

Lunder Conservation Center
SMITHSONIAN AMERICAN ART MUSEUM

THE FOUNDATION
OF THE AMERICAN
INSTITUTE FOR
CONSERVATION
OF HISTORIC AND
ARTISTIC WORKS



Conservation and Exhibition Planning: Material Testing for Design, Display, and Packing

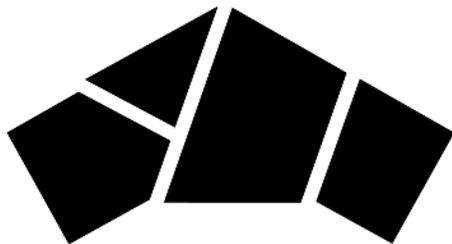
ABSTRACTS

November 19 & 20, 2015

Smithsonian American Art Museum & National Portrait Gallery
Washington, D.C.

Support for this conference comes from the Lunder Conservation Center and the Foundation of the American Institute for Conservation of Historic and Artistic Works Endowment for Professional Development, which was created by a grant from The Andrew W. Mellon Foundation, and donations from members of the American Institute for Conservation and its friends. Professional development events are made possible with the assistance of many AIC members, but no AIC membership dues were used to create or present this course.

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Introduction

It is a pleasure to share abstracts for papers and short submissions from the conference “Conservation and Exhibition Planning: Material Testing for Design, Display and Packing” hosted by the Lunder Conservation Center, home to the conservation departments of the Smithsonian American Art Museum and the National Portrait Gallery. When the Center was established, its mission included an endowment to support public and professional outreach. This conference is part of ongoing programming for museum professionals who work in collaboration with conservators.

“Conservation and Exhibition Planning: Material Testing for Design, Display and Packing” was conceived to address the challenge of determining what materials can be used safely in proximity to and in contact with artworks in museums. Planning for appropriate collection care before, during, and after display is dependent on accessing reliable information about the materials we use. The use of fabrics, painted surfaces, mounts, foams, and board materials facilitates the creative display and storage of artwork. Understanding how these materials will react with artworks over time is a fundamentally challenging, but necessary, undertaking.

Research in the conservation science field has developed new methods for testing materials. These tests expand upon the traditional Oddy test introduced in 1973 by Andrew Oddy at the British Museum. The importance of the Oddy test should not be underestimated as a methodological practice that has improved collection care in museums. As commercial and art-making materials have become more complex in their formulations, and analytical methods applied to the conservation field are more sophisticated, new methodological approaches to testing materials are being developed to answer specific questions. Sharing analytical results about proprietary materials and their interactions with art-making materials has allowed for improved collection care and research. Expanding a network of information sharing between conservators, scientists, exhibit designers, and collections managers will benefit museum exhibition workflows.

Presentations at “Conservation and Exhibition Planning: Material Testing for Design, Display and Packing” focus on designing exhibitions and fabricating display furniture; strategic approaches to collection care during the exhibition implementation process; designing storage environments; conservation work spaces; interpretation and sharing of analytical results from material testing; and monitoring how materials change over time. These abstracts were compiled by Dr. Christopher Mans and were edited by Rebecca Singerman. The papers, which reflect current research, will not be published.

This conference has been organized in partnership with the Foundation of the American Institute for Conservation of Historic and Artistic Works (FAIC). Funding is provided through the FAIC Endowment for Professional Development, created by a grant from The Andrew W. Mellon Foundation, and donations from members of the American Institute for Conservation and its friends. Generous support for the conference has been provided by Artex Fine Art Services, True Vue, Inc., Gaylord Archival, and the Lunder Conservation Center endowment.

I would like to specifically acknowledge the contributions of Abigail Choudhury and Eric Pourchot from FAIC in helping plan, organize and promote the conference. This program would not have been possible to organize without the contributions of former Lunder Conservation Center Program Coordinator, Christopher Wayner. Special thanks are due to the members of the Scientific Committee who helped review submissions to the conference including Jennifer Bosworth, Susan Heald, Emily Kaplan, Dr. Christopher Maines, and Christopher Wayner.

Tiarna Doherty, Chief of Conservation, Lunder Conservation Center, Smithsonian American Art Museum

Ambiguity, Volatility and Chaos: Materials Testing at the National Museum of the American Indian

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National Museum of the American Indian, Smithsonian Institution, Washington, DC

Conservators at the National Museum of the American Indian (NMAI) started systematically recording Oddy test results and protocols in 2002 as we began testing the many materials under consideration for use in NMAI's inaugural exhibitions at the Mall Museum. Though the test procedure is time-consuming and subjective with frequent ambiguous results, the program has allowed us to effectively screen materials and develop some guidelines for material use. We currently have data from about 900 tests in a Microsoft Excel spreadsheet. Data includes product name, manufacturer and distributor, sample source (person, company), material type (adhesive, fabric, etc.), test dates, contact or noncontact coupon orientation, oven temperature, test assessment (pass, fail), corrosion descriptions for silver/copper/lead coupons, results of other tests (AD strip, pH indicator paper), test reference number, person performing test, and comments. We also have images of many of the test coupons. In some cases we avoid using the Oddy test by researching the materials first using technical data sheets and talking to manufacturer representatives, which sometimes provides enough information to pass or fail a material without testing. We often use AD strips and microchemical tests prior to Oddy testing; if the material tests positive for high levels of acids or other undesirable components, we fail the material and skip the Oddy test altogether.

We compile test results into our periodically updated "conservation-approved exhibition materials" document which we give our in-house designers, fabricators and contractors. We gladly share this document and our testing spreadsheets with Smithsonian Institution (SI) museums and non-SI museums as we receive requests – we never turn anyone down. We had hoped to post results on the museum's website but the Smithsonian Office of General Counsel discouraged making results public because they could appear to be endorsements or defamation, despite inclusion of clear disclaimers. One of the challenges of sharing data freely is loss of control - also known as chaos. Our documents and data have turned up in other museums' contract specifications and bid packages where the data is sometimes misrepresented and our disclaimers are excluded. We have also discovered materials advertised as "approved by the Smithsonian" when this is not the case (and a violation of SI regulation). At one point several SI conservators formed a committee hoping to establish an internal Smithsonian Sharepoint site to distribute and share testing data, but this has not come to fruition. However, the recent development of the American Institute of Conservation wiki has great potential for us to share our data with an even wider audience.

Since 1999 we have used three published Oddy test variants: two from the Metropolitan Museum of Art, Bamburger et al, *Studies in Conservation* (1999) and *Bamburger Met Objectives* (2003); and our current method as described by Smith, *ICOM-CC Preprints* (2008). Three of our postgraduate Mellon Fellows devoted many hours to reviewing and updating our protocols and spreadsheets and performing testing. Alyssa Becker's research into fire retardants on wood in 2002 led to the re-specification of wood products throughout the museum due to the spectacular failure of lead coupons. Some more recent changes include a new mechanical convection oven – a marked improvement over our oven without convection, changing cotton wadding sources when we discovered our cotton contained acetic acid, changing glass vessel types, and orientation of coupons in relation to samples. We are also considering using only a sterling silver coupon paired with a lead coupon instead of the standard Oddy triad.

Though we often bemoan the time-consuming Oddy procedure and frequent ambiguous results, we feel we have had success in convincing designers and fabricators to avoid wood products for case interiors because of our testing program. Graphic images of disintegrating lead coupons from Oddy tests of wood products were a compelling argument. We tested numerous wood products to find one with the lowest acidic volatiles. As fabricators prefer wood for its working qualities, we have tested numerous coatings, none of which stop emission of organic acids. This is another challenge – we can say that one coating fails, but not as badly as others, which often gets interpreted as an “approved material”. If wood products are used, we specify barriers such as sign blank aluminum or Marvelseal or Sintra (a rigid PVC foam which we has repeatedly passed Oddy tests). Currently Sintra is NMAI’s preferred material for interior case construction. We continue to search for acceptable alternative tests in which we have confidence. Until one is found, we plan to continue refining our methodology and sharing our results. This symposium is timely and will surely spark continued discussion and collaboration.

Putting the Wiki Platform to Work: Sharing Material Testing Results

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Andrew W. Oddy first introduced an accelerated corrosion test used for evaluating exhibition case materials at the British Museum in 1973. The “Oddy Test,” as it has come to be known, continues to be used by museums as the primary litmus test for materials used in the display of artwork and cultural heritage materials. Several variations and improvements have been published since and almost every institution has their preferred method based on the equipment available to them. Although conservators continue to use the test and informally share results, there has been historical resistance to publicizing them. One of the primary issues with publishing results is fear of manufacturer backlash or alternatively being held responsible for damage caused through use of an “approved” material. In addition, variations in Oddy testing protocol prevent the standardization of results. Finally, the accelerated corrosion test is only one of various methods of evaluation and results may be quickly voided by unannounced product manufacturing changes.

