to gauge the potential of any initial off-gassing within the first day of curing—more relatable to the time frame of when a cast impression or replica might begin to be stored with the artifact—as well as any reaction that may correspond to one of the individual components. In addition, a partial contact test was again utilized for the cured sample—half of the coupon in direct contact and half in contact with any vapors, as it is important to know whether CopyFlex replica can be kept safely in the same enclosure or in contact with an artifact.

4.2.2 Coupons

Coupons made from copper, silver, and lead foil (all of least 99.9% purity), of varying thicknesses, were prepared for testing. The coupons were cut with scissors to size. The copper and silver coupons were polished with precipitated calcium carbonate and deionized water using cotton swabs. They were then rinsed with deionized water and submerged in Mr. Clean liquid cleaning solution (leaves no residue). When removed, they were scrubbed with a stiff-bristle brush and Mr. Clean in the palm of a gloved hand. Finally, they were rinsed thoroughly with deionized water, briefly submerged in acetone, and allowed to air-dry. The lead coupons were not polished or cleaned, although they were submerged in acetone.

4.2.3 Glassware

Each piece of glassware was cleaned using Mr. Clean and then rinsed with tap water followed by washing with deionized water. Last, the glassware was sprayed with acetone and allowed to air-dry.

4.2.4 Oddy Test 2: Preparation

All three coupons were inserted vertically into a small block (approximately 2 × 2 × 1.5 cm, weighing 4.52 g) of cured CopyFlex, which was then placed into a 20-mL beaker. The half of the coupon inserted into the block would be for contact testing, and the other half extending above the silicone rubber sample would be for vapor testing. Liquid components Part A and Part B (each weighing approximately 2.2 g) were poured into their own 20-mL beaker, with coupons bent and hooked over the edge of the beakers (fig. 14). A glass vial filled with 1 mL of deionized water and capped with a perforated plastic lid was placed alongside each beaker in a Kimax ground-glass jar with lid. Teflon tape was wrapped around the ground glass to create a fitted seal between the jar and lid. Gloves were worn at all times throughout test preparation.

4.2.5 Testing Specifics

The test was run against a control for 28 days in an oven maintained at $60^\circ C \pm 2^\circ C$. To ensure that 100% RH stayed constant for the duration of the test, 1 mL of deionized water was added to the glass vials as needed if evaporation occurred.

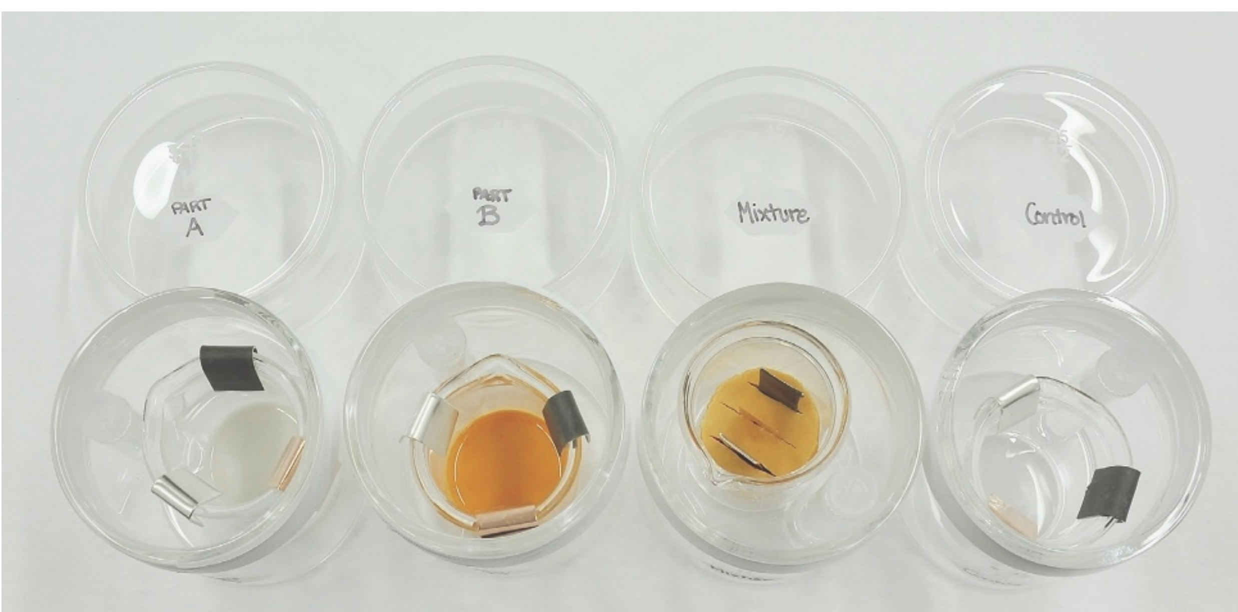

Fig. 14. Oddy test jars ready to be sealed and placed in the oven (Courtesy of Heather White)

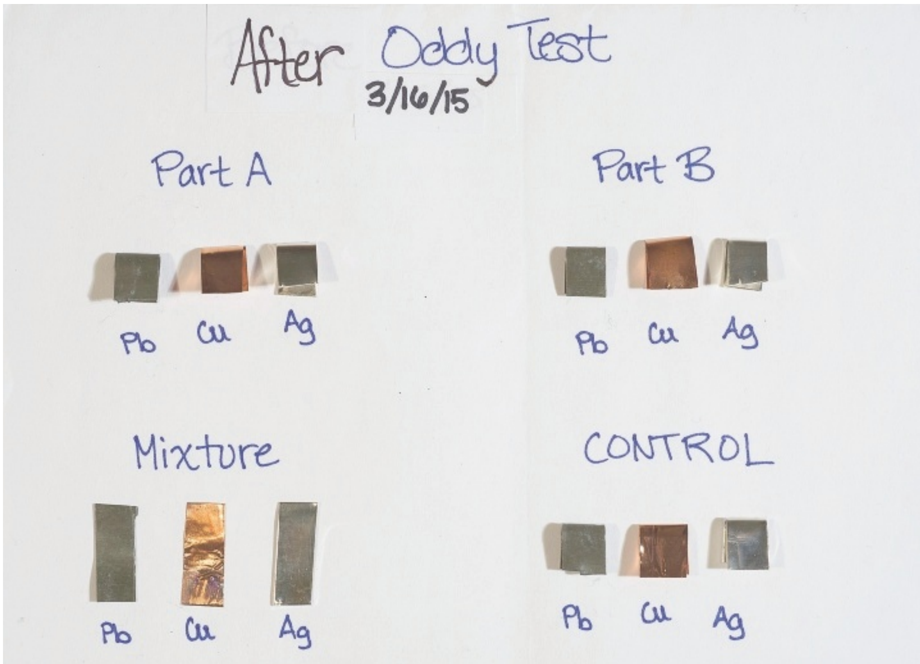

Fig. 15. Results of Oddy test 2 showing the test coupons and the control (Courtesy of Heather White)

4.2.6 Oddy Test 2: Results

All coupons used for the vapor tests showed a negligible amount of tarnishing corresponding to the same seen on the controls. The results for the contact test, however, were different. Although the silver and lead coupons in contact with CopyFlex looked the same as the controls, a great deal of surface change was observed on the copper coupon inserted into the cured silicone rubber (figs. 15, 16).
To confirm these results, the Oddy test was replicated and again resulted in the reaction of the copper

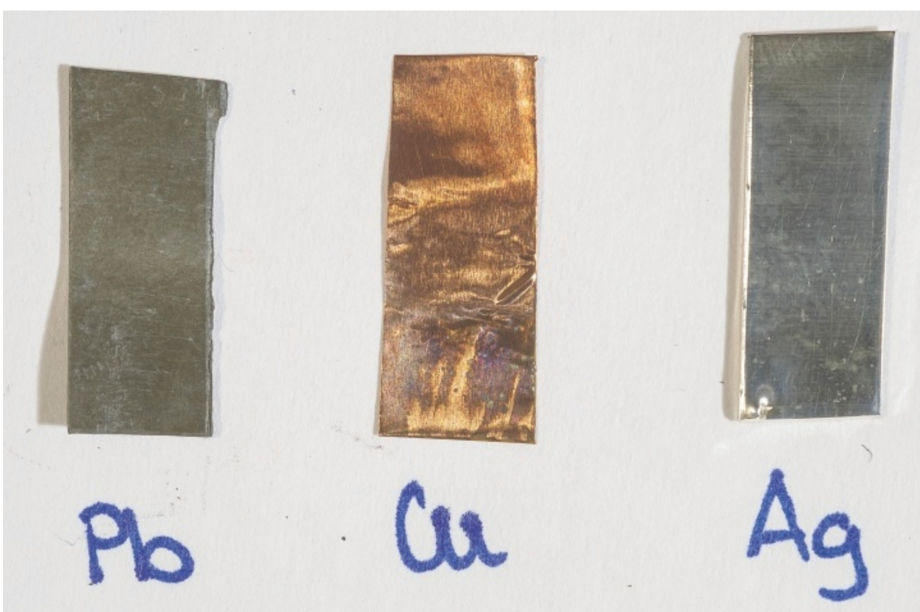

Fig. 16. Detail of the coupons tested with the freshly cured CopyFlex. Note the changes to the lower half of the copper coupon. (Courtesy of Heather White)

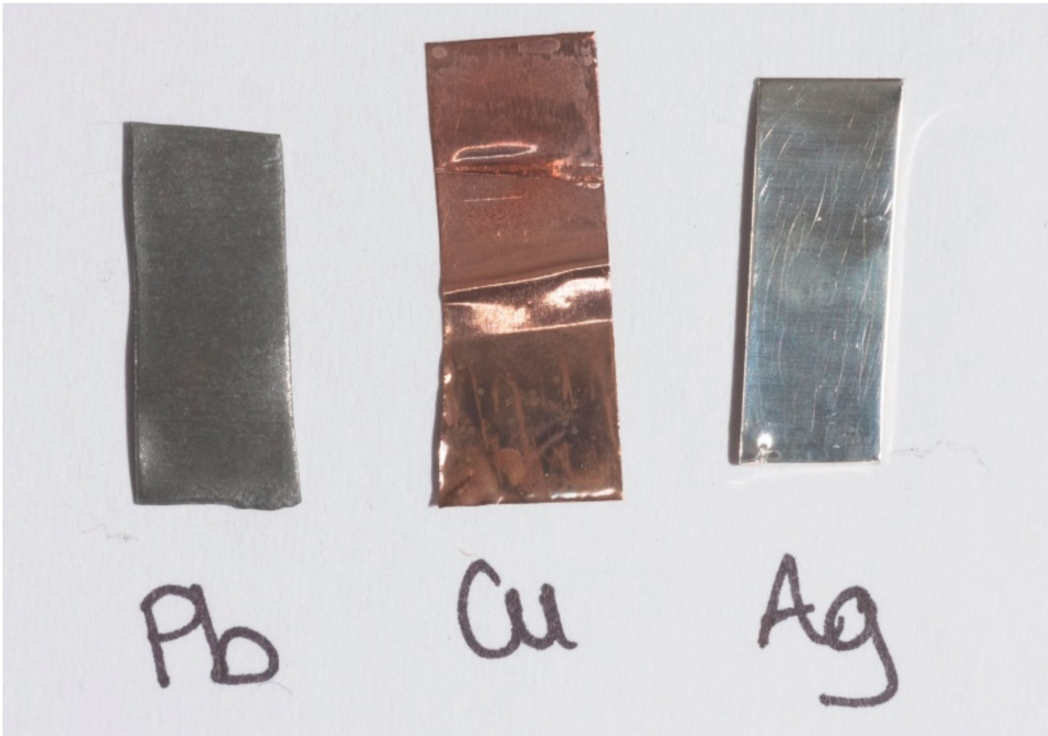

Fig. 17. Results of the replicated Oddy test on the freshly cured CopyFlex showing corrosion on the copper coupon (Courtesy of Heather White)

coupon (figs. 17, 18). The part in contact with the silicone rubber corroded to a purple color with silvery spots, and the upper part of the coupon exposed to vapor showed notable tarnishing greater than what was seen on the rest of the copper tests.

