International Conference On Metal Conservation

METAL 2010

Interim Meeting of the ICOM-CC Metal Working Group

Dear Colleagues,

Welcome to Charleston and the International Council of Museums Committee for Conservation Metal Working Group interim conference, Metal 2010.

This is the first time that this conference has ever been held in the United States and is hosted by Clemson University.

Metal 2010 presents an opportunity for professionals from across the world to convene and discuss current issues in metal conservation. The schedule is an outstanding program that includes both conservation practice and conservation science, with speakers from more than 15 different countries. Participants in this year's conference represent universities, national research laboratories, conservators in private practice and many renowned cultural institutions.

Attached is a CD-ROM that contains the conference proceedings. The final book will be available through www.lulu.com by the end of 2010, and will include the Question & Answers for each paper.

A special thanks is extended to the Program Committee members who provided their expertise to ensure that Metal 2010 will maintain the tradition of producing a peer-reviewed publication.

Thanks are also extended to the many individuals and companies that have made this conference possible. In particular, Warren Lasch generously contributed to a grant that enabled many international speakers to attend the conference. Warren's ongoing support is especially recognized. Robert Armantano of Total Energy is also greatly acknowledged for his conference assistance grant to also enable speakers to attend Metal 2010.

The conference offers many opportunities for us to learn from one another and we hope that you take full advantage of this outstanding week.

Thank you for attending Metal 2010, we look forward to seeing old friends and meeting new ones, and enjoying all that Charleston has to offer!

Paul Mardikian

Conference Program Chair

David Hallam

ICOM-CC Metal WG Coordinator

PHOTOGRAPH ON FRONT COVER: Detail from 'Bridge No. 2' from the series *Rust Never Sleeps*, John Moore, 1996

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Kit Menis

MEETING LOCATIONS

All presentations will take place at the Francis Marion Hotel in the Colonial Room. The Colonial Room is accessible from the Lobby of the hotel, via a short flight of stairs or elevator.

Poster presentations will also take place in the Colonial Room.

REGISTRATION

The registration desk for Metal 2010 is located in the Upper Lobby of the Francis Marion Hotel, accessible from the lobby. Registration desk hours are as follows:

Sunday, October 10
1:00 p.m. – 6:00 p.m.

Monday, October 11
7:30 a.m. – 5:00 p.m.

Tuesday, October 12 through
Thursday October 14
8:00 a.m. – 5:00 p.m.

Friday, October 15
8:00 a.m. – Noon

CONTENTS

SCHEDULE AT A GLANCE

MONDAY
OCTOBER 11

9:00 a.m. – 9:30 a.m.
Welcome and
Opening Remarks

9:30 a.m. – 12:30 p.m.
Session 1:
Treatment of
Archaeological Iron
Chair: Lyndsie Selwyn

10:30 a.m. – 11:00 a.m.
Morning Refreshment Break

12:30 p.m. – 2:00 p.m.
Lunch

2:00 p.m. – 5:00 p.m.
Session 2:
Conservation of Marine
Archaeological Objects
Chair: Paul Mardikian

3:00 p.m. – 3:30 p.m.
Afternoon Refreshment Break

6:00 p.m.
Buses depart from
Francis Marion Hotel
for Opening Reception

6:30 p.m. – 8:30 p.m.
Opening Reception

TUESDAY
OCTOBER 12

8:30 a.m. – 10:30 a.m.
Session 1:
Materials Characterization
and Identification
Chair: Andrew Lins

10:30 a.m. – 11:00 a.m.
Morning Refreshment Break

11:00 a.m. – 1:00 p.m.
Session 2:
Case Studies
Chair: Andrew Lins

12:30 p.m. – 1:30 p.m.
Lunch

1:30 p.m. – 5:30 p.m.
Session 2:
Coatings and
Corrosion Inhibition
Chair: David Thickett

3:00 p.m. – 3:30 p.m.
Afternoon Refreshment
Break

5:30 p.m
Poster Session,
Author in Attendance

WEDNESDAY
OCTOBER 13

8:30 a.m. – 11:30 a.m.
Session 1:
Corrosion and
Deterioration Studies
Chair: Alice Paterakis

9:30 a.m. – 10:00 a.m.
Morning Refreshment Break

11:30 p.m. – 1:00 p.m.
Lunch

1:00 p.m. – 3:30 p.m.
Session 2:
X-ray Fluorescence Ana
Chair: Tom Chase

3:30 p.m. – 4:00 p.m.
Afternoon Refreshment

4:00 p.m. – 6:00 p.m.
Session 3:
Technical Studies
Chair: Tom Chase

THURSDAY
OCTOBER 14

9:00 a.m. – 12:30 p.m.
Session 1:
Caring for Outdoor
Cultural Heritage
Chair: Shelley Sturman

10:00 a.m. – 10:30 a.m.
Morning Refreshment Break

12:30 p.m. – 2:00 p.m.
Lunch

2:00 p.m. – 5:30 p.m.
Session 2:
Engineering and 3D
Technology in Conservation
Chair: Ian MacLeod

3:30 p.m. – 4:00 p.m.
Afternoon Refreshment Break

6:00 p.m. – 9:00 p.m.
Conference Dinner

Photography Exhibition
"Rust Never Sleeps"
by John Moore

FRIDAY
OCTOBER 15

8:30 a.m. – 11:30 a.m.
Session 1:
Preventive Conservation
Chair: Emma Schmuecker

9:30 a.m. – 10:00 a.m.
Morning Refreshment Break

11:30 p.m. – 12:30 p.m.
Lunch

12:30 p.m. – 2:30 p.m.
Session 2:
Innovative Techniques
Chair: David Hallam

2:00 p.m. – 3:15 p.m.
Afternoon Refreshment Break
METAL 2013
Conference Selection

3:15 p.m.
Closing Remarks

4:30 p.m.
Buses depart from
Francis Marion Hotel
for Closing Reception

5:00 p.m. – 9:00 p.m.
Closing Reception

HIGHLIGHTS

Opening Reception & Tour

Monday, October 11 | 6:30 p.m. – 8:30 p.m.

CLEMSON UNIVERSITY'S WARREN LASCH CONSERVATION CENTER LABORATORY

Ticket required (for meeting attendees, your badge is your ticket)

Join us at the WARREN LASCH CONSERVATION CENTER LABORATORY home of the *H.L. Hunley* project. Tours of the submarine will be possible during the reception.

Complimentary food and beverages will be served.