It seems particularly pertinent, having just passed the fortieth anniversary of Andrew Oddy’s initial publication, that we address the topic of materials testing and sharing results, especially in light of the fact that the British Museum has published their results dating from 2009-2014 on their website. In 2012 conservators created a platform for others to do the same on the American Institute for Conservation (AIC) Wiki site. It was established with the hope that colleagues would feel more comfortable sharing information on a collaborative platform, giving them safety in numbers. By establishing best practices for sharing results on the AIC Wiki, such as describing the testing protocol and imaging test coupons, the databases allow conservators to evaluate others’ results for themselves. This initiative began at the request of AIC’s Research & Technical Studies (RATS) Specialty Group, and in 2011 the J. Paul Getty Museum (JPGM) contributed the initial content to the newly established Materials Testing page. This included a general explanation of Oddy testing, a description of their testing protocol, and a list of adhesives and tapes tested by the Getty Conservation Institute in 2000. Around 2011, the Cleveland Museum of Art’s renovation campaign prompted the authors, who were asked to test materials to build an internal reference library, to perform a review of their own Oddy testing protocols. The review included comparing protocols at other institutions, including information available on the AIC Wiki. In January of 2012, after a call for Wiki contributions from AIC e-Editor Rachael Perkins Arenstein, the authors, along with objects conservator Elizabeth Homberger (now at LACMA), volunteered to create a materials database on the Wiki. The project expanded the Oddy testing page, creating a searchable and sortable table of tested materials. In addition, any contributor who shared their protocol could easily add their results to the table. By publishing the results on a neutral site, such as the AIC Wiki, it is the authors’ hope that other institutions will see the benefit of such a resource and begin to participate in greater numbers. Most recently, the National Archives of Australia with PAT results and Autry National Center with a testing protocol joined the group of those sharing information.

The existing content consists of a Protocols page and four Materials Database pages divided into the following categories: Fabrics, Case Construction Materials (including storage and mount materials), Adhesives and Tapes, and Paints and Sealants. Links to manufacturer and supplier sites, related external sites, other published results, and pertinent literature are also provided. Each page contains the important caveat that this information is a reference tool rather than endorsement. The database pages can easily be expanded or adapted based on contributor or user feedback. Recent feedback was solicited from the online mountmakers’ forum and then incorporated into the site. Current goals of the

project include increasing the number of contributors, automating data entry, and integrating feedback from users. The ultimate goal is to create a resource that will aid staff at institutions of every size and type in choosing materials appropriate for their needs and collections.

Flexible Case Design and Tiered Levels of Case Function at the Autry National Center

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The Autry National Center's Conservation, Design, Fabrication, and Collections departments worked together to implement a flexible case design and associated tiered system of case categorization that provides a range of case interior conditions. Each tier defines a case with a specific combination of deck materials, gaskets, and buffering. The cases can mitigate fluctuating RH conditions as well as passively scrub interior air as needed. The case tier categories provide a way to reduce overall materials costs and minimize maintenance requirements without compromising artifact preservation or impinging on curatorial desires.

In 2014, the Autry was faced with several challenges in the midst of planning for a temporary exhibition being generated in-house. The HVAC system in a temporary exhibition gallery space ceased meeting standards necessary to display artifacts sensitive to relative humidity fluctuations. Concurrently, previously acceptable case interior construction materials including expanded PVC foam board and latex paints began to fail in-house Oddy tests. Furthermore some cases would house artifacts that could offgas next to incompatibly sensitive artifacts.

For the Conservation department, in addition to in-house Oddy testing and research, reaching out to other colleagues in the field was critical at this time to keep up with the constantly evolving construction materials typically used to fabricate cases. From the point of view of Conservation and Collections, the casework had to either seal well, or allow passive ventilation as needed, and be able to house adequate quantities of climate buffering material and/or pollutant scavengers in an easily accessible manner. From the point of view of the Exhibition Design and Fabrication departments, the casework had to be flexible, easily produced, and complement the current design of casework on display in the galleries. This casework needed to be reusable and able to house a variety of objects.

Because these problems had to be solved with minimal change to already planned budgets, it was not economically feasible to bring all case interiors to the same preservation-grade quality. However, flexibility in build out proved to be a possible net benefit by meeting different artifact needs. Team members critically examined the casework already used in the museum, identifying the strengths and weaknesses in current case design.

The designer created a new case style that can be fitted out in multiple ways depending on the sensitivity of the object exhibited inside as well as lender specifications. The conservator and the registrar designated three combinations of case fittings for this new style, each called a tier, and determined which objects were assigned to a given tier. Each case was then customized to meet the strictest tier requirement amongst the objects that would be displayed inside.

The first tier housing the most sensitive materials combines gaskets, buffering, passive pollutant scavenging, exterior monitoring capability, and neutral interior case materials that are approved for permanent display by Oddy testing. Decks for this tier are made of expanded PVC board that is sealed with aluminized nylon and polyethylene barrier film and wrapped in exhibition fabric.

In the second tier, the cases are the same as the first, except that the decks are made of painted, expanded PVC board. The paint and expanded PVC board are not an ideal deck material. Recent batches of paints and expanded PVC had failed our in-house Oddy tests or only passed for temporary use. However, it is an improvement on painted MDF and allows for a faster and cheaper construction than the first tier. Scavengers and buffers were only used on an as needed

basis for cases in this tier. This took some burden off staff members tasked with monitoring and replenishing the materials, and the case is still able to withstand a fair amount fluctuation in the gallery's relative humidity.

The third tier cases are built like those in the second tier, but are fitted for extra ventilation. These cases are meant to house artifacts that may evolve volatile acids, but are not as sensitive to relative humidity fluctuations. Objects made of materials such as deteriorating leather were placed into these cases. An additional fourth tier was added, which encompassed several retrofitted old cases.

Installation of the new cases was completed on April 21, 2015. As hoped for, the tier one case has thus far maintained RH between 43-45% with no need to replenish silica gel, despite environmental fluctuations within the gallery. The Autry has capital improvements planned that will address the wilting HVAC system. Nevertheless, we will continue to incorporate this tiered system of case design because of the efficiency at meeting our own institutional and lender standards.

The tier system was an effort taken on by several departments including: Conservation, Collections, Fabrication and Design. Flexibility on the part of every department and numerous solution-oriented meetings throughout exhibit planning were critical to success. All departments continue to explore new materials and methods for meeting tier one standards and closely evaluate the precise needs of what is best for the objects in the collection and what is achievable within our institution's budgets and timelines.

The Exhibition Process at The Field Museum: A Collaborative Process Worth Considering

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The Field Museum, Chicago, IL

Creating an exhibit relies on the talents of many at the Field Museum. Over the past two and a half decades the Exhibitions Department has crafted an Exhibition Process document that delivers an exhibition within budget, creates wonder for the visitor, and provides safety for the objects and specimens. This process has both successfully defined and realized exhibitions such as the recently opened Cyrus Tang Hall of China, and traveling exhibitions Mammoths and Mastodons and Biomechanics: The Machine Inside. It has also pushed the staff to solve the problem of eliminating wood from case interiors and to seek new and exciting fabrication materials and techniques. This presentation will review how Conservation and Production departments collaborate on case design, mount making, and the selection of materials for an exhibit using both the *Exhibit Process* and *Exhibition Guidelines* documents.

The *Exhibit Process*, a regularly updated document, outlines milestones and important steps in the development and fulfillment of an exhibit. This document is supported by the *Exhibition Guidelines* that outlines safe approaches and materials for the design and production of cases, mounts, and gallery finishes. Each exhibit has a designation team that meets weekly and uses these documents in their work. The team includes a project manager, conservator, registrar, developer, 2-d designer, 3-d designer, production supervisor, mount shop supervisor, media supervisor, and other key staff for the project.

The Field Museum exhibit process is organized into four phases. They are: Proposal, Concept development, Design/development, and Production. Each phase has defined and scheduled deliverables for the team and reviews by the Exhibition Department Directors. It defines a coordinated and organized schedule overseen by a Project manager to allow for the work of each team member.

The Proposal phase includes a summary, preliminary budget, and sketch of the exhibit. If the exhibit is approved and funded then the exhibit process continues. During this phase the Exhibition Department leadership contacts staff to see if there are any significant issues that would need to be addressed if the Museum was to either borrow or create the exhibition.

Early review of the exhibit concept allows Conservation and Production to address fabrication and display challenges and issues of safety for the collection. For example, the Field Museum wished to present an exhibit about Haitian Vodou. The 540 objects in the exhibit could not be shown in display cases, and any dust accumulation could not be removed for cultural reasons. Open exhibition is not customary at the Field Museum and dust had been a problem in the gallery. This caused Conservation to test the air quality in the gallery and advise on any needed actions prior to the opening. Ultimately, over a period of two years the Museum funded the complete cleaning of the exhibition hall, ductwork and rebalancing of the HVAC system.

Concept development is a time when the designers create a preliminary exhibit plan, and the developers and curators address the stories that will be told by the objects or specimens selected for the exhibit. Conservation and the mount makers review each selection, collaborate on mount design, and report any significant issues that would either promote or deter selection of any particular objects or specimens. The Exhibition Conservator surveys these selections assessing their condition and defines criteria for the exhibition climate, light levels, need for passive or active climate control, and installation mounts. These criteria are then entered into a shared database for the mutual use of the team. As an example,

over 1,400 objects were recently surveyed for a final group of 440 objects to be exhibited in the Cyrus Tang Hall of China. Design and Production are normally the first to want this information since it defines the performance level of the display case.