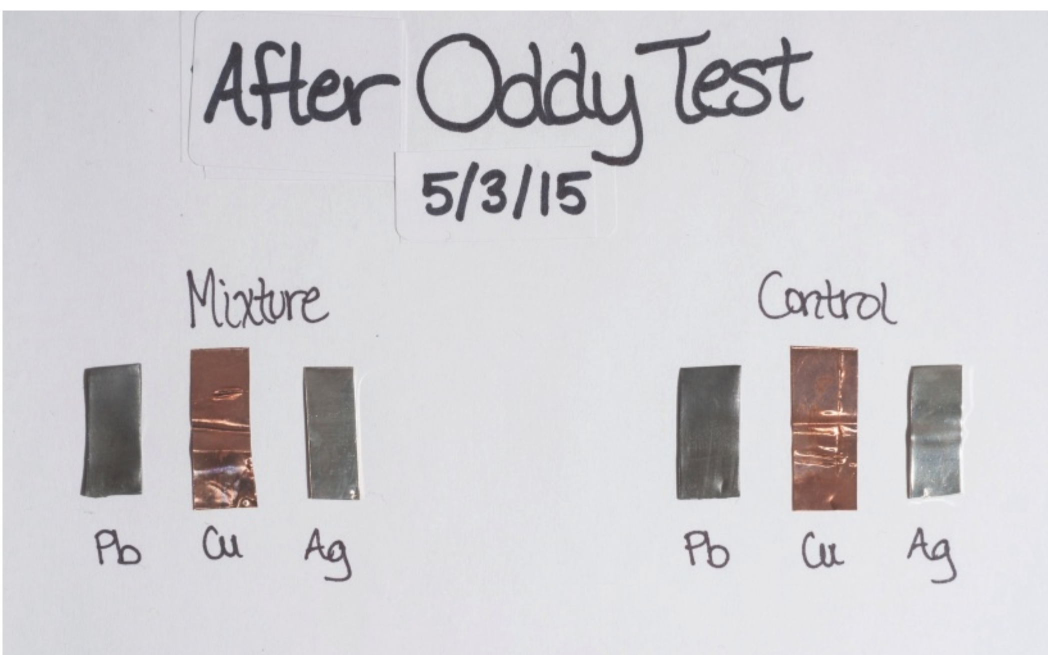

Fig. 18. Detail of the test coupons from the replicated Oddy test showing the corrosion on the copper coupon (Courtesy of Heather White)

4.3 DISCUSSION: ODDY TEST RESULTS

Based on the results of the Oddy tests conducted, it appears that freshly cured CopyFlex corroded the copper coupons during the contact tests and may therefore not be suitable to be stored in contact with archaeological artifacts, at least not copper alloy–based materials. No vapors, however, off-gassed from the freshly cured silicone rubber, and therefore it may be suitable to store objects in proximity to CopyFlex molds/impressions.

CopyFlex testing after several months of curing did not corrode any of the coupons either in the contact or the vapor test. Based on these results, the silicone rubber would be suitable to be stored in proximity or in contact with artifacts two months after the initial cure.

5. CONCLUSIONS AND FUTURE WORK

Based on the field trials, CopyFlex seems to be a low-cost, viable, and effective alternative to other RTV silicone rubbers used for mold making. This silicone rubber is easy to use, has a relatively short cure time, and has low toxicity to the user. CopyFlex successfully made an impression of a ceramic figurine mold found during a survey on the Ancient Methone Archaeological Project, reproducing the mold in fine detail and thus allowing the artifact to be studied and photographed for publication. Because of the success the conservators had with the material in the 2014 field season, the project conservators will continue to use CopyFlex for any future mold making required during the excavation season. Until further Oddy testing can be conducted, any future molds or impressions made will be isolated from any of the artifacts in storage.

Oddy testing will continue to be conducted on CopyFlex to understand the changes observed on the copper coupons during this study. Testing the silicone rubber at different intervals after the initial cure to see how that affects the results of the Oddy test will be undertaken. Further investigations will be conducted using both testing protocols to see if that had an effect on the different results obtained during the contact Oddy tests. Work will focus on the corroded copper coupons to see if the changes observed can be characterized to understand what could have caused the changes to the test coupon.

The excellent results achieved with CopyFlex in the field has encouraged the head conservator on the Ancient Methone project to investigate another material manufactured by Make Your Own Molds: a more viscous, food grade mold-making material known as Silicone Spread (Make Your Own Molds 2015d). The paste-like consistency of this material could allow it to be used for mold making on vertical surfaces and as a low-cost alternative to the use of heavy-body dental impression materials such as Reprosil (vinyl polysiloxane). The conservators on the project will also test the efficacy of cyclododecane as an alternative barrier material/sealant based on its successful use as a barrier, as published by Brs pub et al. (1999) and Maish and Risser (2002).

ACKNOWLEDGMENTS

The authors wish to thank John Papadopoulos and Sarah Morris, Directors, Ancient Methone Archaeological Project; Manthos Bessios, Athena Athanassiadou, Konstantinos Noulas, 27th Ephorate of Prehistoric and Classical Antiquities; Anna Weiss-Pfau, Conservator, University of Chicago, and Conservator, Ancient Methone Archaeological Project; and Lauren Horelick, Conservator, National Air and Space Museum.

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SOURCES OF MATERIALS

Copper foil, Cu000690 (used for Oddy test 1) (99.98%, 0.3 mm thick, #410-528-44), lead foil, PB000400 (99.95% purity, 0.5 mm thick, #474-046-72)
GoodFellow Limited
125 Hookstown Grade Rd.
Coraopolis, PA 15108-9302
http://www.goodfellow.com/

Copper foil (used for Oddy test 2) (99.98% purity, 0.25 mm thick, #349178-49.5G), silver foil (used for Oddy test 1) (99.98% purity, 0.005 in. thick)
Sigma-Aldrich Corp.
3050 Spruce St.
St. Louis, MO 63103
http://www.sigmaaldrich.com/

CopyFlex
Make Your Own Molds
7609 Production Dr.
Cincinnati, OH 45237
http://www.makeyourownmolds.com/

Dow Corning High Vacuum Grease (5.3 oz. tube #14-635-5D), Fisherbrand Autosampler Shell Vials (1 mL #03-391-23), Kimax Borosilicate Weighing Bottles with Ground Glass Outside Caps (45 mL, 40 × 50 mm, 45/12 #03-422F), Kimax Griffin Beakers (20 mL #02-539-1), Lipsol Detergent
Fisher Scientific
300 Industry Dr.
Pittsburgh, PA 15275
800-766-7000
http://www.fishersci.com/

Industrial Fine Eraser E113/F (metal body fine FybRrglass eraser) #AA2120
The Eraser Company Inc.
PO Box 4961
Syracuse, NY 13221-4961
315-454-3237
http://www.eraser.com/

Mr. Clean Multi-Surface Liquid Cleaner
Proctor & Gamble
1 P&G Plaza
Cincinnati, OH 45202
http://www.mrclean.com/en_US

Paraloid B48-N, Paraloid B-72
Conservation Resources
5532 Port Royal Rd.
Springfield, VA 22151
http://www.conservationresources.com/Main/S%20CATALOG/default.htm

Precipitated calcium carbonate
VWR
100 Matsonford Rd.
Radnor, PA 19087-8660
http://us.vwr.com/

PRIMA Plastalina Modeling Clay
Blick Art Materials
PO Box 1267
Galesburg, IL 61402-1267
http://www.dickblick.com/

Silver sheet (used for Oddy test 2) (99.9% purity, 24 gauge (0.020 in. thick) Fine Silver, 6 × 12 in., SI8370-6X12)
Metalliferous
34 W. 46th St.
3rd Floor
New York, NY 10036
http://www.metalliferous.com/

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ERASER CLEANING OF GYPSUM PLASTER: EVALUATING DAMAGE POTENTIAL USING REFLECTANCE TRANSFORMATION IMAGING

KATHRYN BRUGIONI

Practically all methods for dry-cleaning gypsum plaster involve abrasion on some scale. Previous studies of abrasion-cleaning methods have successfully quantified damage potential by imaging test coupons in a scanning electron microscope; however, this instrumentation is not available to everyone. Furthermore, the photomicrographs used show a level of detail that will never be perceptible to the human eye. In the absence of scanning electron microscope analysis, a more accessible method for measuring surface abrasion should be assayed: reflectance transformation imaging. This study explores the extent to which reflectance transformation imaging can reveal these surface changes to gypsum plaster caused by multiple dry-cleaning materials. Reflectance transformation imaging captures were compared to scanning electron microscope photomicrographs, which allowed for a calibration of the data collected with reflectance transformation imaging.

KEYWORDS: Gypsum plaster, Dry-cleaning, Eraser cleaning, Reflectance Transformation Imaging

1. INTRODUCTION

Being moldable, carvable, and paintable, gypsum plaster has been used since the beginning of human history. For all of plaster's versatility and stability, the surfaces of artifacts made thereof can become embedded with dust and grime. A porous material that is often of a uniform color, plaster is one of the most difficult materials to clean successfully without solubilizing the substrate, without creating tide lines, without driving soiling into its pores, and without abrading the surface. To avoid the problems associated with introducing liquids into a plaster-cleaning system, erasers are often employed to dry-surface-clean such objects.