One opening reception ticket is included with each full and October 11 registration. Additional tickets for guests of attendees may be purchased for $55 each in advance or at the registration desk.

Buses will depart the Francis Marion Hotel for the reception at 6:00 p.m. and will return to the hotel at approximately 9:00 p.m.

Poster Session

Tuesday, October 12 | 5:30 p.m. Authors In Attendance

Posters will be displayed throughout the entire week of the conference adding a visual and interactive component to the program. Posters are on display in the conference room.

Join poster authors at 5:30 p.m. on October 12 when authors will be present to discuss their work.

Conference Dinner

Thursday, October 14 | 6:00 p.m. – 9:00 p.m.

FRANCIS MARION HOTEL, COLONIAL ROOM

Ticket required (for meeting attendees, your badge is your ticket)

Join colleagues and new friends for the gala dinner of the conference in the elegant Carolina Ballroom at the Francis Marion Hotel. The Ballroom boasts grand views of Marion Square Charleston.

One conference dinner ticket is included with each full and October 14 registration. Additional tickets for guests of attendees may be purchased for $ 55 each in advance or at the registration desk. The ticket includes all food and beverages.

HIGHLIGHTS *(continued)*

John Moore Photography Exhibition 'Rust Never Sleeps'

Thursday, October 14 | 6:00 p.m. – 9:00 p.m.

FRANCIS MARION HOTEL, COLONIAL ROOM

John Moore is a structural engineer by profession, but photography has been his serious avocation and passion for more than 30 years. Moore's work ranges from approximate documentation of the scene to abstractions, some of which are represented here in the "Rust Never Sleeps" series. The original group of "Rust Never Sleeps" was exhibited at The City Gallery of Charleston in 1997, and has since become an ongoing subject of work.

Moore's photographs have appeared in many local and regional juried exhibits, and he has had several solo shows at local galleries and institutions.

"I was on a camping trip in the mountains photographing with a friend, and we stopped by a bridge over a stream. I was not able to see anything to photograph about the stream, but the bridge was of interest. The closer I looked the more interesting it became. It was a steel bridge, with large gusset plates and varying patterns of rivets on the plates. Many of the surfaces had rusted and had been marked with graffiti. I had recently seen an extraordinary local exhibit of abstract paintings and had become interested in Richard Diebenkorn's work. These images undoubtedly were in the back of my mind when I started photographing parts of the bridge. I found that small scenes can become large worlds when you are looking through the view finder of a camera."

USS Yorktown Closing Reception and Tour

Friday, October 15 | 5:00 p.m. – 9:00 p.m.

PATRIOT'S POINT NAVAL AND MARITIME MUSEUM

Ticket required (for meeting attendees, your badge is your ticket)

Join us at the USS Yorktown for our closing reception and tour of this famous WWII battleship, which is permanently moored at Patriot's Point. The Yorktown has one of the largest collections of war planes used during wars and conflicts spanning from WWII to Desert Storm, and are featured aboard the Yorktown's 40,000 square foot hangar bay and atop the 888 foot flight deck. The reception will be an exhilarating farewell to the conference.

Complimentary food and beverages will be served.

One opening reception ticket is included with each full and October 15 registration. Additional tickets for guests of attendees may be purchased for $ 55 each in advance or at the registration desk.

Buses will depart the Francis Marion Hotel for the reception at 4:30 p.m. and will return to the hotel at approximately 9:30 p.m.

PAPER AND POSTER INDEX

Monday, October 11

Session 1: Treatment of Archaeological Iron

Session 2: Conservation of Marine Archaeological Objects

Tuesday, October 12

Session 1: Materials Characterization and Identification

Session 2: Case Studies

Session 3: Coatings and Corrosion Inhibition

Wednesday, October 13

Session 1: Corrosion and Deterioration Studies

Session 2: X-ray Fluorescence Analysis

Session 3: Technical Studies

Thursday, October 14

Session 1: Caring for Outdoor Cultural Heritage

Session 2: Engineering and 3D Technology in Conservation

Friday, October 15

Session 1: Preventive Conservation

PAPER AND POSTER INDEX *(continued)*

Session 2: Innovative Techniques

Poster Session

Monday, October 11

SESSION 1

Treatment of Archaeological Iron

RESIDUES OF ALKALINE SULPHITE TREATMENT AND THEIR EFFECTS ON THE CORROSION OF ARCHAEOLOGICAL IRON OBJECTS

Melanie Rimmer, David Watkinson

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Abstract

The formation of chemical residues on archaeological iron following its treatment in aqueous alkaline sulphite (NaOH/Na_2SO_3) is simulated by evaporating selected ion mixtures to dryness. The residues are identified by X-ray diffraction (XRD) and their influence on iron corrosion is investigated by mixing them with iron powder and dynamically recording the weight change of these powder mixtures at fixed temperature and relative humidity (RH) in a climatic chamber. Ferrous chloride was dissolved in Na_2SO_4 to simulate Fe^{2+}/Cl^- contaminated Na_2SO_4 solution. This formed $FeSO_4{\cdot}4H_2O$/$FeSO_4{\cdot}7H_2O$/NaCl upon evaporation. Evaporating a $FeCl_2$/NaOH/Na_2SO_3 solution produced either Na_2SO_4/NaCl/γ-FeOOH or $Na_6(CO_3)(SO_4)_2$/Na_2SO_4/NaCl/γFeOOH mixtures according to ion concentration in the initial solution. Iron powder and various residues were mixed and exposed at 75% RH and 20°C; Na_2SO_4/Fe did not corrode iron; $FeSO_4{\cdot}7H_2O$/Fe produced minimal corrosion of iron; during the hydration phase of $FeSO_4{\cdot}4H_2O$ to $FeSO_4{\cdot}7H_2O$ iron corroded; a NaCl/$FeSO_4{\cdot}7H_2O$/$FeSO_4{\cdot}4H_2O$ mixture corroded iron rapidly. Overall, at 75% RH, soluble chloride residues offer a more immediate and significant corrosion risk to iron than Na_2SO_4, $FeSO_4{\cdot}7H_2O$ and $FeSO_4{\cdot}4H_2O$.