Performance is most often defined by how tightly sealed the case is made so that a microclimate can be created by using silica gel. Of course, the more tightly sealed the case, the more important it is to only use materials that are safe for the objects and specimens to be exhibited in the display chamber. Therefore, material testing is done at this time as well to provide Design and Production enough lead-time for their selections.

The *Exhibition Guidelines* include standards defined for the safety of the objects and specimens selected for exhibition. These standards provide information related to the safe exhibition of the collection, including handling, environment, case design, exhibition layout, maintenance, installation mounts, and rotations among others. It also includes generic types of materials that were either denied or approved in the past. However, Conservation tests all exhibit materials using the Oddy test and maintains a shared Materials Database that includes every material tested over the past 15 years. At the end of this phase, the Scope of Work document is completed as approved by the Exhibition Department Directors.

Design/development is the phase in which each object or specimen is designed into the exhibit and final conservation and installation mount decisions are made. All cases and layouts are drawn to scale and circulated for review on a carefully defined schedule. Cases are often prototyped and tested during this stage as well. The Field Museum has a long history of creating climate-controlled cases that are increasingly more efficient and cost-effective to build. The Museum's success in building cases is due to the talent of the staff, and the use of computerized wood cutting equipment. This equipment provides consistency in the joins and ultimately the controlled tightness of the cases.

This phase is also when conservation treatment work is completed, cases are prototyped, and testing of the cases is conducted. Each case type is tested using a Vaisala handheld logger with an attached GMP222 carbon dioxide probe. The probe is placed into the display case and the chamber charged with carbon dioxide. The data is then downloaded to determine the leak rate and ultimately the number of air exchanges per day. Our tightest case to date is 0.05 air exchanges per day. However, we consistently achieve 0.09 - 0.21 air exchanges per day. During this phase there is an exhibition preview, review and two budget checks presented to the Directors.

The Production phase is the time when the exhibit is fabricated, installation mounts are made, and the exhibition installed. This is a time when the staff is nimble and ready for change and refinement. And, again there are reviews for the Directors.

Our future work is based on the challenges of increasingly creative exhibit ideas and the need to create safe and cost effective exhibition environments. Exhibition ideas are being realized by a new era of equipment and materials that are ever dropping in cost. It is now much more common, and will be more so in the future, that museums will have CNC, 3D Printing and digital fabrication equipment. This will permit even smaller institutions to create better, lower cost, and environmentally responsible exhibitions. This in turn impacts the experience of the visitor and the safety and preservation of our collections.

Strange Events Inside Display Cases at the Museum of Fine Arts, Boston, and Lessons To Be Learned From Them – Part 1

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In fall, 2014, the Museum of Fine Arts, Boston (MFA) noticed fluffy white crystals growing on gaskets inside a Goppion display case that had been installed in 2012. Discussions with colleagues suggested that the crystals were due to a reaction between compounds originating in two of the materials used in the construction process: a commercial adhesive and one type of gasket. Less than a month later, crystals were observed growing on two ceramics in another case. This prompted an ongoing examination of all of the museum's Goppion display cases acquired from 2009 (currently a total of 424), focusing on three phenomena that we felt were related in some way to materials used in the construction of the cases: crystals on gaskets, crystals on objects in cases, and hazes on the inside of glass panels. While crystals on gaskets and glass hazes are somewhat common, but by no means ubiquitous, visible crystals have been observed to date on only four objects.

A research partnership was established between the MFA, Goppion SpA, and the University of Turin to characterize this phenomenon. Analysis at the MFA and the University of Turin established that the crystals on the gaskets specifically involved a volatile component (2,2,6,6-tetramethyl-4-piperidinol, or TMP) contained in a hindered amine light stabilizer (Tinuvin 770) added to the adhesive used to bond glass and metal, and a breakdown product (2,4-dichlorobenzoic acid) of a chemical used in the process by which the silicone gaskets were manufactured.

Crystals on objects and hazes involved the same compound (TMP) from the adhesive, which had reacted with chloride ions to form a salt. On objects, the chloride could have been present in or on the surface of the artifacts themselves, but the source of chloride on the glass is not certain.

TMP is a little known chemical whose presence as a free compound in Tinuvin 770 (whose manufacture involves a condensation reaction between TMP and sebacic acid) has received almost no notice to date. Although present at a very small level in Tinuvin 770, the airtightness of the display cases has allowed TMP to accumulate to the extent that the unusual reactions we have noted became possible.

The adhesive and gaskets had passed Oddy tests at the MFA (and elsewhere) when tested individually. Retesting of the adhesive and gaskets together in one tube (a type of testing not generally carried out by institutions that utilize the Oddy test) resulted in no visible reaction on the three (lead, copper, silver) metal coupons, although readily visible crystals grew on the gasket. The surprising phenomena inside the display cases whose materials had been selected primarily based on Oddy testing serve as another reminder of the limitations of this common type of testing, which is not sensitive to all compounds that may outgas from a given material. The phenomena are also a reminder that unpredictable reactions between compounds released by different materials in proximity in closed environments with little air circulation may occur.

The construction materials responsible for the phenomena are no longer utilized by Goppion, and current research at the University of Torino is addressing means of eliminating TMP from accumulating in the air in previously-manufactured cases.

Strange Events Inside Display Cases at the Museum of Fine Arts, Boston, and Lessons To Be Learned From Them – Part 2

Beyond the Oddy Test – the way forward

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S. Goppion (CEO) – Goppion SpA, Milan, Italy

O. Chiantore, T. Poli, C. Riedo – Department of Chemistry, University of Turin, Italy

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Conservators have been noticing cultural artifacts reacting to offgassing indoors and within enclosed environments for many decades. The effects of acids, aldehydes and a host of other pollutants are well-known; examples abound of metal corrosion, alteration of colorants, or the embrittlement of organic materials. Preventive conservation research and methodology has evolved to characterize harmful agents and their effects, and develop testing methods and construction technologies which would lead to safer environments for heritage materials. In spite of these developments, previously undetected reactions between construction materials and objects still occur. Even with our best efforts to test materials prior to use for proximity to objects, it is clear that we are unable to predict all interactions. It is also clear that the most common methods used to test construction materials for use in enclosed environments with cultural heritage are inadequate. The development of well-sealed steel and glass display cases has aided in dramatically reducing risk to objects from environmental agents of deterioration. However, a surprising reaction has highlighted the inadequacy of the standard methods by which we evaluate construction products.

The reaction of the compound 2,2,6,6-tetramethyl piperidinol (TMP), found in the hindered amine light stabilizer (HALS) Tinuvin 770, was found to cause the formation of crystals on or near extruded silicone gaskets crosslinked with 2,4-dichlorobenzoyl peroxide. TMP is present in the construction adhesive we used in extremely small amounts: on the order of 0.1%. Of this amount, some residual, unreacted TMP remains present in the adhesive after curing, and has the potential to react with other compounds. After noticing crystals on the gaskets, they were observed growing on some low-fired, porous ceramics, and on the interiors of glass cases. Some of these crystals proved to be reaction products of TMP with other acidic compounds containing chlorine and sodium, as described in Part I. However, in a number of other instances, crystals observed on objects were identified as unrelated compounds.

The collaborative research group (MFA, University of Turin, and Goppion, SpA) has focused on the characterization of these crystals and the conditions under which they form, and the behavior of TMP in general. The research group has found that TMP is not formed as a deterioration product of Tinuvin 770, but rather is present in excess as an initial reactant. This discovery is critical to the formulation of mitigation strategies, as it indicates that TMP will not continue to be evolved over the lifetime of the products containing it. However, questions remain about the conditions under which TMP reacts with glass display case interiors and the surfaces of some objects, how to prevent the formation of these crystals, and how to remove them.

The research group is in the process of identifying methods for detecting TMP and other compounds which may be present at low levels in exhibition cases, developing solutions for mitigating their presence, evaluating the effects of reaction products, and determining methods for their removal from objects and display case interiors. In recent tests, the crystals were easily removed from ceramic object surfaces and glass, without evidence of damage to the surfaces.

Testing has revealed methods effective in reducing TMP inside exhibition cases, including:

- 1) Moderate increase in temperature for limited periods.
- 2) The use of sorbents with an active filtration system.

New preventive methods are also being examined. In particular, the use of a colorimetric sensor array being developed at the University of Illinois at Urbana-Champaign to detect pollutants, including TMP. Making this technology easy to use, portable, and inexpensive, are key components of its applicability in the cultural heritage environment.

Few construction products are produced specifically with the museum community in mind, because of the limited nature of this market. Typically, products from large manufacturers are tested and adapted for use; however, acquiring sufficiently detailed technical information from producers is challenging, as is gaining information about changes to product lines over time.

Working with The Aerospace Corporation and Jet Propulsion Laboratory, we are exploring the use of resources developed for the aerospace industry to characterize materials appropriate for use in the museum environment. Results found in the NASA Outgassing Database can provide a starting point for the identification of suitable materials not previously considered for use in museum environments, and standard test methods used in industry can help to identify these materials. The term “NASA qualified” represents a standard with which all suppliers to the aerospace industry must comply. The concept of a “Museum qualified” standard will be explored with industry and cultural heritage partners.