After a discussion of the material terminology and principles involved, this article will describe the various precedents in eraser cleaning and the application of this technique to plaster. The use of reflectance transformation imaging (RTI) to evaluate damage potential of such treatments will then be considered in comparison to less accessible methods, such as SEM.

The research presented at the 2015 OSG Tips Session was undertaken in conjunction with a gypsum-plaster treatment, performed at the Conservation Center of the Institute of Fine Arts, New York University, for which an eraser cleaning was indicated. The treatment of this object was employed as proof of concept of the preceding research.

1.1 TERMINOLOGY

Any cleaning method must be designed with the nature of the material in mind; however, there is often confusion over the definition of the word *plaster*. In certain contexts, its meaning depends on material function, whereas in others, its meaning depends on its chemistry. Many discipline-specific lexicons, such as the Getty Research Institute's Art and Architecture Thesaurus Online (Plaster 2004; Stucco 2004) and the Museum of Fine Arts Boston's CAMEO (Plaster 2013; Stucco 2013), tend to define *plaster* and *stucco* differently in relation to the more chemically specific terms, *lime plaster* and *gypsum plaster*. As such, conflations of such terms commonly occur. Although this study was borne of the study and treatment of a gypsum plaster object, the following procedures and findings could be applied to materials of comparable porosity and hardness.

1.2 CHEMISTRY AND STRUCTURE OF GYPSUM PLASTER

Gypsum plaster is mined as the mineral gypsum, calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$). After mining, it is ground, purified, and calcined. This process typically forms the "plaster" product, calcium sulfate hemihydrate ($CaSO_4 \cdot ½ H_2O$), which when mixed with water reforms the dihydrate. The free water (the water in excess of the waters of hydration) evaporates after application or molding of the paste, leaving a hard, carvable, and paintable material, which is reusable if refired.

The most common crystal forms are alpha and beta forms, the former being more acicular and prismatic, and the latter being tabular (Christensen, Jensen, and Nonat 2010). Different manufacturing processes create different polymorphs or different ratios thereof, and these crystal structures impart different properties on the final product (Singh and Middendorf 2007). Alpha-type crystals pack more tightly, forming a less porous, harder, heavier, and less-compressible material that is preferred for sculpture and for detailed mold making. Beta-type crystals form a lighter, more porous, less-durable plaster, favored for certain construction applications (Kogel et al. 2006).

Various additives, including driers, retardants, accelerants, thickeners, plasticizers, and deflocculants, may be used to modify the microstructure of the hardened gypsum; reduce or increase its compressive strength; or modify curing time, density, compressibility, and porosity (Hummel et al. 2003; Singh and Middendorf 2007; Guan et al. 2010). More than one plaster type may be present on the same object in the form of repairs, revisions, or where different plaster properties are needed. Accordingly, cleaning results may vary between different objects or across one surface.

2. PRECEDENTS IN ERASER CLEANING

No matter the formulation of the material used, pores form in cast plaster due to the imperfect packing of crystals and the gradual evaporation of free water from the substrate. This porosity allows soiling—in the form of grease and dust—to become easily ingrained in and below the surface of the plaster (fig. 1). Gypsum plaster is also slightly soluble in water (approximately 2.4 g/L at 20°C), and aqueous treatment of any soiling carries the risk of driving surface dirt farther into the substrate (American Chemical Society 2006) (fig. 2).

Because of its porosity and water sensitivity, plaster is often dry-cleaned with erasers to clear soiling without irreversibly driving it into the pores of the plaster. It is essential, however, that the correct eraser product be chosen, as most plasters are deceptively soft and can be scratched by a fingernail.

Popular in the realm of paper conservation (Pearlstein et al. 1982), eraser cleaning has been adapted for the cleaning of stone by Williams and Lauffenburger (1995). As with any treatment protocol, it is important to first ensure the suitability and stability of the materials used for treatment and then to evaluate their damage potential both physically and chemically.

Pearlstein et al. (1982) and Williams and Lauffenburger (1995) juxtaposed three primary types of erasers: those based on rubber (containing rubber, drying oils, sulfur, and abrasives), factice (containing vulcanized vegetable or animal oils cross-linked with sulfur bonds), and vinyl (usually containing polyvinyl chloride, phthalate plasticizer, and calcium carbonate) (AIC, Book and Paper Group 1992). These studies consider the chemical composition of the various eraser types, their degradation products, their working properties, their efficacy in treatment, and their mechanical damage potential. Although such products should be periodically reevaluated to account for any changes in formulation, the findings detailed in the preceding references provide a point of departure for future testing.

In brief, these studies caution against the use of products based on factice and rubber, as they leave considerable amounts of residue, and this residue then degrades to sulfurous by-products on treated surfaces. These evaluations also establish the importance of screening erasers for the presence of abrasives, which are included to increase grating action, and colorants, which can leave surface streaks. These ingredients are not appropriate in the context of a conservation treatment.

Fig. 1. Soiling, in the form of grease and dust, can become embedded in the porous plaster surface, causing considerable disfigurement. (Courtesy of Badde 2009, 26; Library Company of Philadelphia 2014)

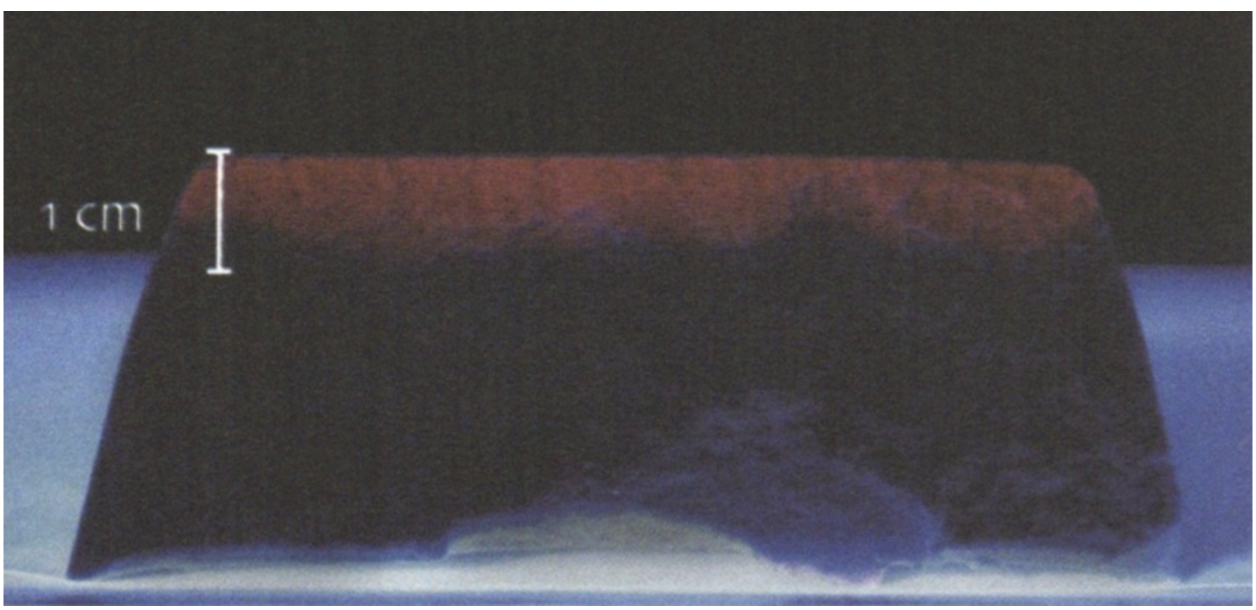


Fig. 2. UV photograph of a cross section of a plaster sample on which water in a cotton compress, tinted with Rhodamine, has been applied for 3 minutes shows its ready absorption of water (Courtesy of Anzani et al. 2008, Fig. 21, Plate 3)

Table 1. Summary of Findings in Williams and Lauffenburger's (1995) Comparative Eraser Study

Product Tested	Staedtler #527-05	Staedtler #526-50	Faber-Castell #79	Koh-i-noor #287	Faber-Castell #75 soft green	Faber-Castell #76 soft pink
Eraser type	PVC	PVC	PVC	PVC	vulcanized rubber/factice	vulcanized rubber/factice
Plasticiser	dialkylthalate ester	dialkylthalate ester	dialkylthalate ester	dialkylthalate ester	none published	none published
Buffer/filler	calcium carbonate (39%)	calcium carbonate (39%)	calcium carbonate (30%)	calcium carbonate (30%)	calcium carbonate (21%)	calcium carbonate (19%)
Colorant	titanium (TiO_2?) (1%)	titanium (TiO_2?) (1%)	none detected	titanium, (TiO_2?) (10%)	green colorant	pink colorant
Abrasive	none detected	none detected	silica (22%)	none detected	diatomaceous earth	diatomaceous earth
Fluorescent residues	none observed	none observed	dull-orange fluorescence	none observed	pea-green fluorescence	yellow-orange fluorescence
Organic residues (as indicated by directional fluorescence)	unknown	unknown	faint, directional (machine-erased, saw-cut area)	unknown	none visible	strong, directional (machine-erased, saw-cut area)
Inorganic residues	none detected	none detected	none detected	none detected	none detected	none detected
Scratching (hand erasing)	none visible	none visible	none visible	none visible	visible at 25x	visible at 25x
Scratching (machine erasing)	none visible	none visible	none visible	none visible	visible to naked eye	visible to naked eye
Oddy test results	no significant reaction	no significant reaction	very light corrosion film to Cu coupon	no significant reaction	heavy layer of black sulfide corrosion(?) on Ag and Cu coupons; heavy Fe corrosion	heavy layer of black sulfide corrosion(?) on Ag and Cu coupons; heavy Fe corrosion

As indicated by the findings of Williams and Lauffenburger, Mars Staedtler eraser products have been favored for their chemical stability, as well as for their lack of residue deposition, abrasives, and colorants.

3. CASE STUDY

The research presented here was undertaken in conjunction with a conservation treatment performed for an advanced treatment course taught by Sarah Barack (SBE Conservation, LLC and Adjunct Faculty, Conservation Center) at the Conservation Center of the Institute of Fine Arts, New York University, in September 2015. The object, *Plaster Bust of a Man*, was lent for treatment by the Avery Architectural and Fine Arts Library, Columbia University. Technical study and treatment were performed in close collaboration with Dr. Roberto Ferrari, Curator of Art Properties at the Avery Library (fig. 3).

Fig. 3. Front view, before treatment. *Plaster Bust of a Man*, plaster. Avery Architectural and Fine Arts Library. (Courtesy of Conservation Center, Institute of Fine Arts, New York University)

The composition of the substrate was confirmed to be gypsum plaster with XRF (fig. 4). Although the plaster was coated, a dry-cleaning approach was chosen both because of the solvent sensitivity of the coating and the presence of graphite pointing marks over the surface (figs. 5, 6). These graphite points, resulting from the use of a so-called pointing machine, were to be preserved as evidence of the plaster bust's use as a replication model for copies in marble or bronze (figs. 7a, 7b).