CHLORIDE CALAMITIES: ASSESSMENT OF RESIDUAL CHLORIDE ANALYSIS TO COMPARE IRON DESALINATION METHODS

Britta Schmutzler, Gerhard Eggert

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Abstract

An analytical protocol was designed for the analysis of chloride ions in treatment solutions as well as in solids after desalination to avoid chloride loss during the digestion process. The alkaline sulphite method originally suggested by North and Pearson (North and Pearson 1975) was tested with varying concentrations of sodium hydroxide and sulphite under nitrogen. The excellent desalination efficiency of sodium hydroxide solutions under de-aerated conditions reported by Al Zahrani (1999) could not be confirmed, but this technique seems to be more efficient than alkaline sulphite. Results suggest the use of oxygen-free sodium hydroxide as a desalination technique should be more suitable for mass treatment of terrestrial iron.

KEEP COOL? DEEP-FREEZE STORAGE OF ARCHAEOLOGICAL IRON

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Abstract

Post excavation corrosion of archaeological iron can cause severe damage to iron artifacts, particularly due to the formation of akaganéite. In this study, powder test samples of a 1:1 mixture of iron and iron(II) chloride tetrahydrate were stored at -23 °C (± 3 °C) and at room temperature, 21 °C (± 3 °C), to test whether storage at low temperature could inhibit corrosion. The oxidation of a synthetic iron and iron(II) chloride tetrahydrate mixture to form akaganéite, β-FeO(OH), mimics the reactions that take place during post excavation corrosion of archaeological iron. The formation of akaganéite was observed by Fourier transform infrared (FTIR) spectroscopy on the test samples over a period of two and a half years. Compared to the test samples that were stored at room temperature, the conversion of the initial compounds appears to be delayed at -23 °C (± 3 °C), but slow conversion is clearly visible. This study demonstrates that storage of archaeological iron artifacts at -23 °C (± 3 °C) does not appear to completely inhibit post excavation corrosion.

THE USE OF SUBCRITICAL FLUIDS FOR THE STABILIZATION OF CONCRETED IRON ARTIFACTS

Nestor González-Pereyra[1], Typhaine Brocard[2], Stephanie A. Cretté[1], Philippe de Viviés[3], Michael J. Drews[1], Paul Mardikian[1]

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Abstract

The objectives of this study were to determine whether marine or terrestrial archaeological iron artifacts can be effectively stabilized using a subcritical fluid prior to cleaning, and to evaluate the effects of this technique on the artifact's concretion or mineralized layers. The artifacts treated were two wrought iron nut and bolt assemblies from the American Civil War-era submarine, H.L. Hunley (1864) and four Medieval iron nails from a terrestrial site at Formigine castle in Modena, Italy. Four of the artifacts were stabilized using a subcritical, 0.5 wt.% NaOH solution at 180°C and a pressure of 50 bar. No stabilization required more than 10 days. The effect of the subcritical stabilization on the artifacts was evaluated by visual and instrumental assessment, including digital radiography, electron microscopy and micro Raman spectroscopy. Based on the assessments pre- and post-treatment, it was concluded that the artifacts had been stabilized and that, when present, the concretion or the mineralized layers remained intact. Results from this study suggest that it is possible to stabilize an artifact prior to deconcretion or cleaning using subcritical treatment.

Monday, October 11

SESSION 2

Conservation of Marine Archaeological Objects

CORROSION AND CONSERVATION MANAGEMENT OF THE HMAS AE2 SUBMARINE (1915) IN THE SEA OF MARMARA, TURKEY

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Abstract

The wrecksite of the Australian World War I submarine HMAS AE2 in the Sea of Marmara, Turkey, had a salinity of 26‰ (parts per thousand) for the first 13 metres, which increased to 41.3‰ at 21 metres. At this point, the salinity remained constant to the seabed at 72 metres where the dissolved oxygen was 3.1 parts per million (ppm). The vessel is protected by a very dense anaerobic concretion and lies half buried in a silt mound. Cross-sections of concretion samples revealed the original surface, associated paint films and a series of burial-exposure episodes that reflected periodic changes in the silt levels associated with major storm events. Core samples of sediment have established the impact of the vessel on the site. Corrosion simulation experiments have established the direct linkage between chloride levels underneath the concretion layer and the pH of the entrapped solution. This data has lead to the development of in-situ conservation models that will be applied in 2012.

APPROACHES TO THE PRESERVATION OF SUNKEN HISTORIC AIRCRAFT

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Abstract

Despite more than 30 years experimentation and research, comprehensive and widely accepted treatment and management plans for sunken aircraft have yet to be standardized. This is primarily due to the complexities of corroding aluminum alloys and duplex metals, coupled with the fundamental philosophy of many aviation museums and enthusiasts who favor completely rebuilt structures to the preservation of original, historic materials. This paper outlines the preservation challenges, ethical concerns, and research potential of recovering sunken aircraft, raises questions regarding the future of this particular discipline within the field of preservation, and offers possible solutions to some of the management and preservation problems.

DISASSEMBLY OF USS MONITOR'S COMPLEX MECHANICAL COMPONENTS

David Krop, Eric Nordgren

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Abstract

National Oceanic and Atmospheric Administration (NOAA) archaeologists have recovered numerous complex mechanical components from the wreck of the USS Monitor*, including the ship's vibrating side-lever steam engine, condenser, and auxiliary machinery. These mechanical items are being conserved at The Mariners' Museum (TMM) in Newport News, Va. After thorough consideration, TMM conservators have opted to disassemble complex mechanical components from the* Monitor *to allow for more thorough cleaning and effective removal of chloride salts. Disassembly also allows for separation of iron, copper alloys and organic materials for material-specific treatment. Experience working with* Monitor *artifacts has shown that disassembly requires careful planning and is made more difficult by the corrosion processes that have occurred during 140 years in seawater. The challenges and limits of disassembling complex artifacts made of deteriorated metals and organic materials will be discussed with examples.*

A CASE STUDY OF IN SITU MONITORING ON AN ANCHOR FROM THE *QUEEN ANNE'S REVENGE* (1718)

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Abstract

North Carolina shipwreck 31CR314 is believed to be Queen Anne's Revenge, *the pirate Blackbeard's flagship that ran aground in Beaufort Inlet in 1718. Large iron artifacts, such as anchors and cannon, provide an excellent opportunity for corrosion potential studies. A preliminary in situ study began on Anchor 3 in the fall of 2008 to obtain an indication of the inherent stability. Research has suggested that attaching a sacrificial anode to improve the corrosion potential and begin conservation treatment by removing chloride ions can protect artifacts in situ. This study aims to provide an indication of how a changing environment may further affect preservation of artifacts in situ and provide the basis for continuing conservation in subsequent years. This paper will outline the processes, data obtained and conclusions drawn from this project.*

Tuesday, October 12

SESSION 1

Materials Characterization and Identification

HOT-TINNING OF LOW TIN BRONZES

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Abstract

Identification of hot-tinning on corroded bronze is often a challenging task due to the various mechanisms by which shiny or grey surface finishes can be formed. The nature of intermetallic compounds formed during hot-tinning changes during use because of solid state diffusion of copper, or due to application of heat at temperatures above the melting point of tin. To identify their presence, a clear understanding of tinning microstructures must be combined with knowledge of their forms relative to corrosion structures developed from general corrosion of the underlying bronze. This study reports on the examination and identification of the intermetallic phases associated with tinning. Reported experimental work is designed to examine aspects of the formation and detection of intermetallic compounds that can be used to discuss the challenges associated with definitive identification of tinning on low-tin bronzes.