Implementation of Solid-Phase Microextraction (SPME) for Assessment of Exhibition & Storage Materials

Christopher A. Maines (Senior Conservation Scientist)

National Gallery of Art, Washington, DC

Solid phase microextraction (SPME) coupled with gas chromatography / mass spectrometry (GC/MS) overcomes many of the shortcomings of the conventional methods for analyzing evolved gasses: identification, rapid sampling, and quantitation. SPME has been in use since the early 1990's for the analysis of trace amounts of volatile compounds [1] and since the late 1990's with on-fiber derivatization for the analysis of gaseous compounds. [2] SPME with on-fiber derivatization allows for simultaneous analysis of all species of interest, including those otherwise too volatile for detection by GC, and can result in stable derivatives with on-fiber lifetimes at room temperature of several hours allowing for remote sampling followed by later chromatographic analysis. Optimized SPME methods for analysis of exhibition and storage materials will be presented along with examples comparing results from conventional evolved gas analysis with SPME – GC/MS analysis.

While there has been an increase in use of SPME in studies of cultural heritage materials, the emphasis has been on detection of degradation products and other off-gassed compounds amenable to detection by GC techniques. [3-6] This laboratory's modification of the original on-fiber derivatization technique overcomes known problems associated with conventional SPME analysis: pollutant evolution rates; representative sampling; and detection of small molecules otherwise invisible to GC analysis, such as formaldehyde and acetaldehyde. Materials of interest are enclosed in 10ml vials and pre-heated to 60°C before sampling, which allows for both accelerated evolution of vapor- and gas-phase components as well as their complete mixing. There is a loss of analyzable material from the fiber because of repartitioning at 60°C, but the sensitivity is much better than 10ppbv, and considerably better than the "Oddy Test". Offgassing rates at RT can be estimated varying the mass, the volume exposed for sampling, and the pre-heating period. An autosampler is necessary for precise sampling times and reproducibility of SPME fiber introduction and desorption in the GC injector.

The additional advantage of the technique over conventional GC analysis is the ability to detect those compounds that will be off-gassed. GC analysis of samples introduced via solution injection or pyrolysis will not necessarily distinguish among compounds that will be off-gassed from those that will remain in the material. A sample of asphalt that had been intended for a history museum display was shown to off-gas appreciable amounts of aldehydic compounds. The "Oddy Test" for the asphalt had been inconclusive, while conventional pyrolysis-GC/MS was unable to show which compounds within the asphalt could cause damage to surrounding objects.

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Assessing Materials for Use with Paper-Based Collections: An Alternative to the Oddy Test

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The Library of Congress has a quality assurance program for testing materials that come into contact with collections in storage or on display to ensure those materials will not harm collections. The program utilizes standard tests to ensure materials meet specifications and uses the Oddy test for specific materials assessment. The traditional Oddy test assesses the impact of material off-gassing on collection items through the corrosion of metal coupons, a result that does not necessarily correlate well to the Library's primarily paper-based collections. This presentation focuses on research in the Preservation Research and Testing Division that uses paper instead of metal as a sensor and multiple analytical methods to assess the degradation level of the paper sensor.

Common book and paper preservation materials such as book cloths, binding boards, foams, and adhesives were subjected to accelerated aging in the presence of Whatman No.1 filter paper (cellulose). Samples were pre-equilibrated at 23°C and 50% relative humidity prior to being sealed in glass containers and placed in a 100°C oven for 6 days. Traditional Oddy tests were also performed on all materials. The paper sensors were removed from the aging containers and extracted into water to collect small molecule cellulose degradation products and other chemicals that evolved from the preservation material and absorbed into the paper sensor. Ion chromatography (IC) was used to assess and compare the aqueous extracts. Gas chromatography-mass spectrometry (GC-MS) was the primary technique implemented to identify the origin of IC signals that both related to cellulose degradation products and volatile organic compounds that absorbed into the cellulose sensor. In addition, samples aged for 10 days were assessed with fiber optic reflective ultraviolet-visible spectroscopy (FORS-UV/Vis), which was shown to serve as a rapid screening method for materials determined to be 'unacceptable' for use with collections by the IC test.

Analysis of corrosion products formed on the metal coupons was completed with x-ray diffraction (XRD) in an attempt to understand the origin or cause of corrosion when using the Oddy test. The Oddy test and paper-based IC test were compared for their ability to differentiate preservation materials. Materials providing acceptable for use ratings with the Oddy test were sometimes determined to be unacceptable for use by the IC test, and vice versa. In addition, the IC test allowed for the identification of preservation materials that off-gassed and absorbed into the paper sensor. The chemical identification of these off-gassing products along with the evaluation of the degree of paper degradation provided a method of evaluating whether or not the preservation materials were a threat to paper-based collections.

In this presentation, examples of polyethylene and silicone foams will be presented. While this is not an exhaustive study of foams used for preservation, it displays a range of results from unacceptable to acceptable for use with collections. Determinations that are assessable using both the IC test and FORS-UV/Vis spectroscopy will be used to demonstrate the variety and interpretation of results. Overall, a new test will be presented that both provides often contradictory results when compared with the Oddy test and is poised to better inform the library, archive, and museum paper conservation community about preservation material selection.

Materials Suitability Testing at the Indianapolis Museum of Art: Successes and Challenges

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In March of 2011, the Indianapolis Museum of Art (IMA) opened a new scientific analysis facility for the study and protection of the museum's encyclopedic collection of artworks. Almost simultaneously, the IMA embarked on a number of new construction projects that included a redesign of the display space for its African collection and the creation of a new 11,000 ft² gallery for contemporary design objects [Figure 1]. IMA scientists and conservators were called on to vet all of the construction, display, and storage materials for each of these major projects. As a result of the heavy workload needed to assess these samples, the process for materials suitability testing was significantly refined. This lecture will describe the analyses (Oddy tests and fading experiments) performed to assess the various materials used in these construction projects and will highlight the various successes and challenges experienced. The collections care staff had to balance comprehensive testing with tight construction timelines, a bold artistic vision with adequate artwork protection, and minimizing risks with minimizing construction costs. As is the case in any such large endeavor involving contributions from numerous institutional collaborators, many negotiations and compromises were part of the process of bringing these new gallery spaces into being.

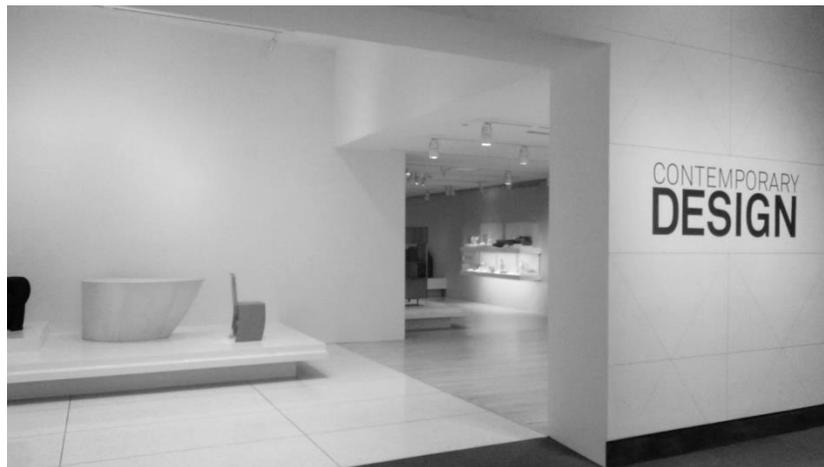


Figure 1. The entrance to the IMA Contemporary Design Galleries showing the variety of surface finishes and construction materials.

The inevitable last minute changes and overall rapid pace of these renovation projects has encouraged the exploration of faster methods for vetting materials at the IMA. One instrumental approach that has proven quick, reliable, and comprehensive is the direct analysis of volatile organic compounds (VOCs) emitted by construction materials using evolved gas analysis – gas chromatography – mass spectrometry (EGA-GC-MS). This approach, which was developed in-house at the Indianapolis Museum of Art to speed up the testing process, uses a pyrolysis sampling accessory that is commonly available in many museum laboratories. The EGA sampling technique gently heats a potential construction material while entraining the emitted vapors onto a cool GC column. With as little as half a minute of sample heating, a representative collection of VOCs can be generated. This sample mixture is then separated on the GC in less than 40

minutes, and each component is identified by its mass spectrum, Figure 2. Furthermore, semi-quantitative to quantitative data can be generated by the EGA technique for common pollutants if the proper standards are available for calibration.