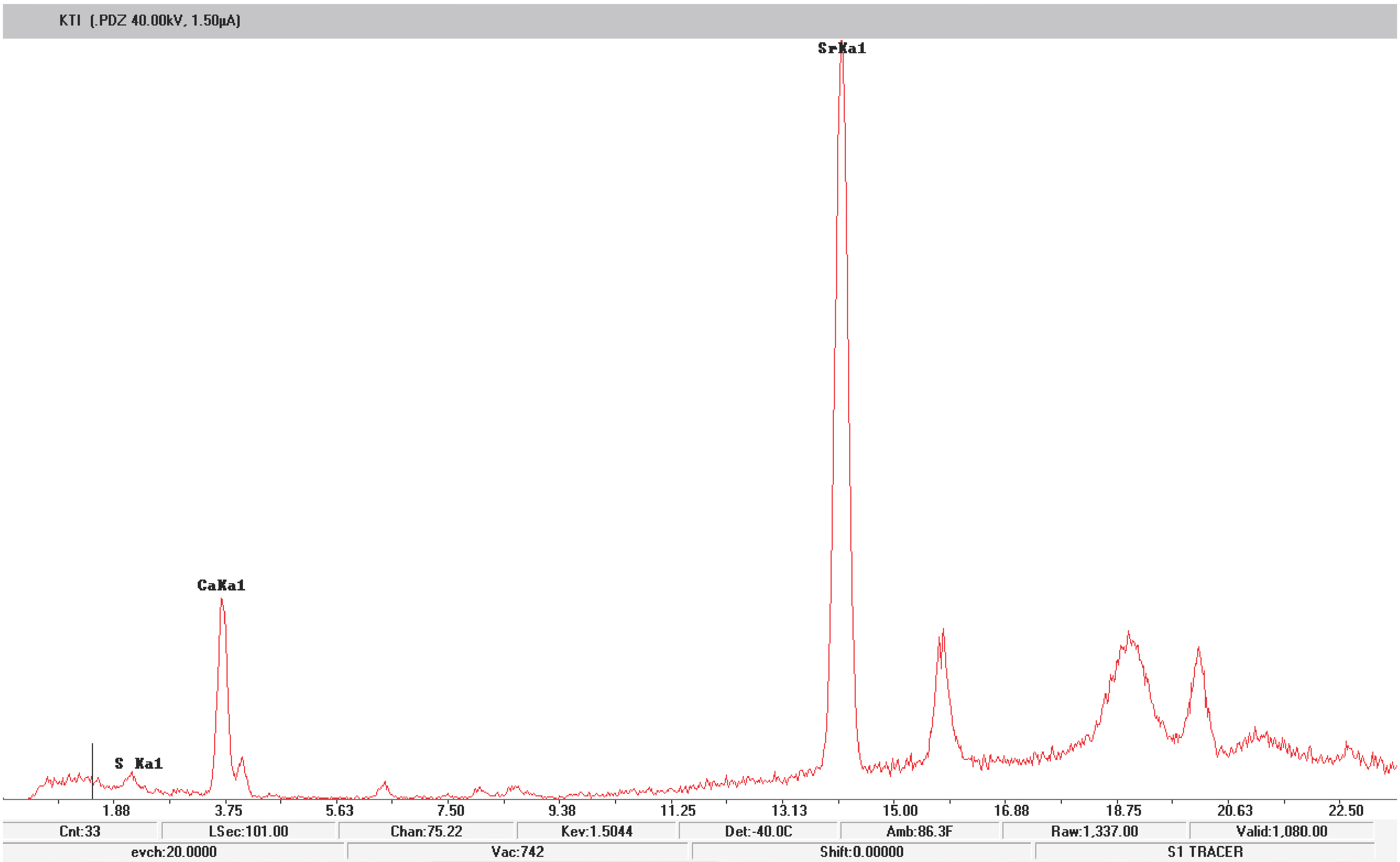
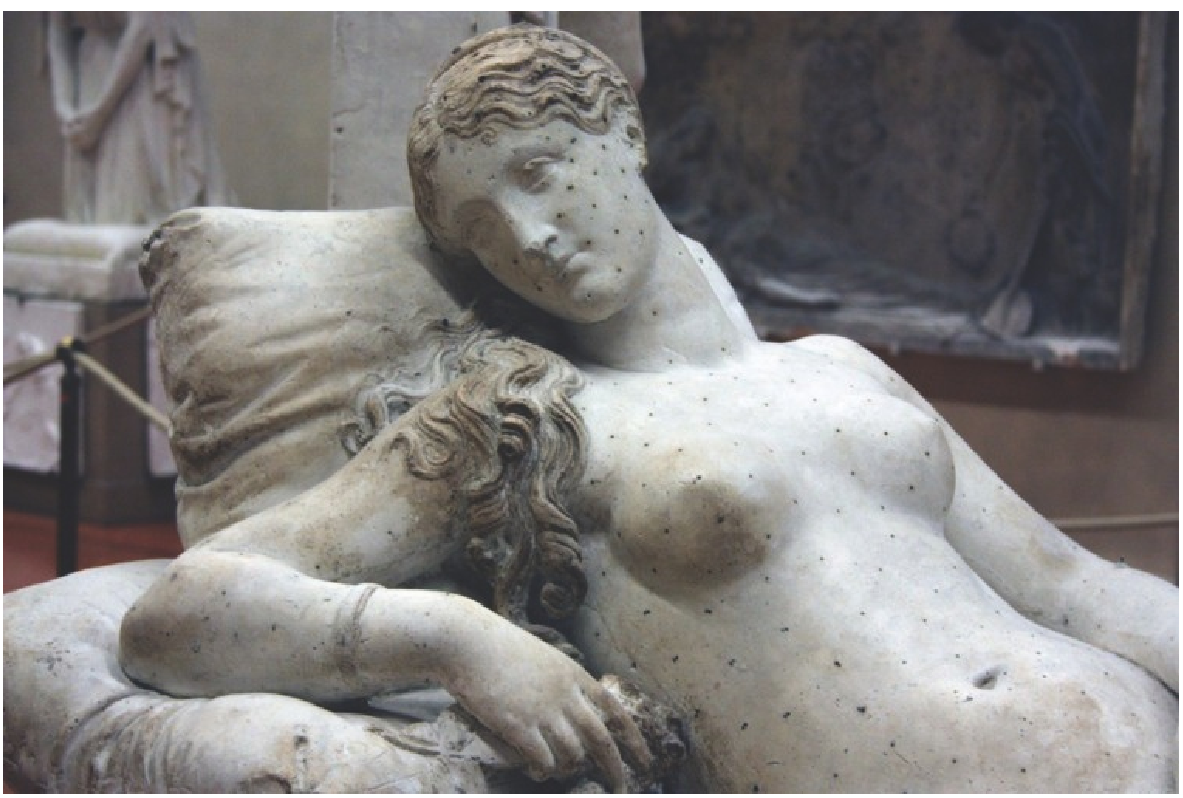


Fig. 4. The composition of the substrate of *Plaster Bust* was confirmed with XRF (data collected with a Bruker Tracer III SD at 40 kV, 1.50µA, and read with S1PXRF software). (Courtesy of Conservation Center, Institute of Fine Arts, New York University)

Fig. 5. *Plaster Bust of a Man*. Top view. Before treatment. Visible-radiation photograph shows the uneven surface coating (top) compared to an ultraviolet-induced luminescence (UVL) photograph (bottom) showing the UVL fluorescence of the surface coatings. (Courtesy of Conservation Center, Institute of Fine Arts, New York University)

A review of the literature and of current practice at the Conservation Center pointed to the use of Staedtler Mars erasers (Staedtler 526 50 Mars Vinyl Erasers and Staedtler 527 05 Eraser Strips Electric Eraser Refills) as the most feasible option for the successful cleaning and visual reintegration of the surface (fig. 8). Since there is no comparative study of the use of erasers on plaster surfaces to justify the preceding choice, this experiment was undertaken to evaluate the damage potential of eraser products on plaster. The coated plaster was assumed to be less susceptible to abrasion by the eraser, but all testing was performed on *uncoated* plaster for the sake of applicability to a wider range of substrates.

Fig. 6. *Plaster Bust of a Man*. View of graphite pointing marks on proper left cheek. Before treatment. September 25, 2014. (Courtesy of Conservation Center, Institute of Fine Arts, New York University)



Figs. 7a, 7b. Objects that have been marked up for reproduction with a pointing machine (Courtesy of Galleria dell'Accademia 2015; STONE Project 2015)

Fig. 8. Mars Staedtler products used: Staedtler 527 05 Eraser Strips (left) and Staedtler 526 50 Mars Vinyl Erasers (right) (Courtesy of Kathryn Brugioni)

4. METHODOLOGY

Although similar studies of cleaning principles, methods, thresholds, and effectiveness have been undertaken with the use of an SEM (Wharton, Maish, and Ginell 1990), this tool is out of the reach of many conservators. To enable the conservator to conscientiously assess and compare treatment options, a more accessible method to evaluate damage potential—RTI—was identified and tested.

Following the findings of the many published analyses of eraser products, this article focuses on the RTI testing of Staedtler Mars erasers as the most available, amenable, and appropriate tool for this particular treatment.

This study included three parallel components. First, a controlled evaluation of the damage potential of various products was conducted with an SEM. Second, the sensitivity of an RTI capture of the same controls was tested. Third, a before- and during-treatment RTI capture of the surface of *Plaster Bust of a Man* was presented as proof of concept.

4.1 RTI SCRATCH TESTS

Because RTI offers a dynamically relightable description of surface topography, it seems to be an obvious choice for inexpensive and accessible detection of surface abrasion. Coupons abraded with

Micro-Mesh were compared to those abraded with various eraser products in an attempt to quantify the magnitude of the abrasion resulting from the erasers tested. Methods of sample preparation and capture are described in the following, as are the results observed.

4.1.1 Sample Preparation

Each scratch test was performed on coupons prepared by casting gypsum plaster in small paper cups. Coupons were made by slowly spooning calcium sulfate hemihydrate into approximately 2 cm of tap water until it formed a small mound in the center of the cup. The plaster was gently stirred into the water with a bamboo skewer so as not to form bubbles. After stirring, the bottom edges of the cup were lightly tapped against the countertop until most remaining bubbles came to the surface. The coupons were left to cure and air-dry overnight. As it was found that paper fibers from the inside of the waxed paper cups had stuck to the surface of the first cast-plaster coupons, the remaining cured coupons were soaked before peeling them away from their molds. These were then dried for 8 to 24 hours before use.