CONSERVATION OF PIGEON CAMERAS: A COLLABORATIVE APPROACH BETWEEN CONSERVATORS AND SCIENTISTS

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Abstract

This paper presents findings from the examination and technical analysis of three small pigeon cameras from the 1930's belonging to the Swiss Camera Museum in Vevey, Switzerland. The analysis was undertaken in 2006 in preparation for a new exhibition 'des pigeons photographes' at the Museum. The small cameras were designed for attachment to the underbelly of carrier pigeons to obtain aerial photographs for military use. The components of the camera are very small and consist of different metal alloys, paint, textile and glass. Some of the components were covered by a thick later of white corrosion products. Compositional information was obtained using energy dispersive X-ray spectroscopy (EDS). The corrosion products were analyzed with micro X-ray fluorescence (XRF), micro Raman spectroscopy and micro Fourier transformation infrared (FTIR) spectroscopy. Results indicate that the alloys used in the manufacture of the camera are aluminium/magnesium, magnesium/zinc and copper/zinc alloys. The white corrosion products were found to be a mixture of magnesium acetate and magnesium carbonate hydroxide hydrate. Results also establish the presence of cellulose acetate, the likely cause of the corrosion.

TECHNICAL ANALYSIS OF MUNTZ METAL SHEATHING FROM THE AMERICAN CLIPPER SHIP *SNOW SQUALL* (1851-1864)

Molly O'Guinness Carlson[1], Nathan R. Lipfert[2], Erik A. R. Ronnberg[3], David A. Scott[4]

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Abstract

Sheathing materials from the American clipper ship Snow Squall *(1851-1864) were examined with polarized light microscopy (PLM), Fourier Transform Infra-Red (FTIR) Spectroscopy, x-ray fluorescence (XRF), scanning electron microscopy (SEM) electron probe microanalysis (EPMA) and metallographic techniques. Results indicate the padding beneath the sheathing is jute, with evidence of shellac and tar. Sheathing without a Muntz stamp is an alpha phase brass analyzed as 67.9% copper and 30.1% zinc. Sheathing with a 'Muntz's 24 Patent' stamp is an alpha phase brass on the verge of beta phase formation, analyzed as 64.5% copper, 37.4% zinc, 0.1% lead and a trace of iron. Patent stamped sheathing analyzed from the barks Petrel (1847-1853) and* Eglinton *(1848-1852) are contrasted with Snow* Squall's *analyses and together suggest a change in Muntz alloy composition occurred between 1847 and 1863. Muntz stamp designs and Muntz family patents are also briefly described.*

Tuesday, October 12

SESSION 2

Case Studies

THE EXAMINATION AND CONSERVATION OF A 17TH CENTURY INDIAN HORSE ARMOUR

Emma Schmuecker[1], Rose Lees[2], Thom Richardson[3]

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Abstract

In 2006, an opportunity arose for conservators and curators from the Royal Armouries to conserve and study important horse armour from India. The armour is one of the earliest acquisitions from the Indian subcontinent in the museum and is usually on display. The armour is formed of iron and copper alloy plates joined by links of mail, and retains a lining of quilted textile. Study and treatment revealed unknown details of the construction and restoration of the object, including an unusual type of mail link not widely published. Conservation treatments included cleaning using Melinex barriers that allowed both textile and metal to be cleaned without separating the lining from the armour, the selective removal of previous restorations to balance aesthetics, non-destructive reinforcement of weight-bearing plates, and localised humidification to relax and reshape the lining.

EXAMINATION AND TREATMENT OF THE CEREMONIAL WAGON OF STRETTWEG

Ulrike Lehnert

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Abstract

In 1851, a small copper alloy wagon was found in an early Iron Age grave near the village of Strettweg, Austria. Since its discovery, it has undergone several restorations, some of which have resulted in damage to the wagon. In 2006, the Universalmuseum Joanneum in Graz, Austria, approached conservators at the Römisch-Germanisches Zentralmuseum (RGZM) in Mainz, Germany, to restore the wagon for a new exhibition on prehistory. This provided the first opportunity to fully examine the wagon's condition and observe technical details, particularly regarding casting and construction methods. Technical examination included the minimally invasive techniques of X-radiography (X-ray) and X-ray fluorescence (XRF). The wagon was dismantled, cleaned and reassembled using reversible methods. Carbon fiber was used for in-fills on the wagon and in areas that required additional physical support.

DRY ICE BLASTING FOR THE CONSERVATION CLEANING OF METALS

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Abstract

This research was carried out to assess the feasibility of dry ice blasting as a replacement for solvent cleaning for the removal of organic layers from metal cultural heritage objects. The effects of dry ice blasting on test samples of aluminium, bronze and weathering steel were studied along with its effectiveness at removing organic layers from four objects. Metal surfaces were studied in detail before and after cleaning using light microscopy, scanning electron microscopy (SEM), and X-ray diffraction (XRD). It was possible to remove wax layers from most of the metal samples. The removal of spray paint from aluminium was very successful, however, its removal from weathering steel proved very difficult. The gradual removal of patina/corrosion from weathering steel and bronze was possible without damaging the substrate. Results indicate that dry ice blasting is a good alternative to other air abrasive methods, such as sandblasting or walnut shell blasting.