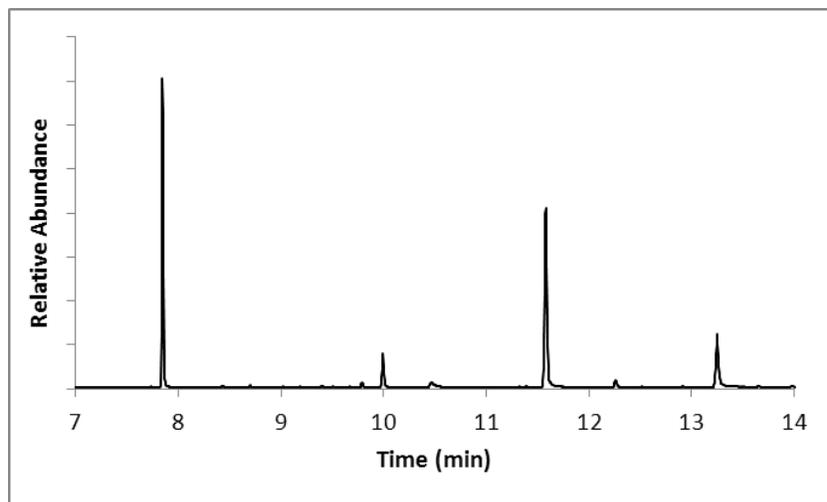


Figure 2. Chromatogram for the EGA-GC-MS analysis of a black polyester-based polyurethane packing foam. Peaks were identified by their mass spectrum as the internal standard hexadecane (7.85 min) and off-gassed pollutants 4-decylmorpholine (10.00 min), 4-dodecylmorpholine (11.58 min), and 4-tetradecylmorpholine (13.26 min).

The EGA-GC-MS approach to materials suitability testing is still under development and has not supplanted the Oddy test at the IMA. Current research in our lab seeks to relate any adverse effects observed in Oddy tests of construction materials to the various VOCs observed in their EGA chromatograms. For regularly stocked conservation and construction materials (e.g. Volara[®], EthafoamTM, Sintra[®], glues, paints), the emission profile from a new batch of product can be quickly compared to the VOC profile observed for older batches that have already passed the Oddy test. In this way, one can be confident - without the need for lengthy testing - that no negative formulation change has occurred in the product since the last order was placed.

Silver Nanofilms as Oddy Test Sensors to Assess Storage Materials for Sensitive Silver Objects

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The Oddy test is a low-tech method commonly used in institutions across the globe to assess the suitability of materials for storage and display of objects of cultural significance. While there have been a handful of variations developed over the years, The Metropolitan Museum of Art uses a 3-in-1 Oddy test with silver, copper, and lead foils. [1] Generally, metal foils are a good representation of metal objects found in museums, except when metal is present in very thin layers or as nanoparticles, such as in daguerreotypes (mercury-silver or mercury-silver-gold amalgam nanoparticles on silver-coated copper). Other sensitive silver objects include: salted paper prints, *niello* style objects, and composite objects that have metal elements, metal leaf, or metal plating. Generally, these objects cannot be polished and therefore the materials used to display and store them need to pass more rigorous testing. During the Oddy testing of materials to re-house daguerreotypes, we noticed that silver foil did not reflect the sensitivity of a daguerreotype image under the same conditions. This prompted the need to identify a more suitable silver corrosion sensor. Several groups of researchers have suggested using silver nanofilms with thicknesses from 25 to 200 nm to replace the silver foil or silver coupons typically used. [2,3] We chose to make a series of vapor-deposited silver nanofilms on glass with thicknesses between 7 and 200 nm and test their response to sulfur-containing pollutants. The silver films were deposited on microscope slides using an in-house vacuum unit that is generally used to coat samples for scanning electron microscope (SEM) analysis or to make surface enhanced Raman spectroscopy (SERS) substrates. [4] The silver nanofilms were tested in the presence of a sulfur-releasing control material in an Oddy-like setup and the responses were compared to those of laboratory-made daguerreotypes. The 7 nm silver nanofilm was determined to be the one that best reflected the sensitivity of a daguerreotype image after one week of exposure. There was an easily observable color change from purple to pink/orange in the films. Additional 7 nm silver nanofilms were made and used to test a small subset of mat boards, tapes, and other storage materials and the results were compared to those obtained in a standard 3-in-1 Oddy test. Rising Photomount board (white non-buffered 4-ply) was the only mat board to pass both tests. Filmoplast P90, 3M double sided tape, and several Volara samples passed both tests. The silver nanofilm sensors in an Oddy test setup is not proposed as a replacement for the standard Oddy test but as an additional assay to be used in the case of sensitive silver objects.

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Reuse of Silica Gel Pellets: Chemical Retention

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Freer and Sackler Galleries, Smithsonian Institution, Washington, DC

Silica gel pellets are commonly used for humidity control in the museum environment. Silica gel pellets adsorb and desorb water to maintain humidity, but they also can adsorb and desorb other chemicals such as hydrochloric acid, acetic acid, and formic acid that can cause the deterioration of artifacts and objects. These acids and their sources can be found in wooden cases, adhesives, and other materials within the museum environment. While silica gel pellets may act as passive sinks for acids and other detrimental chemicals, they can also release or desorb these chemicals. This means that “dirty” silica gel pellets, or ones that have chemicals adsorbed on them may be sources of detrimental chemicals within the museum environment.

It can safely be said that no institution is intentionally using dirty silica gel pellets, however many institutions reuse their silica gel pellets to control humidity in different enclosures. Conditioning procedures are employed to prepare used silica gel pellets with a desired percent relative humidity (RH). These procedures do not consider the removal of adsorbed materials other than water. To understand how well conditioning procedures remove other chemicals from the silica gel pellets this research uses Thermal Desorption-Gas Chromatography/Mass Spectrometry (TD-GC/MS) to identify adsorbed chemicals that are retained in silica gel pellets after conditioning. Samples of conditioned silica gel pellets were obtained from a variety of institutions along with the method they used to condition their silica gel pellets for reuse.

The analyses found a variety of chemicals on reconditioned silica gel pellets. Desorption of chemicals during future reuse poses a potential hazard to museum objects that is dependent on the concentration and type of chemicals that are released. This does not mean that the reuse of silica gel pellets should be suspended. Rather it means that silica gel pellets need to be evaluated prior to reuse for retained chemicals, and the methods used to condition silica gel pellets for reuse need to be reconsidered in light of the potential exposure of objects to hazardous chemicals.

Communicating Perspectives: Unified Approach to Selection of Storage and Exhibition Materials at the National Gallery of Art

Christopher A. Maines (Senior Conservation Scientist), Bethann Heinbaugh (Head of Preventive Conservation), Cecily Grzywacz (Facilities Scientist), Judy Ozone (Senior Conservator), Sarah Wagner (Senior Photograph Conservator), Andrew Watt (Armature Maker/Projects Coordinator), and Gordon Anson (Deputy Chief of Design)

National Gallery of Art, Washington, DC

The National Gallery of Art (NGA), Washington, DC has recently revisited its procedures for selection and review of all materials that come in to the NGA. There have been several attempts over the past ten years to streamline the process and to involve all necessary participants. The two motivations for this are 1) health and safety for the staff, contractors and visitors, and 2) preservation of the works of art. Careful attention has always been paid to the acute issues of human exposure to toxic materials, most often with respect to solvent fumes from paints or adhesives used in non-art containing spaces, as well as to materials in close proximity or direct contact with works of art, such as case materials, mounts, or wall paints. However, it is only within the past several years that more attention has been paid to how materials used throughout all areas of the NGA can have an impact on the long-term stability of works of art. The three largest obstacles to a successful implementation have been: 1) maintaining a consistent communication and review chain with all relevant parties, 2) making sure there is no “approval drift”, i.e. - materials approved for one situation do not get used inappropriately in another, and 3) establishing a duty cycle for testing and review of materials to insure that any potentially harmful formulation changes are caught.

After a series of regular meetings to establish a chain of communication, a workflow for the review and approval process, and a series of classifications for use categories, the NGA has implemented a system based around its chemical data management software, Sitehawk, whose primary purpose is to keep track of material data safety sheets for all chemicals on site as required by federal regulation. As the system can be set to send out updates and notifications when new materials are added to the system as well as a hierarchy of review and approval, it is ideal for making sure everyone is notified and can give input on a material’s suitability, as well as keep track of the use category and the use history for any given material.

The presentation will discuss through various examples, the history of past attempts at a unified system, the most critical points of failure as identified from previous attempts, how the cycle for retesting materials gets established and revised, the most important differences in perspectives among the various stakeholders, and the methodology for revising the overall workflow.

Materials Testing in New Museum Construction: A Case Study and Lessons Learned at the Harvard Art Museums

Angela Chang (Assistant Director and Conservator of Objects and Sculpture), Peter Atkinson (Director of Facilities Planning and Management), Kathy Eremin (Patricia Cornwell Conservation Scientist), Kathleen Kennelly (Collections Information and Database Specialist), Narayan Khandekar (Director of the Straus Center for Conservation and Technical Studies and Senior Conservation Scientist), and Georgina Rayner (Andrew W. Mellon Postdoctoral Fellow in Conservation Science)

Harvard Art Museums, Cambridge, MA

This talk will present a materials testing program devised for the new construction of two recent major building projects undertaken by the Harvard Art Museums from 2008-2014. Lessons learned will be shared about this ongoing program. Conservators, Conservation Scientists, and administrators played integral roles in a collaborative design and planning process. They devised a materials testing program to review all construction materials proposed first for an off-site storage and interim facility and then for the renovated the Harvard Art Museums, which re-opened in November 2014. The program sought to minimize harmful off-gassing of construction materials by making the best choices of materials where possible, understanding that concessions would be necessary. Over eight years of testing, 900+ materials were evaluated for use in over 75,000 square feet. The unusual circumstance of having two sequential building projects allowed the process to be continuously refined.