Seven coupons were then abraded with one of seven different grades of Micro-Mesh: 400, 600, 800, 1200, 1500, 1800, and 2400. The Micro-Mesh fabric was first cleaned of debris in tap water and dried. Each grade was dragged twice over the surface of the corresponding coupon in a single direction and with consistent pressure. Coupons were labeled with the abrasion grade (400, 600, etc.) on the unmolded surface.

4.1.2 Capture

These coupons were then captured using an RTI setup of consistent camera distance, lens focus, and lighting parameters—respecting the imaging protocol defined by Cultural Heritage Imaging—to produce the most reliable and reproducible RTI capture.

A Nikon D700 camera with a 60-mm macro lens was used. The aperture and exposure time were fixed at f/11 and 0.64 seconds, respectively, for all acquisitions. The camera has a spatial resolution of 4256 × 2832 (12.1 megapixels) and a ground-pixel size of 0.1 mm. The camera was operated tethered to a MacBook Pro running Nikon Camera Control Pro tethering software at ISO 100 and in RAW capture mode.

Two methods were used to control for focal distance: a knotted string and the EXIF data associated with the NEF RAW images. A laser distance measurer could also be used, if available, and fixed to the camera body or tripod. Two lasers at set angles and positions might also be used to triangulate the correct distance (Lum, pers. comm.). A bubble leveler was also used to ensure optimal positioning perpendicular to the subject being captured.

Ideally, future experiments in this vein will better optimize the distance-to-subject variable, maximize the spatial resolution, and minimize the resolution cell for detection of the smallest of surface features. Although it takes longer to capture coupons individually, filling the camera frame with the surface of interest will give more finely graded results.

The coupons were lit continuously with an Aspherilux Midi LED handheld light at 15°, 30°, 45°, and 60° angles at each of the 12 positions around the subject (figs. 9a, 9b). Three ½- in. (12.7 mm) reflective ceramic ball bearings, purchased as part of Cultural Heritage Imaging's RTI Highlight Capture Starter Kit, were polished with lens-cleaning solution and a lens cloth before inclusion in the capture.

The 48 images in each capture were white-balanced against an AIC PhD Target in Adobe CS6 Camera Raw 8.8. For processing in Camera Raw, all other fields were zeroed out (i.e., no sharpening or lens correction was applied). The open-source RTIBuilder software was used to build the RTI images from the RAW image set using the hemispherical harmonics function (v. 2.0.2). This RTI build could then be viewed in the open-source RTIViewer program (v. 1.1.0).

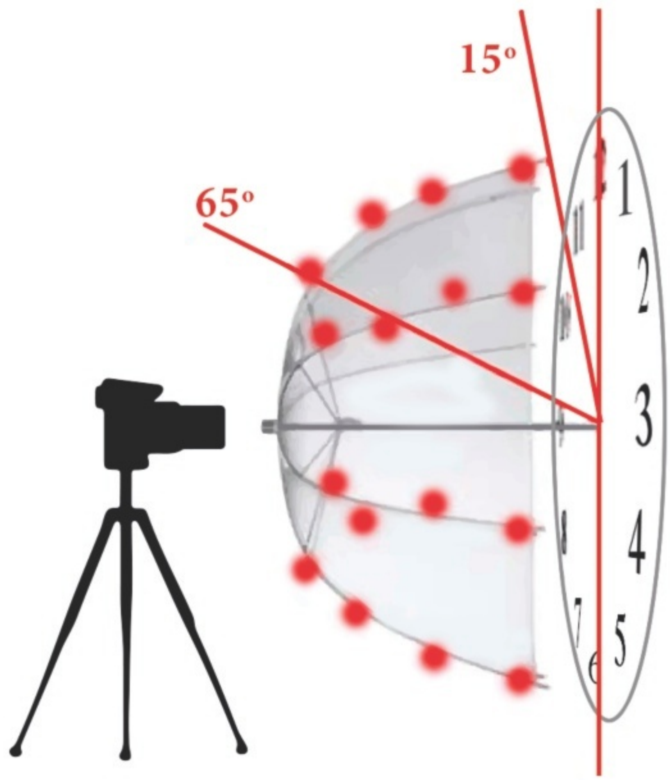


Fig. 9a. Diagram of RTI setup (Courtesy of Cultural Heritage Imaging)

Fig. 9b. Various test coupons during RTI capture. March 1, 2015. (Courtesy of Conservation Center, Institute of Fine Arts, New York University)

4.1.3 Results of RTI Capture

At the distance and pixel density of the capture, damage in the form of directional scratching was detected with RTI on all coupons except on the 2,400-grit sample (fig. 10). These results contrast with normal visual evaluation, which could only detect up to 1,200-grit damage in ambient light (i.e., not raking) of about 500 lux.

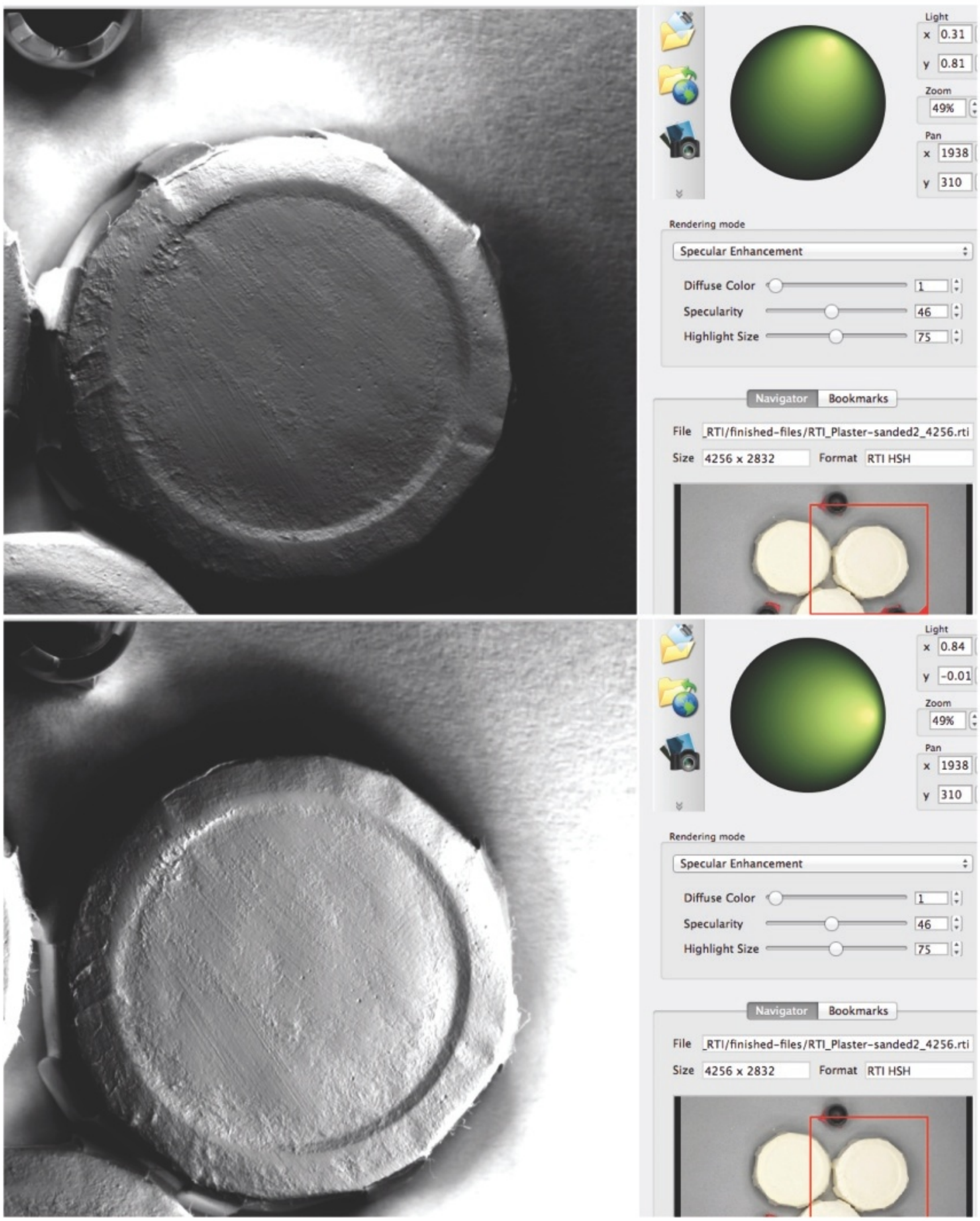


Fig. 10. The RTI capture of the 1,200-grit coupon, as viewed in RTIViewer 1.1.0 software, clearly shows directional abrasion. March 1, 2015. (Courtesy of Conservation Center, Institute of Fine Arts, New York University)

4.2 SEM SCRATCH TESTS

Before these data can be deployed, the capture needs to be calibrated to determine the actual magnitude of damage (in the form of directional abrasion related to eraser cleaning) that can be detected at a specific focal length and pixel density.

4.2.1 Capture

An abridged range of coupons were analyzed using SEM: 100, 200, 600, 1,200, and 1,800. A control coupon (polished to 12,000 grit), a coupon abraded with a Staedtler 526 50 Mars Vinyl Eraser, and a coupon abraded with a Staedtler 527 05 Eraser Strip were included for a total of eight test coupons.

Coupons were brushed thoroughly with a Japanese *hake* brush to remove potentially deleterious plaster powder from the coupon before insertion into a Hitachi TM3000 TableTop SEM. The instrument was run in Standard observation mode, and the Analytical beam condition was chosen due to the low-contrast nature of the specimen. As the coupons were sizable, they were analyzed and imaged during individual runs of the instrument.

Bruker QUANTAX 70 software was used to select and image three areas on each coupon at 30x, 60x, and 120x, for a total of nine images per sample. Each fully magnified image contained two features of interest (i.e., scratches). The brightness and contrast of the images were adjusted in the QUANTAX software as necessary for best resolution of features, and the Auto Focus function was executed prior to image capture at each magnification.

4.2.2 Analysis

The width (in micrometers) of each of the features was measured at each magnification for each sample. This measurement was recorded as a weighted average, reflecting the increased measurement accuracy at the larger magnifications (table 2).

The average scratch magnitude (in micrometers) of each Micro-Mesh-abraded sample (table 2) could then be used to calibrate the observations collected with RTI capture to determine the magnitude of scratching or pitting observable with RTI (fig. 11). Results of the calibrated eraser abrasion tests are reproduced below (table 3).

4.2.3 Results

The RTI capture at the given focal distance and pixel density was able to detect surface change up to a magnitude of 1,800 grit. SEM calibration shows that this equates to a 17-μm scratch, on average, that is detectable by RTI at the focal distance and pixel density employed (see table 2).