Tuesday, October 12

SESSION 3

Coatings and Corrosion Inhibition

AN INVESTIGATION OF GLYCOL BASED CORROSION INHIBITORS IN MUSEUM COLLECTION VEHICLE BRAKING SYSTEMS

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Abstract

An investigation into a variety of commercial glycol-based inhibited brake fluids was conducted to assess their suitability for use in maintenance regimens for museum collection vehicles. Testing of fluids incorporated weight loss, accelerated weight loss and potentiodynamic electrochemical analytical techniques. All of the glycol-based fluids tested performed significantly better than the uninhibited control fluid. A number of the U.S. Department of Transport (DOT), DOT 3 classified fluids generally performed well inhibiting corrosion on steel, aluminium alloy and brass with addition of 0-5 wt.% water and one DOT 4 fluid performed exceptionally well. The DOT 4 fluid has been selected in consultation with our engineers for use in National Museum of Australia collection vehicles. Addition of dodecanedioic acid to the control fluid was shown to increase performance and reduce corrosion rate two orders of magnitude. Further testing in glycol based brake fluids is recommended to determine efficacy in scheduled maintenance programs. Overall we can conclude that the museum's current regime of changing fluid at intervals of approximately two years will provide sufficient protection of all the systems surfaces and could be extended to between three and four years.

DEVELOPMENT OF NEW ENVIRONMENTALLY SAFE PROTECTION SYSTEMS FOR THE CONSERVATION OF IRON ARTEFACTS

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Abstract

In the framework of safeguarding iron artefacts belonging to museum collections, the anti-corrosion performances of two new non-toxic corrosion inhibitors, based on carboxylic acids extracted from vegetable oil, were evaluated. Electrochemical measurements, accelerated and natural ageing tests have demonstrated the efficiency of these inhibitors as temporary treatments. Surface analysis experiments undertaken with field emission gun scanning electron microscopy (FEG-SEM) and Raman spectroscopy, have revealed that their anti-corrosion properties are correlated to the precipitation of an iron carboxylate protective layer at the metal surface. Evaluation of their potential application for preservation of cultural heritage is addressed.

BETTER THAN PARALOID B-72? TESTING POLIGEN® WAXES AS COATINGS FOR METAL OBJECTS

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Abstract

This paper presents results from a comparative test of six products for coating metal objects. Poligen® ES 91009, Poligen® ES 91012, and Poligen® ES 91018 were tested and compared to Paraloid® B-72, Paraloid® B-44 and Cosmoloid® H80. Tests were undertaken on copper alloy and ferrous coupons, and ferrous nails, which were coated by brushing, immersion or impregnation. The coupons and objects were subjected to natural and accelerated aging under different climatic conditions (humidity and polluted atmospheres) and within museum galleries. Corrosion monitoring, as well as computer-assisted optical inspection techniques, were used to evaluate coating qualities. Results to date indicate that Poligen® ES 91009, Poligen® ES 91012, Paraloid® B-72 and Paraloid® B-44 offer comparable surface protection when applied to different ferrous metals, whereas Poligen® ES 91018 and Cosmoloid® H80 are inferior. On copper alloys, Paraloid® B-72, Paraloid® B-44 and Cosmoloid® H80 show better results than Poligen® ES 91018.

THE CORROSIVE INFLUENCE OF ACETIC ACID EMISSIONS ON BRONZE AND THE EFFICACY OF TWO PROTECTIVE COATINGS

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Abstract

Acetate corrosion has been found predominantly on archaeological copper alloys that have been commonly stored in wooden cabinets. The purpose of this study is to assess the protective qualities of two coatings on two copper alloys exposed to the corrosive action of acetic acid vapor by simulating storage environments under accelerated conditions. The test coupons consisted of a copper tin alloy (ASTM B584) and a leaded copper tin alloy (ASTM B505). Two protective coatings were tested: Incralac® (acrylic copolymer with benzotriazole) and Poligen® ES 91009 (ethylene copolymer emulsion). The test coupons were exposed to acetic acid vapor of 4 ppm concentration in a relative humidity of 86% at 30ºC for eight weeks. The efficiency of the protective coatings was assessed according to ASTM D1654-05, Standard Method of Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments.

THE APPLICATION OF NON-TOXIC CORROSION INHIBITORS FOR THE TEMPORARY PROTECTION OF IRON AND COPPER ALLOY IN UNCONTROLLED ENVIRONMENTS

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Abstract

Two non-toxic corrosion inhibitors in a solution elaborated from a carboxylic acid were tested for the temporary protection of iron and copper alloy objects in the collections of the Historical Swiss Army Material Foundation (HSAM Foundation). These objects are stored in an uncontrolled environmental in storage facilities in or near Thun and Burgdorf, Switzerland. Application procedures were optimized during testing of the inhibitors on two groups of metal coupons and objects from the HSAM collection. The goal of the study is to field-test the efficiency of the carboxylate-based corrosion inhibitors over time while ensuring that the treatment is reversible. To achieve this, optical microscopy and X-ray microdiffraction (μXRD) were used. This study, named the POINT (Protection temporaire d'Objets métalliques base fer et cuivre à l'aide d'Inhibiteurs de corrosion Non-Toxiques) research project is ongoing at the time of writing and should be concluded by the end of 2010.

ON THE USE OF ALCOHOLIC CARBOXYLIC ACID SOLUTIONS FOR THE DEPOSITION OF PROTECTIVE COATINGS ON COPPER

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Abstract

This paper describes the use of ethanolic solutions for the deposition of carboxylate coatings on copper, with the objective of developing an environmentally friendly, reversible and retreatable coating for archaeological objects. The coatings were characterized with optical and electron microscopy and electrochemical tests were performed to compare the corrosion currents before and after the application of the coating on standard copper coupons. Preliminary results suggest that treatment of copper with carboxylic acid solutions in ethanol with more than 10 carbon atoms, and pH 7–7.5, improves the corrosion resistance of copper. Nevertheless, the use of ethanolic solutions of carboxylic acids is not suitable for use on cultural heritage material because of the irreproducibility of the results and the blue color of the copper carboxylate.

Wednesday, October 13

SESSION 1

Corrosion and Deterioration Studies

CORROSION EVALUATION OF GHIBERTI'S "PORTA DEL PARADISO" IN THREE DISPLAY ENVIRONMENTS

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Abstract

The 'Porta del Paradiso' by Lorenzo Ghiberti, also known as the 'Gates of Paradise', will soon be unveiled to the public after undergoing lengthy conservation. This project is at the stage where it is necessary to define environmental criteria for the long-term display of the doors. In this paper, three possible methodologies for display of the doors are considered: a showcase purged with nitrogen; a showcase with low, controlled relative humidity; an open showcase with a controlled microclimate. Galvanic sensors were used inside the cases to continuously monitor the macrocouple current of the doors and establish which case provided the most stable environment for display. Results to date indicate that the showcase with low, controlled humidity may offer the best solution for long-term display of the doors.