Prior to construction, the materials testing program was devised in consultation with the Museums' facilities and operation department, architects, contractors, and project managers. No prior materials testing practice was in place. With the support of the museum administration, all stakeholders worked together to determine a work flow and time requirements for processing materials to be used, attaining samples, testing, recording, and communicating test results and approvals. All materials to be used inside the vapor barrier of art spaces (galleries, art storage, art study centers, and conservation laboratories) were evaluated. The testing methods were openly discussed to ensure all understood the process and its limitations. A sample submission form required information about each material's intended use, location, and quantity. This information was considered in the evaluation of test results. Reference lists of materials such as "no testing required" and "banned substances" served as helpful guidelines for architects and contractors. Oddy testing was the primary technique. Several microchemical tests were considered, and occasional further analyses of samples by the Museums' conservation scientist were undertaken. Oddy testing was adapted in several instances in unconventional ways to test the ability of coatings and other materials to encapsulate unacceptable substances. A FileMaker Pro database was designed to track results and material information including manufacturer, supplier, MSDS, and intended use.

Primary lessons learned from this program included:

- Conservators and Conservation Scientists' involvement from the earliest planning stages was critical. Museum administration understanding and appreciation of the process was a key component of this.
- The materials testing process required flexibility. Refinement of nearly every aspect of the program was necessary, including communication, testing methods, and evaluation of results.
- The costs, time, staffing and impact on construction schedule could not be underestimated.
- Many concessions were made for design reasons, as well as the lack of substitutions for many products.

- Questions remain about how to evaluate the success of the program, and research and monitoring are in progress. We are currently monitoring pollutant levels in our art spaces, exhibition cases, and art storage cabinets. Monitoring techniques include inserting polished coupons inside cases and quantitative passive reactivity monitoring using a commercial product. Options for mitigating pollutants include adding scavengers to sealed environments and installing selective gas-phase filtration in the building's air handling units. Current challenges include the identification of materials which have individually passed Oddy testing but have shown to interact in situ.

SHORT SUBMISSIONS

Effective Sampling and Analysis of Surface Efflorescence/Deposits on Art Objects: A Case Study Involving Polyester Polyurethane Foam

Adriana Rizzo (Associate Research Scientist), Lisa Gulian (Andrew W. Mellon Fellow), Mechthild Baumeister (Conservator)
The Metropolitan Museum of Art, New York, NY

One of the challenges of the analysis of surface efflorescence and deposits is their effective sampling for analysis. This superficial accumulation can be very difficult to sample due to its sticky and fuzzy and/or electrostatic nature.

Among materials commonly used in contact with or near artworks, polyester polyurethane foams have been found to cause surface efflorescence/deposits on objects of various substrates. Over a prolonged period, and exacerbated by intimate contact and enclosure, these foams release alkylmorpholines and (N,N dimethyl) alkylamines, which are catalysts used in their production. [1]

An effective method for surface sampling of organic deposit/efflorescence for GC/MS analysis is the use of inert materials that are not affected by solvents, derivatization agents or the high temperatures used for desorption methods and pyrolysis. One such material is glass wool. The Auto-Rx Discs (Frontier Lab, Japan) are disks made of ultra-fine glass fibers, which are commercialized to improve reactive pyrolysis in the sample cup. These disks are an ideal new sampling substrate, which can be handled with tweezers, wiped over the surface of the artwork, and analyzed as such by different chromatographic and/or mass spectrometric techniques, including HPLC, GC, thermal desorption, pyrolysis- GC/MS, with and without derivatization.

The efficacy of Auto-Rx Discs as sampling tools, compared to cotton swabs, was tested on an organic efflorescence/ deposit, which developed inside a varnished wooden cabinet (The Backgammon Players, British 1861, acc. # 26.54) designed by Philip Webb, manufactured by Morris, Marshall, Faulkner & Co and painted by Sir Edward Burne-Jones. While on loan from The Metropolitan Museum of Art (MMA) the cabinet was exhibited closed for a period of three months with a piece of black open-cell polyester polyurethane foam completely covered in *Tyvek* inside. The foam was placed by the MMA packers to prevent the opening of the interior double doors during shipment and display.

A whitish efflorescence was present in all areas covered by the foam block, however areas where green masking tape was placed to hold the *Tyvek* together, exhibited hardly any efflorescence, indicating that off-gassing of the black polyester polyurethane foam caused, or contributed to, the whitish surface appearance.

Analysis of deposit/efflorescence was performed by thermal desorption-GC/MS (TD-GC/MS). The tips of the swabs or disks were placed in the pyrolysis cup (Eco-cup, Frontier lab) and the efflorescence/ deposit was thermally desorbed between 100-300°C. The results indicated accumulation of free fatty acids, probably deriving from a beeswax coating and the oil-resin varnish surface treatments of the cabinet. Furthermore, the white accumulation showed (N,N dimethyl)hexadecylamine, from the polyurethane foam. The (N,N dimethyl)hexadecylamine is not present in areas where the green tape was in contact with the cabinet's surface, indicating that the tape acted as a sealer while in all other areas the hexadecylamine must have escaped the foam through the *Tyvek*.

With the study we can conclude that the glass fiber disks are superior to the cotton swabs for TD-GC/MS analysis of the deposit/ efflorescence collected on them, as they do not release any chemical component during thermal desorption or pyrolysis.

Furthermore this study highlights the off-gassing of polyester polyurethane foams and cautions about their use for mid-term storage in enclosed environment, even if wrapped in *Tyvek*.

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Air Corrosivity Monitoring in Museums

Ed Light (President, Building Dynamics), Cecily Grzywacz (Facilities Scientist, National Gallery of Art), Kelly Horiuchi (Laboratory Director, ALS Environmental), Kathryn Makos (Research Collaborator, National Museum of Natural History), Catharine Hawks (Conservator, National Museum of Natural History), Michael Hunt (Industrial Hygienist, Smithsonian Institution), and Sophia Kapranos (Industrial Hygienist, Smithsonian Institution), and Roger Gay (Industrial Hygienist, Building Dynamics)

Display materials may emit corrosive vapors, potentially damaging artworks and artifacts. Various air monitoring methods are in use to screen display materials for corrosive emissions, but there are no universally accepted protocols for monitoring the corrosivity of ambient indoor air quality (IAQ) in display and storage areas.¹

METHODOLOGY

The authors compared three passive air monitors over a range of environmental conditions to quantitative chemical measurements for common corrosive agents (acetic and formic acid by ALS Method 102; formaldehyde and acetaldehyde by EPA Method TO-11A). Samples were collected in outside air, general museum air, inside two types of wooden storage cabinets and in a storage cabinet with particleboard and oak wood added. Passive samplers were: A-D Strips. Treated tape which measures the acidity of air and is commonly used to monitor film storage.² Diffusion Tubes. Gastec Acetic Acid Passive Dosi-tubes.³ Air corrosivity probes. Measures the net effect of corrosive agents in the air based on changes in electrical conductivity resulting from copper loss (sensitivity in nanometers).⁴

RESULTS (table 1)

Outdoor air at the HVAC intake had only trace levels of carboxylic acids and aldehydes. Levels slightly increased in museum indoor air (two different zones, each receiving mixed air from public, office and storage areas). Equilibrium concentration inside sealed cabinets increased significantly (acetic acid: 520 - 680ppb, formic acid: 180 - 265ppb, acetaldehyde: 30 to 65ppb, formaldehyde: 16 - 18ppb). Adding pieces of wood inside a cabinet increased formaldehyde by an additional order of magnitude.

The three passive monitoring methods vary with respect to sensitivity and selectivity. A-D strips did not detect air acidity where acetic acid was less than 16ppb and formic acid less than 8ppb (no color change). At elevated levels of the carboxylic acids (i.e., >200ppb), A-D strips changed color to a category (1) reading (on a scale of 0 - 3). These latter strips showed only trace color change at three days and needed seven days to show significant color change. A-D strips have potential for detecting significant carboxylic acid emissions from display materials.

Diffusion tubes were more sensitive than the strips, and were able to detect a low level of acetic acid (pump/sorbent tube sample was 16 ppb vs. diffusion tube reading of 70ppb). The maximum detection limit of 600ppb was exceeded in 7 days. This semi-quantitative method demonstrated potential to screen for moderately elevated levels of acetic acid.

The air corrosivity probes remained unchanged at all sites (below the detection limit). European research in this area suggests that this method has potential for monitoring air corrosivity in museums by adjusting metal type and thickness in the probes.⁵

RECOMMENDATIONS

1. Museums should continue favoring non-wooden storage cabinets to avoid potentially corrosive emissions from both pressed- and natural-wood.
2. Additional research is needed to better define acceptable levels of carboxylic acids and aldehydes with respect to protection of artworks and artifacts.
3. Additional research is needed to define the pros, cons and limitations of air monitoring methods for corrosive agents and to develop standardized protocols for museum use.