The two eraser products evaluated for use—the Staedtler Strip and the Mars Plastic erasers—were observed to cause an average of 64- and 22 μm wide pits, respectively. This equates to a Micro-Mesh grit

Table 2. Scratch-Size Measurements of Abrasion Caused by Various Micro-Mesh Grades

Grade	Magnification	Scratch Size (μm)
100	30x /60x /120x	260
200	30x /60x /120x	140
600	30x /60x /120x	50
1,200	30x /60x /120x	30
1,800	30x /60x /120x	17

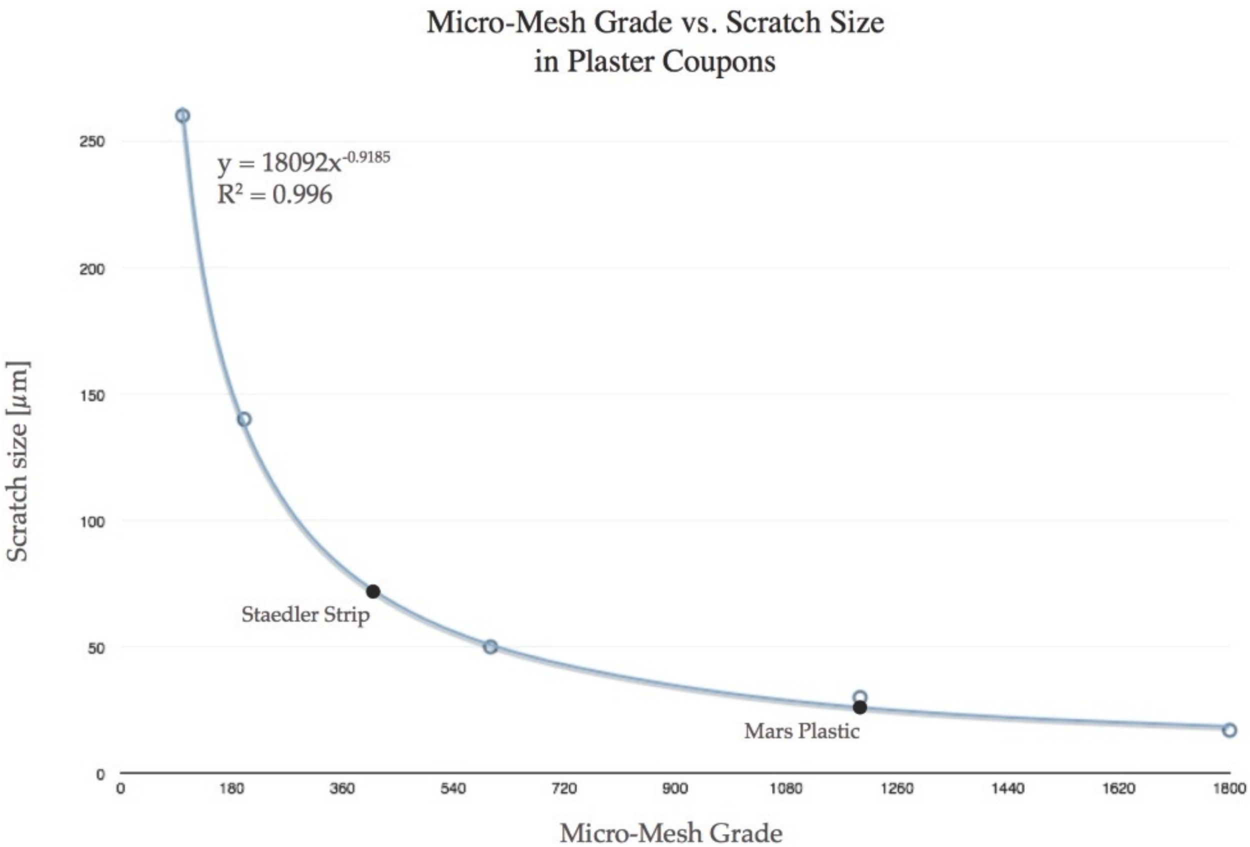


Fig. 11. Calibration curve showing the relationship between Micro-Mesh grade and scratch size on the Micro-Mesh-abraded test coupons (blue circles). The eraser-abraded test coupons (black circles) are graphed by scratch size observed with the SEM. (Courtesy of Kathryn Brugioni)

of 466 for the Staedtler Strip and 1,492 for the Mars Plastic, meaning that the former has more damage potential (table 3). Recall that the upper limit of damage detectable *visually* is 1,200 grit for the particular plaster product used in the samples.

This pitting observed with both test erasers is likely caused, to an extent, by inadequate clearing of spent eraser crumbs. If not cleared, these crumbs are driven into the surface by the action of the eraser. Although this pitting phenomenon was not investigated further, it serves to illustrate the importance of continual clearance during the treatment of sensitive surfaces (for descriptions of viable clearing methods, see AIC, Book and Paper Group 1992, 14: 35–36). Note also that the pitting measured earlier was created using the maximum reasonable force for a dry-cleaning treatment. Therefore, these data should represent the upper limit of damage that these products might cause to an uncoated, homogeneous gypsum plaster. Of course, testing should always be undertaken and the results analyzed when evaluating treatment options.

Table 3. Average Abrasion Magnitude Caused by Various Micro-Mesh Grades

Tool	Magnification	Scratch Size (μm)	Grade
Control	30x /60x /120x	0	12,000
Staedtler 526 50 Mars Vinyl Eraser	30x /60x /120x	22	1,492
Staedtler 527 05 Eraser Strip	30x /60x /120x	64	466

4.3 PROOF OF CONCEPT

The two eraser products evaluated for use—the Staedtler Strip and the Mars Plastic erasers—were deployed in test swatches on the object, *Plaster Bust of a Man*. Although the Staedtler Strip product was observed to have higher damage potential when compared to the Mars Eraser, it was tested for its ease of use—when sharpened to a point, it could easily be used around the aforementioned graphite marks. Two inconspicuous sites on the neck of the bust were chosen for the testing of the two products.

4.3.1 RTI Capture

A before-treatment RTI capture was performed to record the surface topography before and after the coated plaster was treated with the two erasers (Staedtler 527 05 Eraser Strips Electric Eraser Refill and Staedtler 526 50 Mars Vinyl Eraser). To ensure consistent framing of the RTI capture in both the before- and during-treatment RTIs, a Mylar overlay was cut and marked to register the edges of the camera sensor with the pointing-mark features. Distance and configuration was also measured using a bubble leveler, a string of set length, and the EXIF data associated with the RAW digital images. A Nikon D700 camera with a 60-mm macro lens was used, with the same RTI equipment, lighting, distance, camera settings, and processing protocols as before.

4.3.2 Results

The after-test capture using the Staedtler Strip eraser best reproduced the before-test parameters. As it also represented the product with the most damage potential, screen captures from this test are reproduced here as proof of concept.

A comparison of the RTI captures of the two cleaning swatches before and after testing did not reveal any abrasion or other surface change. Note that this proof of concept was performed on coated plaster, in contrast to the test coupons.

5. CONCLUSIONS

After experimentation with mock-ups of soiled plaster, the Staedtler 527 05 Eraser Strips Electric Eraser Refill and Staedtler 526 50 Mars Vinyl Eraser were identified as potentially effective tools for the dry-cleaning of coated and uncoated plaster surfaces.

Cast-plaster coupons were produced and abraded with various grades of Micro-Mesh for comparative examination in normal light settings and in RTI capture. This showed that whereas visual examination can detect directional abrasion of 30-μm magnitude, RTI can detect damage on the 1,800-grit-abraded coupon (at a focal distance of 36 cm and a pixel density of 12.1 megapixels).

To calibrate the magnitude of damage observed in the RTI capture, the Micro-Mesh-abraded coupons, the eraser-abraded coupons, and a control were analyzed using a Hitachi TM3000 TableTop SEM. This analysis showed that RTI can detect scratches up to 17 μm wide with the parameters employed.

Staedtler products produce small pits on the surface of treated coupons if the eraser crumbs are not cleared regularly during cleaning or if too much force is used. These pits are on the order of 1,500-grit Micro-Mesh; thus, in principle, if you are abrading the surface of your object during cleaning, it will be detectable using RTI if the ground-pixel size is at least 0.1 mm.

After completing a proof-of-concept phase to ensure the suitability of the products on *Plaster Bust of a Man*, the entire surface of the object was dry-cleaned. This treatment successfully reintegrated the surface with no detectable abrasion and left the coating and the graphite points undisturbed (fig. 12).