PREDICTING THE CORROSION BEHAVIOUR OF OUTDOOR BRONZES: ASSESSMENT OF ARTIFICIALLY EXPOSED AND REAL OUTDOOR SAMPLES

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Abstract

This paper examines the effect of acid rain on sheltered and unsheltered areas of the patina of an quaternary bronze sculpture of King Louis XIV located in Versailles, France, as well as on artificially corroded G85 bronze coupons. The corrosion behaviour of the coupons was examined through wet-dry tests to simulate the stagnant and leaching rainfall conditions found on the sculpture. The results show that in sheltered conditions, the patina is a multi-layered system with an inner tin-enriched layer covered by copper and lead compounds. In runoff conditions, a tin-rich patina behaves as a thin porous layer allowing significant dissolution of the other alloying elements of the bronze. Therefore, properly aged surfaces, reflecting the complexity of real patinas, are needed for adequately testing corrosion inhibitors.

THE DELHI IRON PILLAR: A STUDY OF THE CORROSION FORMED IN AREAS OF SURFACE DEFORMATION

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Abstract

The Delhi iron pillar has long been considered a corrosion resistant structure. Recently, a fast growing deterioration in the form of yellow colored corrosion has been observed, especially in an area on the surface that suffered impact from a cannon ball in the 18th century. This type of corrosion is causing accelerated corrosion of the structure. Close observation of the pillar surface shows that large areas below the impact site are developing iron oxides of different colors on the surface. This paper discusses the possible causes of this deterioration and suggests a plausible scenario to explain this phenomenon. Based on historical information concerning the development of dents in the surface of the pillar, a laboratory-simulated dent was formed on a piece of iron with similar composition to that of the pillar. Electrochemical impedance spectroscopy (EIS), and cyclic polarization were performed on the sample. The results corroborate our proposed mechanism for the deterioration of the pillar. It is concluded that the dented area is subject to tensile stress and is simultaneously exposed to a corrosive environment, and is therefore corroding preferentially to the rest of the pillar.

THE EFFECTS OF FINGERPRINTS ON SILVER

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Abstract

Sweat deposited by human fingertips can corrode many polished metal surfaces. Sweat consists of salts of light metals, particularly chlorides, traces of heavy metals, and organic compounds, such as fatty acids and urea, in solution in water. The combination of chlorides and fatty acids are the source of the corrosion. This paper describes the monitoring and characterisation of fingerprints on fine and sterling silver using a combination of microscopies and microanalytical techniques. Particularly useful were optical metallography, high-resolution scanning electron microscopy with energy dispersive X-ray spectrometry and 3D visualisation, and compositional mapping using monomer ion beams and time-of-flight mass spectrometry. These techniques have charted the evolution of the fingerprints and have conclusively demonstrated the damage caused.

Wednesday, October 13

SESSION 2

X-ray Fluorescence Analysis

AN EVALUATION OF INTER-LABORATORY REPRODUCIBILITY FOR QUANTITATIVE XRF OF HISTORIC COPPER ALLOYS

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Abstract

This paper reports the results of a study conducted to evaluate the current state of inter-laboratory reproducibility when conducting quantitative XRF analysis of historic copper alloys. Fourteen institutions, primarily from the museum community, participated in the study, using a total of 19 X-ray fluorescence instruments. The design of the study was based largely on ASTM standard E1601, Standard Practice for Conducting an Interlaboratory Study to Evaluate the Performance of an Analytical Method. *In addition to addressing overall inter-laboratory reproducibility, we also attempt to evaluate the accuracy of individual laboratories. By determining correlations between accurate results and experimental methods and procedures, we are able to propose recommendations regarding best practice and ways in which reproducibility might be improved.*

THE APPLICATION OF ALLOY ANALYSIS TO QUESTIONS OF ATTRIBUTION: GIOVANNI FRANCESCO SUSINI AND THE WORKSHOP OF GIAMBOLOGNA

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Abstract

This study considers the application of alloy analysis using X-ray fluorescence (XRF) spectroscopy to the attribution of small 'bronzes' by the 17th century Florentine artist Giovanni Francesco Susini. Documented works by this artist were analyzed and compared to reference works by the closely related artists Giovanni Bologna and Antonio Susini. Analyses were primarily performed on a handheld portable Bruker Tracer III-V XRF spectrometer for which a custom calibration has been developed for accurate quantification of historic copper alloys. Prior analyses performed on a laboratory-based Kevex 0750A XRF on a number of relevant objects are also considered. Quantified results from the two instruments are compared and integrated. Examination of the combined data reveals that certain alloys can be associated with production by Gianfrancesco, providing an additional means of determining attribution.

BRINGING CONTEXT TO THE SMITHSONIAN COLLECTIONS OF PRE-COLUMBIAN GOLD FROM PANAMA THROUGH TECHNICAL EXAMINATION AND ANALYSIS

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Abstract

The study of pre-Columbian gold in Panama has been slow to progress due to the relative scarcity of well-contextualized materials. While the original contexts of many museum objects have been lost, the Smithsonian collections of Panamanian gold were re-evaluated for their potential to answer key questions about gold working in the region. Over 300 objects underwent technical examination and calibrated X-ray fluorescence (XRF) analysis to provide information on fabrication techniques and composition. The results have already begun to contribute to our understanding of gold working in the Isthmian region.

THE EFFECT OF SURFACE CHANGES IN HEAT TREATED BRONZE SAMPLES ANALYZED BY X-RAY FLUORESCENCE SPECTROMETRY

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Abstract

X-ray fluorescence spectrometry (XRF) is often used to determine the composition of bronze sculpture. The limitations of XRF are well known: patinas, platings or other surface treatments can potentially interfere with the accuracy of results. However, the influence that previous restorations involving the use of heat may have on surface analysis has not been studied. In this study, XRF was used to examine the effect of heat treatment on 37 copper alloy samples of varying composition, following a simulated restoration treatment with temperatures above 680°C. Cross sections were studied by reflective microscopy and SEM-EDS. Results indicate that restoration treatment using heat causes a difference in the surface composition of many alloys. In particular, lead-containing alloys are highly influenced by heat treatment; both zinc and tin-containing alloys change to a lesser extent, and the use of acid pickling also plays an important role.