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Table 1.**Museum Air Corrosivity Pilot: Preliminary Results**

Site	Acetic ppb	Formic ppb	Acetaldehyde ppb	Formaldehyde ppb	Diff. Tube ppb	Acid Strip Color Class	Probe
<i>Angstroms/30days</i>							
<i>ambient air:</i>							
outdoor	<5	4	9	6	0	0	<50
rotunda	16	8	7	12	70	0	<50
mammal 5	<	8	7	0	0		<50
<i>inside cabinets:</i>							
Paleo	680	182	66	16	>600	1	<50
Freer	520	265	31	18	>600	1	<50
Freer+wood	520	203	30	112	>600	1	<50

ACKNOWLEDGMENTS:

ALS Global Air Lab for contributing analytical services.
 Smithsonian Museum of Natural History for use of facility.

Evaluation of Display Frames for Photographs using a Design of Experiment Approach

Ana Martins (Associate Research Scientist) and Lee Ann Daffner (Andrew W. Mellon Foundation Conservator of Photographs)

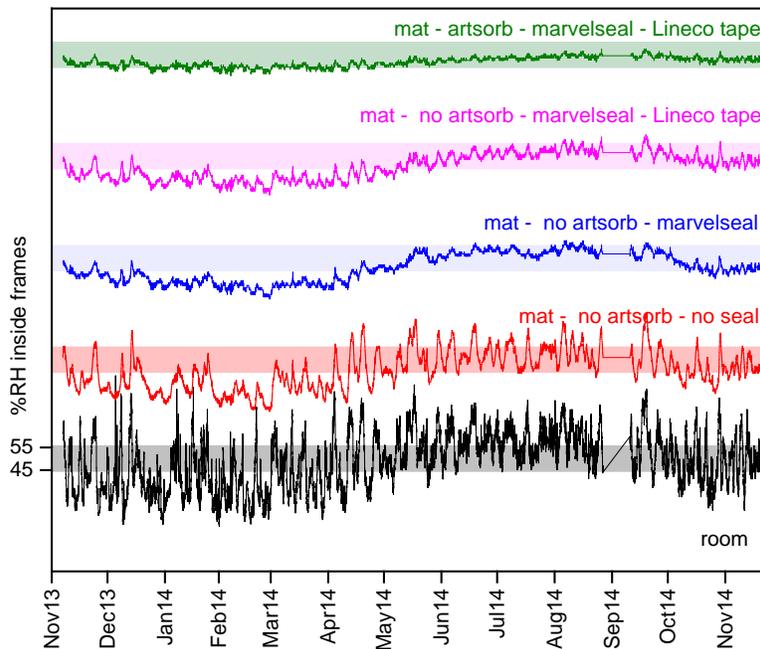
The Museum of Modern Art, New York, NY

The stability and integrity of photographic prints are known to be affected by the environmental conditions in which they are stored or displayed. Microclimate frames can help mitigate the impact of poor environmental conditions and protect the objects from the effects of light, relative humidity, environmental pollutants, pests and mold. They also grant some flexibility in the provision of climatic conditions in the case of loans to institutions with different set points, during transit or for display in nonstandard gallery spaces.

The gallery set points at The Museum of Modern Art (MoMA) in New York City are $45\pm 5\%$ RH, $68\pm 4^{\circ}$ F in the winter and $50\pm 5\%$ RH, $72\pm 4^{\circ}$ F in the summer. Thus the current policy is to use conventional frames (conservation quality mounting and glazing) for the in-house display of prints, and to use either encased (added vapor barrier), sealed (vapor barrier and sealing tape around the edges), and buffered (vapor barrier, sealing tape and climate reservoir) frame packages for prints travelling on loan. This policy was drawn from guidelines, best practices, and published research, but a systematic study was needed to validate the choice of materials and evaluate the impact, cost and benefit of the different frame designs and assembling methods.

A *Design of Experiment* (DoE) approach was used to outline a systematic study of the effect of incorporating a number of framing components: the back and window mat (4ply board – Legion Paper), the addition of a vapor barrier (sheet of Marvelseal 470), a buffering material (sheet of Artsorb – Fuji Silysia Chemical - pre-conditioned at 50%), and the use of pressure sensitive tape seals around the entire frame package (Permacel J-Lar Polypropylene Clear-To-The-Core tape or Lineco Frame Sealing Tape). Based on a full factorial design, a total of sixteen different frames were assembled (see table below). Each frame includes a temperature and relative humidity sensor set up to measure the microclimate conditions every 15 minutes (HOBO U23 Pro v2 datalogger equipped with an external temperature/relative humidity probe with fast sensor response and suited for deployment in tight spaces).

During Phase 1 of the project, the 16 frames were displayed for a full year in a location at the museum with no environmental control. They were thus subjected to more extreme conditions than the museum galleries but still within the range of temperature and relative humidity that can be experienced in locations such as historic buildings or during transit. Selected %RH graphs are shown in the graph below. Currently in the Phase 2 of the project, the frames are being exchanged between two environmentally controlled locations at 35%RH and 50%RH to determine the response rate to changing relative humidity conditions.



The %RH data for a few selected frames is compared to the %RH in the room over the period of one year. The graph clearly shows how both the seasonal and daily %RH fluctuations are mitigated by the conventional framing and that the conditions can be improved considerably by adding a vapor barrier, by sealing the framing package with tape and by adding a climate reservoir.

Analysis of Variance (ANOVA) is being used to estimate the impact of matting, encasing, sealing, and buffering (see corresponding improvement over the conventional frame in the table below) by examining their effect on a series of metrics reflecting both the short term and long term conditions in the frames. Ideally the photographs should remain in a 45-55%RH range, with a maximum drift of 5%RH over a month (seasonal fluctuation) and 5%RH drift over 24 hours (daily fluctuation). Three of the metrics examined are described below and results are given in the table for the 16 frames:

- **%RH stability:** % of year time the relative humidity remained within the 45-55%RH
- **%RH monthly fluctuation:** average monthly %RH range
- **%RH long term drift:** % of year time the monthly relative humidity range remained within 5%
- **%RH daily fluctuation:** average daily %RH range
- **%RH short term drift:** % of time the daily relative humidity range remained within 5%.

Frame	Matting	Buffering	Sealing	%RH stability (% time)	%RH monthly fluctuation (%)	Long term drift (% time)	%RH daily fluctuation (%)	Short term drift (% time)
<i>Room where the frames were displayed</i>				-	32	0	16	6
1	none	none	none	36	26	0	6.7	35
2	back +window	none	none	35	21	0	5.2	48
3	none	Artsorb sheet	none	42	18	1	3.8	72
4	back +window	Artsorb sheet	none	37	16	2	3.0	87
5	none	none	Marvelseal + Lineco tape	38	11	4	3.4	86
6	back +window	none	Marvelseal + Lineco tape	45	8.1	9	2.9	95
7	none	Artsorb sheet	Marvelseal + Lineco tape	48	3.5	83	1.7	100
8	back +window	Artsorb sheet	Marvelseal + Lineco tape	69	3.1	96	1.8	100
9	none	none	Marvelseal + J-Lar tape	46	12	2	3.6	80
10	back +window	none	Marvelseal + J-Lar tape	63	5.0	50	2.6	98
11	none	Artsorb sheet	Marvelseal + J-Lar tape	54	3.8	83	2.5	98
12	back +window	Artsorb sheet	Marvelseal + J-Lar tape	63	4.4	70	1.8	100
13	none	none	Marvelseal	39	15	1	4.0	69
14	back +window	none	Marvelseal	45	6.4	26	2.3	99
15	none	Artsorb sheet	Marvelseal	54	4.0	70	1.9	100
16	back +window	Artsorb sheet	Marvelseal	45	4.4	64	1.7	100
Improvement over the conventional frame								
Back +window mat				1.1x	27%	1.5x	23%	1.1x
Artsorb sheet				1.2x	45%	4x	41%	1.2x
Marvelseal				1.2x	63%	48x	47%	1.5x
Marvelseal + Lineco tape				1.3x	68%	62x	48%	1.6x
Marvelseal + J-Lar tape				1.5x	69%	47x	44%	1.6x

A four preliminary conclusions can be drawn from the graphs and metrics above:

- The conventional framing (matting and glazing) provides substantial protection. It is particularly effective at mitigating the daily %RH fluctuation, but much less at protecting from the seasonal fluctuations or maintaining the microclimate within the ideal %RH range.

- Frames that include a mat and window mat have a slight extra protection especially from seasonal fluctuation because of their extra buffering capacity. The presence of Artsorb, also a buffering material, has a similar but more significant impact.
- Encasing the package with a sheet of Marvelseal substantially increases the protection against seasonal and especially against daily fluctuation. It is more advantageous than adding Artsorb and less costly.
- Sealing the encased package with tape, either Lineco or J-Lar improves the microclimate conditions a bit further and will help mostly maintain the conditions within the 45-55%RH range. It is a labor intensive step however, for both application and removal, and may not be required if environmental conditions are not too extreme.