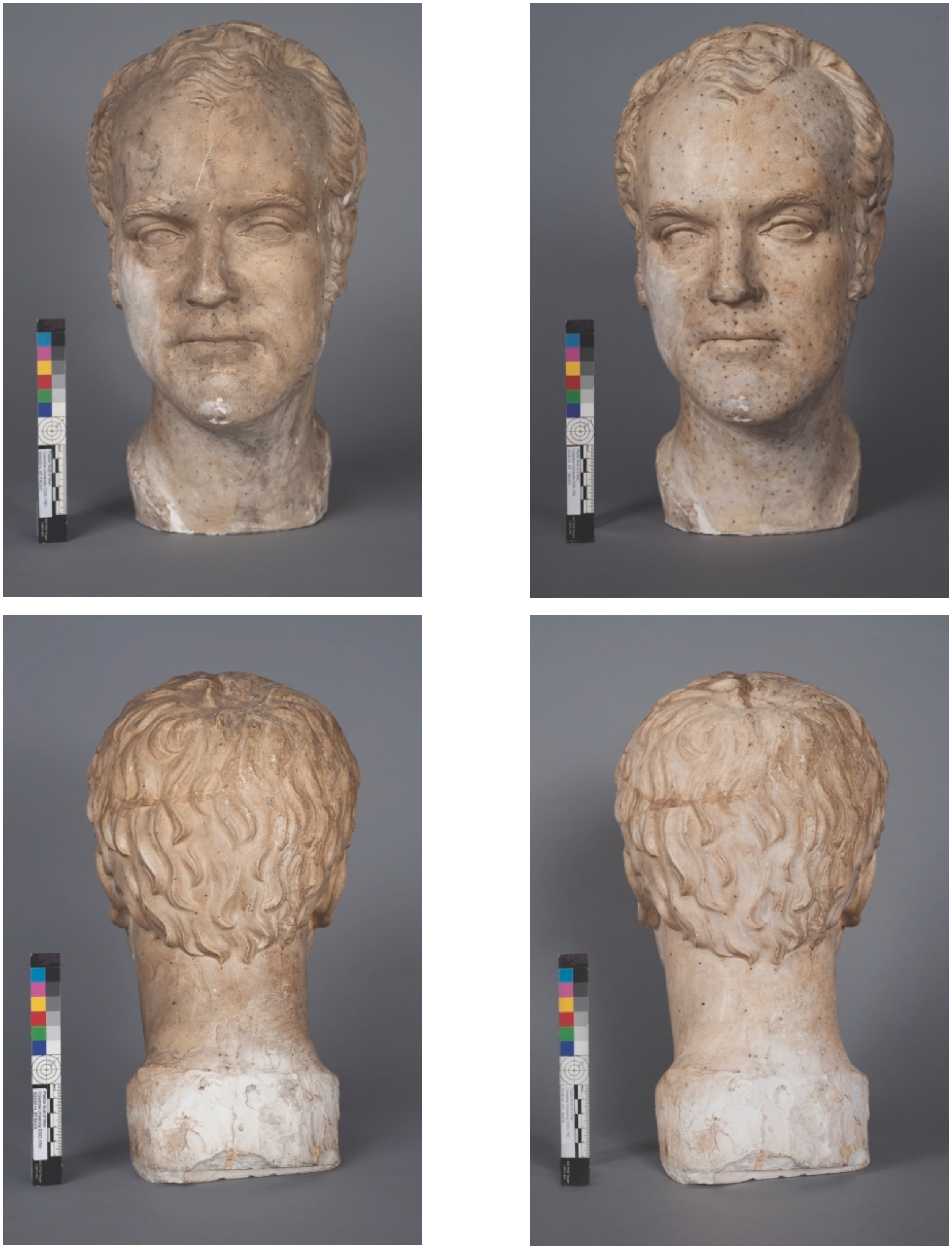


Fig. 12. *Plaster Bust of a Man*. Left: before treatment (September 25, 2014) and right: after treatment (December 18, 2014). (Courtesy of Conservation Center, Institute of Fine Arts, New York University)

ACKNOWLEDGMENTS

The author would like to thank Sarah Barack for her guidance and support over the course of this treatment and research project; Dr. Roberto Ferrari, Curator of Art Properties at Avery Library, Columbia University, for his collaboration with the students at the Conservation Center; the faculty and staff at the Conservation Center, Institute of Fine Arts, New York University, for their instruction and support; and the Objects Specialty Group of the AIC for allowing me to present my research in such a stimulating environment.

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Calcium sulfate, Hemihydrate, powder (S25231A, S93166 equivalent replacement), purchased October 2010
Fisher Scientific
81 Wyman St.
Waltham, MA 02451
781-622-1000
https://www.fishersci.com/us/en/home.html

Micro-Mesh (grades 400, 600, 800, 1,200, 1,500, 1,800)
Scientific Instrument Services
1027 Old York Rd.
Ringoes, NJ 08551-105
908-788-5550
http://www.sisweb.com

RTIBuilder 2.0.2, RTIViewer 1.1.0, RTI Highlight Capture Starter Kit
Cultural Heritage Imaging
2325 Third St., Suite 323
San Francisco, CA 94107
415-558-8672
http://www.culturalheritageimaging.org

Staedtler 526 50 Mars Vinyl Erasers, Staedtler 527 05 Eraser Strips Electric Eraser Refills
Staedtler Mars GmbH & Co. KG
850 Matheson Blvd. West, Unit 4
Mississauga, ON L5V 0B4, Canada
800-776-5544
http://www.staedtler.us/en/

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FLEXIBLE FILLS: A TECHNIQUE FOR IMITATING ASIAN LACQUER

ELLEN PROMISE, JESSICA CHLOROS, AND HOLLY SALMON

Compensating for loss on an Asian lacquer object is a challenging task. To achieve an unobtrusive fill, the gloss, color, decoration, and surface condition must be matched while accounting for surface sensitivity and considering reversibility. To create lacquer fills, conservators have used a wide variety of materials and techniques, ranging from Japanese paper to bulked adhesive to Urushi itself. Each method has advantages and disadvantages and must be targeted to the needs of the object and the treatment goals. This article outlines another approach, which the authors have employed successfully, utilizing fills cast from bulked acrylic emulsion paint.

Fluid acrylic emulsion paints are mixed to the appropriate color with added acrylic matte gel, creating a paste-like consistency. This mixture is spread on a sheet of silicone-release Mylar to a thickness approximating the depth of the loss being targeted. When the cast fill is dry, it is peeled off the Mylar, revealing a glossy surface. The fill can be refined, with some success, by sanding on the underside. A tracing of the loss is then made and placed over the cast acrylic film to cut out the fill with a sharp scalpel. The fill can then be adhered in place with a reversible adhesive.

This method can be used to match the color and gloss of a lacquer surface as well as the surface condition in cases where the lacquer has not taken on a craquelure pattern. Matching decorative elements requires additional experimentation. Some success has been achieved by reverse-painting the desired presentation surface on the Mylar for the first layer. Overall, this fill method was found to be effective and efficient and to present little risk to the lacquer object. With some customization, it could be employed for loss compensation on a variety of lacquer objects.

KEYWORDS: Lacquer, Loss compensation, Acrylic, Removable fill

1. INTRODUCTION

Conservators have explored many materials and preparation methods for imitating the aesthetic characteristics of Asian lacquer and creating a convincing fill. Some options have inherent disadvantages, such as the relatively poor aging and reversibility of epoxy, as well as the unsuitable surface gloss of resins like Paraloid B-72 (Webb 1998). Other options have been utilized successfully. Impressive results have been achieved using dyed acrylic emulsions, such as Acrysol WS-24, and building up the medium in layers (Webb 2000). This layered process can be time-consuming, however, and using materials that must be sanded down in situ always introduces the risk of damaging the surrounding Urushi. This is especially true when the loss is adjacent to a network of stabilized cracks and flakes. As an alternative, attempts have been made to cast sheets of resin, like polyester, to allow fills to be cut and finished independent from the object. In practice, pure polyester has proven too brittle for this purpose, and bulking the polyester with softening agents interferes with its tone and opacity (Webb 1998). More promising ex situ fills have been achieved using painted and glazed paper (Chao 2014), but a sizable gap in available options remains within this category of lacquer fills.

2. FILL PRODUCTION METHODOLODY AND CASE STUDY

With this history of fill techniques in mind, I approached the treatment of a late 1800s' Japanese red lacquer box at the Isabella Stewart Gardner Museum (fig. 1). Before treatment there were several long cracks and networks of smaller cracks with lifting lacquer flakes adjacent to two losses on the box lid. Avoiding unnecessary manipulation of these areas was desirable. After some discussion with my co-authors, the idea of casting a fill was proposed, and a bulked acrylic paint was suggested as a medium. This would incorporate some of the some of the desirable properties of acrylic emulsions into a cast, removable fill.

Fig. 1. Japanese red lacquer box, 1870, wood and lacquer, 15.2 × 49.5 × 31.8 cm, Isabella Stewart Gardner Museum, M11w2 (Courtesy of the Isabella Stewart Gardner Museum)

In considering bulking agents, Golden Regular Gel (Matte) was selected. Initial tests showed that it produced a frosting-like consistency when mixed with acrylic paints, would take on the finish of the casting surface, and retained flexibility when dry. Sheets were cast on silicone-release Mylar. I created low barriers using bamboo skewers and wooden tongue depressors to allow a more uniform spreading of the paint mixture and to help control film thickness (fig. 2).

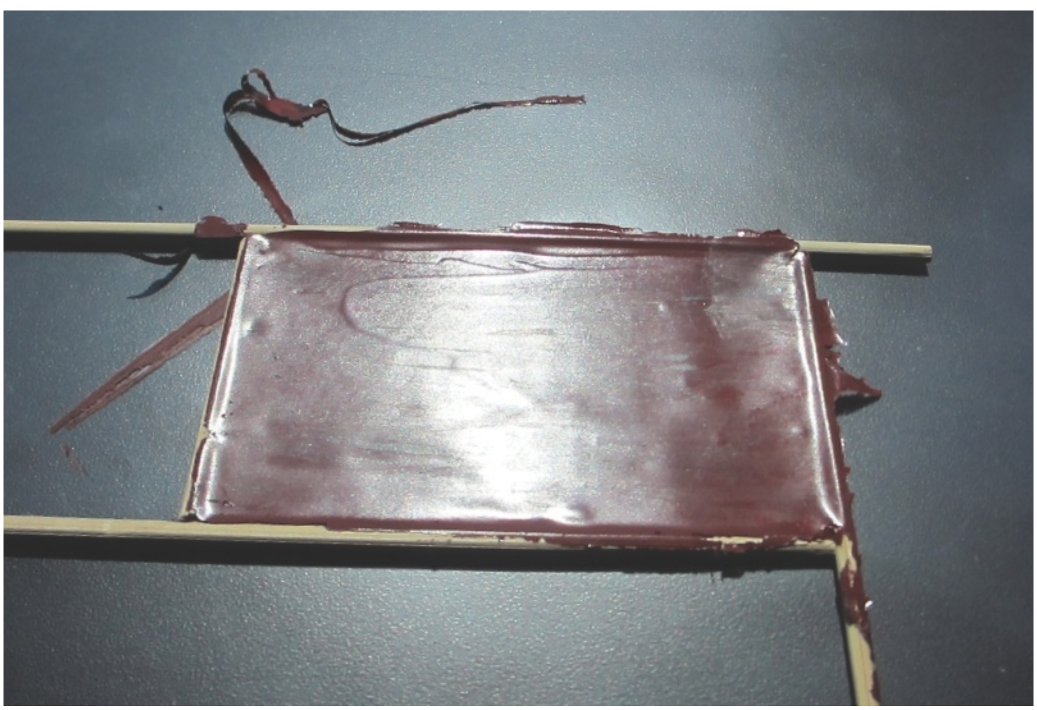

Fig. 2. Presentation surface of cast bulked acrylic film (Courtesy of Ellen Promise)