Wednesday, October 13

SESSION 3

Technical Studies

BLISTERS IN FIRE GILDINGS ON SILVER: AN INVESTIGATION INTO BLISTER FORMATION AND THE EFFECT OF CONSERVATION TREATMENTS

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Abstract

Blisters in the gilding layer were noted on a number of fire-gilt objects at the Rijksmuseum, Amsterdam, particularly on objects that had been subjected in the past to restoration treatments involving heat. In many cases, blistering was accompanied by delamination and losses within the gilding layer. Research was undertaken to examine the mechanism of blistering and to determine the effect of current conservation treatments on a blistered gilding layer. Fire-gilt and partially burnished sample coupons were heated to simulate soldering. It was found that blistering only occurred in burnished areas. SEM-EDS analysis showed that mercury was present in these areas, whereas in the unburnished areas it had evaporated. In addition, electroplated samples treated the same way did not blister. This suggests that mercury plays an active role in blister formation. Simulated conservation treatments show that the use of a steam cleaner, ultrasonic cleaner, silver dip and polishing with precipitated calcium carbonate can all damage blistered fire-gilt surfaces to a certain extent, so it is important to be aware of the presence of blisters before choosing a treatment.

ORGANIC COATINGS FOUND ON TIBETAN BUDDHIST GILT COPPER ALLOY STATUARY AT THE AMERICAN MUSEUM OF NATURAL HISTORY

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Abstract

An investigation was undertaken to characterize surface coatings, residues and accretions found on Tibetan Buddhist gilt copper alloy figures in the collection of the American Museum of Natural History. The purpose of the study was to guide conservation treatment. Pinaceae (pine family) resin, Acacia catechu extract and tung oil, sometimes with urushi, are among the materials found in the coatings, characterized by spectroscopic and chromatographic techniques. Fat and oil residues were also present on some surfaces. Identification of the materials in the coatings was confirmed by comparison with analysis of available reference standards. These findings will inform conservation treatments, provide a basis for future research and comparison, and supplement art historical research.

IMITATION-BRONZE PAINTS ON AMERICAN ZINC SCULPTURE

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Abstract

A study of imitation-bronze paints on American zinc sculpture reviews historical information on bronzing, presents analytical results for original paints sampled from zinc artifacts, and surveys outdoor statues repainted recently to imitate bronze. Guidance is provided for conservators who seek to apply historically appropriate replacement coatings.

Thursday, October 14

SESSION 1

Caring for Outdoor Cultural Heritage

REGILDING THE GOLDEN GODDESS: THE CHALLENGE OF CONSERVING A MONUMENTAL BRONZE STATUE 20 STORIES OFF THE GROUND IN MADISON, WISCONSIN

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Abstract

Conservation of outdoor monumental statuary placed in difficult locations presents unique challenges to examination and treatment. Thorough examination should precede treatment, but this is not always possible; sometimes both must operate concurrently. This was the case with the conservation and regilding of a monumental bronze statue by Daniel Chester French (1850-1931) named 'Wisconsin.' Installed in 1914, the 5.4 meter figure is perched 20 stories (over 100 meters) above the ground atop the dome of the Wisconsin State Capitol. This paper describes the many challenges faced when conserving this state icon in 1990 and 2005, including studying its condition remotely by telescope, scaffolding the site, conducting chemical analyses, stripping and repairing the surface, and gilding with 18,000 sheets of gold leaf. Also included are costs, conservation history of prior gildings in 1932 and 1957, material research, coating systems, gold leafing techniques and the impact of peregrine falcons that nested near the statue and damaged the gold.

SURFACE PREPARATION AND COATING APPLICATION PRACTICES FOR THE CONSERVATION OF LARGE-SCALE METAL ARTIFACTS

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Abstract

The protective coating of large-scale metal artifacts (LSMA) presents challenges, not least of which is scaling treatment to the sheer size of these objects. The conservator must develop and implement a solution that is thorough enough to achieve the goals of the project, yet practical enough to be applied by non-conservation professionals. Development of this regimen requires a delicate balance between the micro issues of surface preparation and coatings technology — which focus on surface profile, preparation, durability and reversibility — and macro issues relating to sustainability, safety and health, environmental controls, and economic necessities. The coatings industry produces a vast amount of research and technical articles annually on the subject of premature coatings failure. The National Association of Corrosion Engineers (NACE) and the Society for Protective Coatings (SSPC) have developed stringent preparation and application guidelines to combat this problem. Innovations in test equipment and techniques used in coatings inspection and monitoring provide more accurate information about whether a coating is correctly applied and performing as expected. Conservators have successfully applied these guidelines to their otherwise unconventional approach to treatments. This paper illustrates how to identify coating failures and test for their root causes. It also discusses how to choose an appropriate coating system, proper surface preparation prior to coating, and using industry tools and techniques to correctly monitor coating application and performance.

TRADITIONAL ARCHITECTURAL IRONWORK: SCIENTIFIC APPROACHES TO DETERMINING BEST CONSERVATION PRACTICE AND THE BUTE CANOPY CASE STUDY

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Abstract

This paper outlines recent scientific research conducted by Historic Scotland in partnership with Edinburgh Napier University, investigating methods for cleaning and repairing traditional ironwork. In particular, we have examined cleaning of grey cast iron and repair of grey cast iron and wrought iron. The aim of this work is to translate these findings into recommendations and guidance for conservation and repair. Details are given in this paper of a 19th century cast iron entrance canopy on the Isle of Bute, Scotland, which was intended to provide a case study of best practice.

A STUDY OF COATING MATERIALS FOR OUTDOOR IRON OBJECTS

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Abstract

This paper presents results from tests to determine the effectiveness of a coating system for outdoor cast iron objects. The anti-corrosion primer VpCI-383 and fluorocarbon topcoat V-Flon#200 were tested in different combinations that included cured V-Flon#200 (CF), uncured V-Flon#200 (F), topcoat V-Flon#200 combined with primer VpCI-383 (VF), uncured, and V-Flon#200 mixed with nano silica white (NF), also uncured. The tests also included samples coated with microcrystalline wax as a reference (MW), and all coatings were applied to samples of grey cast iron. The anti-corrosion properties and the weatherability of the coatings were studied through salt spray and field exposure tests. Results suggest that the coating system consisting of VpCI-383 primer and V-Flon#200 topcoat performed the best. A second phase of this study, which also gave promising results, involved the application of this coating system in the conservation treatment of an iron cannon from the Qing Dynasty.