Knowledge of the conditions in which the object will be displayed is essential for determining the most cost effective and protective frame design and materials. When the object is displayed in a controlled environment with set points close to the recommended ones, traditional framing is sufficient. A sheet of Marvelseal should be included if the conditions are known to fluctuate significantly over short periods of time. Sealing the frame with tape, and adding Artsorb, on the other hand, will help maintain the conditions within the ideal %RH range in locations with more extreme conditions.

Acknowledgements: *The authors are grateful to H. Murata, K. VanWart, D. Bell and MoMA art handlers and framers for assistance during this project.*

Testing Liquid Barrier Layers for Medium Density Fiberboard (MDF) to Prevent Corrosive Emissions

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¹ Research completed as an Object Conservator at the British Museum

The suitability of a material for use in a museum display case is commonly determined using an accelerated corrosion test, or Oddy Test, to screen materials for the emission of harmful pollutant gasses. Wood products, such as medium density fiberboard (MDF), are commonly used for their pragmatic and cost effective qualities. However, wood products emit volatile organic compounds (VOCs)--such as acetic and formic acid, as well as formaldehyde--that cause significant deterioration of objects, and are therefore unable to pass an Oddy Test. If the use of wood products in display cases is unavoidable, they must be sealed with a surface barrier to limit the emission of VOCs into the environment.

Manufactured films, such as Marvelseal, have been proven to fully prevent corrosive emissions, but liquid coatings are often preferred for their ease of application. Some epoxies and powder coatings have proven to reduce VOC emissions, but are not the most efficient processes for museums without large production shops or budgets. Testing at the British Museum for an easily applied liquid coating concluded that Dacrylate Acrylic Glaze performed the best of those available. However, Dacrylate performed very poorly compared to the manufactured films, and therefore further testing was required to improve the method of application and sealing efficiency.

An Oddy Test was devised to analyze the number of coats of Dacrylate required to reduce VOC emissions combined with the best-case scenario for application and drying. After only seven days, all the tests showed at least the first signs of corrosion, and by the ninth day they were fully corroded. The test jar containing MDF sealed with Dacrylate and a layer of paint that remained intact along the compact manufactured surfaces but cracked along the cut edges. This crack indicated that the MDF had absorbed water and swelled to expose fresh and unsealed wood particles. Water accelerates the degradation of MDF, producing higher amounts of organic acids. Once fresh MDF is exposed to the test environment, the sealing efficiency of the Dacrylate can no longer be effectively analyzed.

In a typical Oddy Test, these results would be considered a failure and the material in question would not be used with museum objects. However, a typical test only analyzes the suitability of a single material, and not how a known suitable material is able to control a known problematic material. The results of the Dacrylate sealed MDF differed greatly from that of the Marvelseal wrapped MDF. Marvelseal passed the twenty-eight day cycle without causing corrosion of the lead coupons. This suggests that Oddy Testing using high heat and humidity is not an acceptable method for examining MDF sealed with liquid coatings.

Assessing the sealed MDF with realistic conditions, using ambient temperature tests or with other analytical methods, may enhance the comprehension of sealing properties, limiting the necessity to utilize Oddy Testing on this type of material altogether. Emissions tests have shown the ability of water-borne coatings to reduce formaldehyde emissions, but also increase acetic and formic acid emissions due to solvent evaporation. While these coatings failed the accelerated corrosion tests at 100% Relative Humidity, they performed better in the ambient test at 50% RH, suggesting that they may be suitable sealing materials for temporary use, but that their use in high humidity environments must be considered a risk.

Although this project could not determine a definitive application for a liquid coating, hopefully it will create the awareness needed to question the current preventive conservation practice for display cases. The failed Oddy Tests used

one of the better liquid sealing options and was able to turn a lead coupon into pure corrosion product in only seven days, demonstrating the issue of using MDF in conjunction with vulnerable museum objects. Perhaps this research will make the complications of MDF usage in the museum environment better known, understood, and appreciated.

Reevaluating the Oddy Test: An Examination of the Diversity in Protocols Used for Material Testing in The United States

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It has been over forty years since Andrew Oddy first published on the methods used for materials testing at the British Museum. In recent decades, multiple newer variants, alternatives, and technologies have also been developed for such testing. However, when evaluating the suitability of materials for use in storage and display environments, the museum community still relies in large part on what has come to be known as the “Oddy Test”. Institutions run these tests in-house, provide results to institutions unable to maintain their own testing programs, and request Oddy test results from manufacturers.

In 2014, the authors surveyed conservators at museums and institutions in the United States to learn more about the protocols they follow for in-house materials testing. Overall, 43 institutions responded to the initial survey. Of this group, 31 are conducting their own in-house Oddy tests. The tests being carried out in these 31 institutions represent 19 separate and distinct Oddy testing protocols. This is perhaps the direct result of the fact that no single method has ever been clearly defined as best practice.

Survey respondents were also asked questions regarding their satisfaction with their chosen testing method. Many expressed frustrations with their testing procedures and the subjectivity of evaluating results. Most still reported, however, that their method was successful in identifying materials not suitable for use in their institutions.

Variations among testing methods can create wide discrepancies in results, making it possible for the same material to pass one test and fail another. This makes it impossible to compare results generated at institutions using different protocols and therefore impossible for the field to collect and share meaningful data.

Results of the survey will be presented, and information gathered about the factors involved with making the sharing and standardization of data possible in the future will also be discussed.



Several online resources developed by the American Institute for Conservation (AIC) and the Foundation of the American Institute for Conservation (FAIC) contain useful information for conservators and museum professionals investigating, testing and using materials for exhibition and storage. Each of these sites is overseen by an individual or group actively developing and updating this content, and each site should be considered a work in progress. Collaboration is key to strengthening these resources for the entire preservation and museum community and each group is actively seeking editorial contributions. For more information on how to participate in the advancement of these e-resources please contact AIC's e-Editor Rachael Perkins Arenstein at rachael@amartconservation.com and additional contact information is available on each site.

Storage Techniques for Art, Science and History Collections - www.STASHc.com

In 2014 the FAIC, in collaboration with the Society for the Preservation of Natural History Collections (SPNHC) and with the support of the Kress Foundation, created STASH, a website designed to provide museum professionals with an online resource to consider and discuss solutions for storage and support of cultural property. The site features overviews of different types of supports or storage solutions with downloadable case studies containing step-by-step instructions on creating safe storage solutions. The resources section identifies products used in the articles by their material component, brand name, manufacturer and supplier. The STASH News blog is a platform for announcement and discussion of new initiatives, tools, materials and items of interest that relate to storage and rehousing of collections. To contribute to STASH please use the Contact Us form on the website.



Mountmakers Forum - www.conservation-wiki.com/wiki/Mountmaking

The Mountmakers Forum was created by a group of museum professionals from across the globe to exchange knowledge and ideas regarding all aspects of mountmaking. The group has collaborated with AIC to make the content from their biannual meetings freely available online on AIC's Wiki site. Abstracts, pdfs and videos on innovative mountmaking materials and techniques on their pages are available for download. Information on how to participate in the Forum's upcoming programming is available on the webpage.



Exhibition Standards & Guidelines - [http://www.conservation-wiki.com/wiki/Exhibition Standards %26 Guidelines](http://www.conservation-wiki.com/wiki/Exhibition_Standards_%26_Guidelines)

The goal of the Exhibition Standards & Guidelines is to ensure that exhibits are safe for collections on display. The Standards are intended to establish object-safe practices when exhibits are designed in-house and also to guide the procurement process when exhibits are to be developed by contractors. The Standards & Guidelines put exhibition material choices into context and is addressed to the full array of professionals who work with collecting institutions. It endeavors to demonstrate the importance of conservation efforts, providing not only the "hows" of conservation practices but also emphasizing the "whys." This material was written and developed by the late Toby Raphael, AIC Fellow, Conservation Advisor to the Board of the National Association for Museum Exhibitions and Felicity Devlin, Museum Consultant. The work was funded, in part, by a FAIC Samuel H. Kress Conservation Publication Fellowship. The first two sections on Exhibit Planning and Design are available online with placeholder text for the Fabrication and Installation sections (content is expected in early 2016).



Conservation Materials & Materials Testing - [http://www.conservation-wiki.com/wiki/Materials Testing](http://www.conservation-wiki.com/wiki/Materials_Testing)

The AIC wiki section on Materials testing, under the auspices of AIC's Research and Technical Studies (RATS) Specialty Group, aims to become a central collection point for recording protocols and results from Oddy and other materials tests. Individuals and institutions have long been reticent about sharing Oddy testing information because of the vagaries of the test and subjectivity of evaluation. The AIC wiki page was started based on feedback that numerous institutions were willing to share their data if the content was hosted on a neutral site. The collaborative and open nature of the AIC wiki makes this the ideal platform for sharing this information and allowing users to examine different institutional testing protocols and results for their own uses. The expanding Materials Database includes information on exhibition fabrics, case construction materials (including storage, packing, and mountmaking materials), adhesives and tapes, paints and sealants.