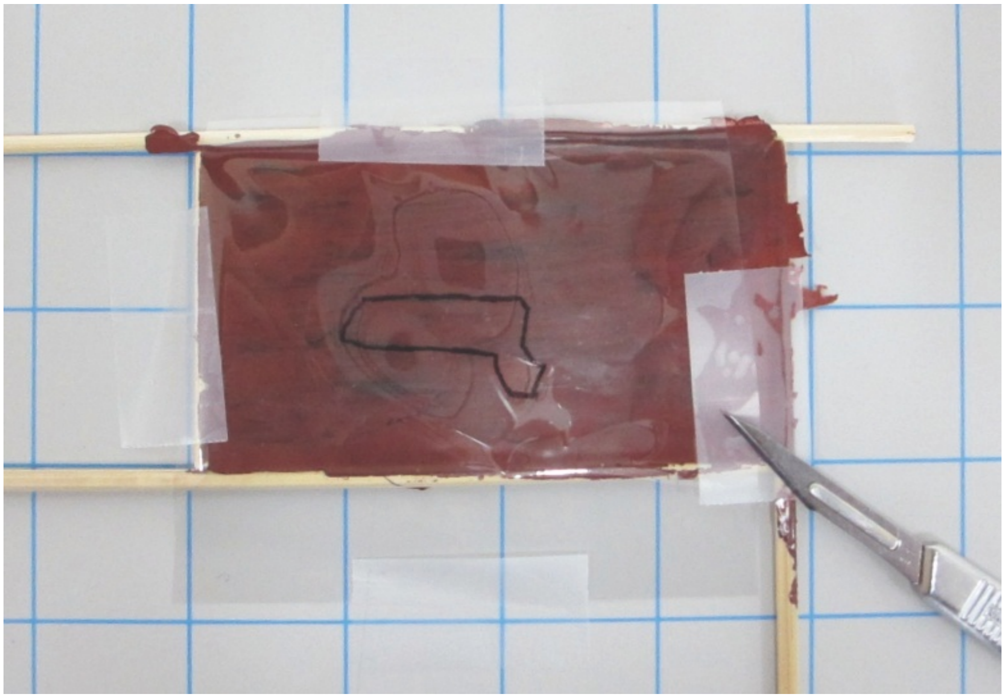

Fig. 3. Tracing of loss ready for cutout (Courtesy of Ellen Promise)

When dry, the cast film could be lifted easily from the silicone-release Mylar. I created a tracing of the loss using a fine-tipped marker on a thin sheet of Mylar. Securing the tracing to the cast film, I was able to cut out the fill shape using a sharp scalpel (fig. 3). The fill could then be modified on the underside by shaving with a scalpel or lightly sanding the surface where it was too thick or by adding drops of acrylic paint where it was too thin. When the fill is prepared, it can be secured in place on the object using a reversible adhesive, such as cold fish glue or Paraloid B-72.

The matte gloss of silicone-release Mylar taken on by the cast fill proved to be an ideal match for the semi-gloss surface of aged, somewhat degraded Asian lacquer. To match the lacquer surrounding the losses, however, surface irregularities and fine sprinkled gold *nashiji* designs also required imitation. This required some experimentation. I found that it was possible, although difficult, to approach the initial casting step like reverse-painting on glass, using a thin wash of a darker acrylic before spreading the bulked mixture to emulate streaks in the lacquer, for example. This is a promising method, as it does not add any dimension or change the gloss of the presentation surface, but it may not be practical when reproducing parts of complex design details.

3. REPLICATION OF SURFACE DECORATION AND CASE STUDY

As a fellow at Historic New England, I worked on a second Asian lacquer object, a Chinese export sewing table dating to the 1840s (Crossman 1991) (fig. 4). Before treatment, the table was in poor condition, with many lifting flakes of lacquer and large losses. The condition issues made this object another good candidate for the flexible fill technique.

Having settled on painting the lost gold designs on the red lacquer box with metallic acrylic paints and mica pigment powders, I was eager to explore alternatives in my treatment of the sewing table.

Fig 4. Chinese export sewing table, 1840, wood, lacquer, metal, and silk, 28⅜ × 24¾ × 17⅝ in., Historic New England, 1964.10 (Courtesy of Historic New England)

For the red box, acrylics were chosen as the best option in light of time constraints, but it proved difficult to replicate designs without adding visible dimension to the surface. I also found that the metallic particles in mica powders and the acrylic paints were much larger and less evenly dispersed in comparison with the original gold designs, making the color and gloss match less convincing from some angles. I did have success using a fine-tipped black marker to introduce veining on a leaf element on one of the fills and wanted to pursue the idea of using markers further (fig. 5).

I decided to compare 11 different metallic media options on the basis of eight characteristics: adhesion to acrylic, opacity, ease of use, granularity of metallic particles, line fineness, line crispness, and color and gloss match for my application. The results, ranked on a basic scale building from poor to fair

Fig 5. Detail of fill in area of leaf design on red lacquer box, M11w2 (Courtesy of the Isabella Stewart Gardner Museum)

to good to very good, are recorded in table 1. The tested media included five commercial markers, four paint mixtures applied by brush, and two attempts at dusting metallic particles over an adhesive or sizing agent. Not recorded is an attempt I made to use a Rapidograph, a fillable, fine-nibbed pen—various metallic media all proved to be too viscous for use in the pen.

Several of the commercial markers were highly satisfactory tools, but the color and gloss match excluded them from consideration for my purposes. Tools with a poor or fair color match, six in total, were ruled out first. Two water-based options were also ruled out because, as expected, their adhesion to

Table 1. Metallic Media Comparison

	Adhesion	Opacity	Ease of Use	Granularity	Line Fineness	Line Crispness	Color Match
Faber-Castell ink pen	Very good	Very good	Very good	Very good	Poor	Very good	Poor
Pentouch marker	Very good	Very good	Very good	Very good	Good	Very good	Fair
DecoColor Opaque paint marker	Good	Fair	Good	Good	Poor	Fair	Very good
Gelly Roll Metallic	Fair	Fair	Very good	Fair	Fair	Fair	Poor
Pentel metallic brush	Very good	Very good	Very good	Very good	Fair	Fair	Poor
Kremer metallic watercolors	Poor	Poor	Fair	Poor	Very good	Fair	Very good
Acrylic mixed with mica	Very good	Good	Fair	Fair	Fair	Fair	Fair
Laropal A 81 mixed with mica	Very good	Good	Good	Fair	Fair	Fair	Fair
Aquazol 500 mixed with mica	Poor	Poor	Poor	Poor	Poor	Poor	Very good
Rolco dusted with shell gold	Very good	Poor	Poor	Poor	Poor	Poor	Very good
Laropal A 81 mixed with shell gold	Very good	Good	Good	Good	Very good	Very good	Very good

Fig. 6. Detail of fills on the crossbar of sewing table, 1964.10 (Courtesy of Historic New England)

acrylic was poor. The remaining dusting method was eliminated because it produced a poor gloss match and most of the other working properties were also poor. This left two acceptable options: a xylene-based paint marker and the mixture of Laropal adhesive with shell gold. I chose the paint marker for its nearly ideal color and gloss match, thin texture, and ability to be used in marker form, for larger fill areas, or released into a palette well and diluted with xylene for brush application when fine lines were necessary (fig. 6). All work with this medium was carried out under a fume extractor.

4. CONCLUSION

The diversity of forms, condition issues, and corresponding treatment needs when considering Asian lacquer objects suggests that one uniform approach to loss compensation is unlikely to be effective in all cases. Cast acrylic fills can boast a quick and simple preparation process, a strong gloss match with slightly degraded lacquer surfaces, and easy reversibility. On the other hand, the seam between the fill and the original material will always be visible, even if a nearly perfect cutout is achieved. The seam can be minimized to some extent by filling with the bulked acrylic paint in liquid form, but this negates some of the desirable properties of this technique as an ex situ fill. It can also be difficult to control the film thickness when casting to obtain a flush surface with the original lacquer. For these reasons, the technique is probably best suited to filling areas of loss on aged lacquer surfaces with other visible cracks and irregularities that allow the fill to blend.

ACKNOWLEDGMENTS

The authors would like to acknowledge the support of their colleagues at the Isabella Stewart Gardner Museum, especially Preparator David Kalan for his assistance in constructing a shimbari frame for the Japanese red lacquer box. We would also like to thank Conservator Melissa Carr for her advice and consultation regarding treatment.

Author Ellen Promise would like to thank her colleagues Alex Carlisle and Michaela Neiro at Historic New England for their support, assistance, and input concerning the treatment of the Chinese export sewing table. She would also like to thank Elizabeth La Duc for her loan of several metallic pens and Susan Jackson for her advice in preparing shell gold from gold leaf.

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——2000. *Lacquer: Technology and conservation: A comprehensive guide to the conservation of Asian and European lacquer.* Oxford: Butterworth-Heinemann.

SOURCES OF MATERIALS

Aquazol 500
Polymer Chemistry Innovations Inc.
4231 S. Fremont Ave.
Tucson, AZ 85714
520-746-8446
http://www.polychemistry.com/

DecoColor Paint Marker
Uchida of America Corp.
3535 Del Amo Blvd.
Torrance, CA 90503
800-541-5877
http://www.uchida.com

Golden Fluid Acrylics, Golden Regular Gel (Matte)
Golden Artist Colors Inc.

188 Bell Rd.
New Berlin, NY 13411-9527 USA
800-959-6543
http://www.goldenpaints.com/

High Tack Fish Glue
Lee Valley Tools Ltd.
PO Box 1780
Ogdensburg, NY 13669
800-871-8158
http://www.leevalley.com/us/

Kremer Metallic Watercolors
Kremer Pigments Inc.
247 W. 29th St.
New York, NY 10001
800-995-5501
http://kremerpigments.com/

Laropal A 81, Paraloid B-72
Conservation Resources International LLC
5532 Port Royal Rd.
Springfield, VA 22151
800-634-6932
http://www.conservationresources.com/

Metallic PIT Artist Pen GOLD
Faber-Castell USA Inc.
9450 Allen Dr., Suite B
Cleveland, OH 44125
216-643-4660
http://www.fabercastell.com/

Mica Powders and Mylar
Conservation Support Systems
PO Box 91746
Santa Barbara, CA 93190
800-482-6299
http://www.conservationsupportsystems.com/main

Pentel Metallic Brush Pen
Pentel of America Ltd.
2715 Columbia St.
Torrance, CA 90503
760-200-0547
http://www.pentel.com/

Pentouch Paint Marker and Gelly Roll Metallic
Sakura of America
30780 San Clemente St.
Hayward, CA 94544
http://sakuraofamerica.com/

Rolco Quick Dry Gilding Size
Rolco Labs
655 Washington Ave.
Carlstadt, NJ 07072
866-271-5367
http://www.rolcolabs.com/

Sepp Gold Leaf
Sepp Leaf Products Inc.
381 Park Ave. South
New York, NY 10016
800-971-SEPP
http://www.seppleaf.com/

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HOLLY SALMON has been a Conservator at the Isabella Stewart Gardner Museum for more than 10 years and currently heads the Objects Conservation Lab. Holly received her MS in art conservation from the Winterthur/University of Delaware Program in Art Conservation in 2001. Her graduate internships included work at the Philadelphia Museum of Art; Harvard's Peabody Museum of Archaeology and Ethnology; and the National Conservation Centre in Liverpool, England, where she studied laser cleaning. After graduating, Holly received a Mellon Foundation Fellowship at Historic New England and an advanced-level fellowship from the Straus Center for Conservation at Harvard. She also received a Luce Scholars Program Fellowship to spend a year studying at the Kyoto Lacquer Restoration Institute.

ISSN (print version) 2169-379X
ISSN (online version) 2169-1290

AMERICAN INSTITUTE FOR CONSERVATION OF HISTORIC AND ARTISTIC WORKS