SAVING YOUR SPANGLES: THE CONSERVATION AND CARE OF GALVANISED STEEL SCULPTURES

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Abstract

Continuous or mill hot dip galvanised steel sheeting is the most commonly used type of galvanised steel for sculptures and has been extensively used by artists such as Donald Judd. This paper examines the main causes of degradation of this material. Current methods for replicating lost surfaces are evaluated and the results discussed. Common coatings, namely Frigilene (Cellulose Nitrate), Paraloid B48N and B72, Regelrez™ and Rennaissance Wax (Microcrystalline Wax Blend), were evaluated for use as an indoor coating on galvanised steel sheeting to slow down zinc corrosion based on appearance and ease of application. Three of the coatings were selected for corrosion testing using Electrochemical Impedance Spectroscopy. The results suggest that Regelrez 1094 is a more promising coating than either Paraloid® B48N or Renaissance Wax. Regelrez 1094 may form a pore blocking structure providing increased protection from corrosion.

Thursday, October 14

SESSION 2

Engineering and 3D technology in Conservation

TREATMENT OF THE DAMAGED BRONZE OF RODIN'S *THE THINKER* FROM THE SINGER MUSEUM IN LAREN, THE NETHERLANDS: AN INNOVATIVE APPROACH

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Abstract

This paper will discuss the innovative treatment of a severely vandalised bronze sculpture, The Thinker *by Auguste Rodin, from the Singer Museum in Laren, The Netherlands. It gives a step-by-step account of the practical work undertaken to restore the sculpture, as well as an insight into some of the technology used. Additional aspects of this complex treatment, such as decision-making and documentation are also discussed. A variety of analytical techniques were employed to identify the materials and casting method of this well known bronze. These methods ranged from X-ray fluorescence (XRF), X-ray diffraction (XRD) to tensile strength testing of the alloy. The paper concludes with an evaluation of the complex treatment and gives recommendations for similar future treatments.*

DIGITAL DOCUMENTATION OF HISTORIC FERROUS METAL STRUCTURES: 3D LASER SCANNING AS A CONSERVATION TOOL

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Abstract

Digital documentation via 3D laser scanning is rapidly becoming a tool of choice in heritage recording. Traditional survey of historic ferrous metal structures can be particularly difficult due to the complexity of their construction, and laser scanning offers a highly accurate, objective and informative method of documentation. The authors outline the process by which such recording is undertaken and then present the results of three recent case studies that highlight the potential of this technique as part of a conservation tool kit.

AN INTEGRATED STRUCTURAL HEALTH MONITORING SYSTEM FOR THE PRESERVATION OF THE HISTORIC FIREBOAT *ALEXANDER GRANTHAM*

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Abstract

The structural integrity of a metal artifact is always of concern to conservators and curators, particularly if the object is very large and intended for permanent display outdoors. Being the first vessel preserved as a historical relic in Hong Kong, the Fireboat Alexander Grantham was lifted from the sea and has been on public display since 2006. Given the unfavorable, yet uncontrollable outdoor environment, the fireboat will inevitably suffer from degradation and perhaps structural failure, which may not be easily detected or identified at an early stage through visual inspection. For the sake of her long-term preservation, the Central Conservation Section in Hong Kong has pioneered the development of an integrated Structural Health Monitoring system to monitor the structural stability of the vessel on exhibition. This paper will discuss the conservators' experience in devising the system and the preliminary findings obtained from the program to illustrate the merits and limitations of its application on historic vessels.

FINITE ELEMENT ANALYSIS OF THE *H.L. HUNLEY* SUBMARINE: A TURNING POINT IN THE PROJECT'S HISTORY

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Abstract

Conservation efforts for the 40-foot-long H.L. Hunley *submarine (1864) have now reached a point that requires mechanical rotation of the vessel's hull. This new course of action has raised a number of important questions regarding the submarine's structural integrity. In response, project scientists have developed a finite element numerical model of the hull in its current state in an attempt to answer these questions. Data for the numerical model was obtained from archaeological documentation, as well as analytical data from non-destructive evaluation and metallurgical studies. Although finite element analysis is commonly used for structural analysis in many fields of engineering, its application to a historical structure such as the* H.L. Hunley *brings significant challenges. In particular, the exact degree of deterioration and the heterogeneous nature of the corrosion create uncertainty in identifying material properties. The finite element analysis provides conservators with a theoretical framework to assess the impact that rotation of the hull's original orientation might have on its overall structural integrity and provides a basis for conservation-related decisions.*

FINITE ELEMENT ANALYSIS OF CORROSION-INDUCED PROGRESSIVE COLLAPSE OF THE WRECK OF THE USS *ARIZONA*

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Abstract

A finite element model (FEM) is a computer-based engineering model that calculates theoretical stresses, propagation of force, and shape changes to a structure under loads using thousands, or even millions, of individual elements whose individual responses are well understood. An FEM of an 80-feet long (25 m) midships section of the USS Arizona site was created to analyze archaeological site formation processes on the sunken battleship, in particular to determine the current condition of the wreck and predict its future strength and structural integrity as it continues to corrode. The FEM incorporates findings from other key components of the USS Arizona Preservation Project, such as steel-hull corrosion rates, structural surveys of the vessel, sediment compaction studies, and analysis of the concretion that covers the ship's hull, into a single tool to predict how the wreck will degrade.

Friday, October 15

SESSION 1

Preventive Conservation

PRACTICAL APPLICATION OF SORBENTS

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Abstract

Metal artefacts are particularly susceptible to the effects of gaseous pollutants including ethanoic acid, hydrogen and carbonyl sulphide. Sorbents are often used in an attempt to slow corrosion caused by these pollutants. Once a sorbent has been selected, the quantity required and how it will be deployed must be ascertained, and a replacement regime must be considered. There are anecdotal reports of adsorbents off-gassing large concentrations of pollutants. This work presents a series of experiments and case studies using charcoal cloth, Corrosion Intercept and Puraspec 5040 to address these issues for lead and silver objects.

CONSERVATION MAINTENANCE PROGRAMS FOR FUNCTIONAL OBJECTS

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Abstract

Multiple and often mutually exclusive points of view develop around collections and their uses as social resources. In this context, conservators require a decision-making framework for care and maintenance of functional objects. In this article, the authors explain some of the ethical and practical considerations that have led the National Museum of Australia (NMA) to adopt maintenance programs as the best strategy for the conservation of technological heritage collections. The deterioration caused by passive storage is outlined and the lack of deterioration caused by systematic maintenance programs is enunciated. The idea of imbedding a constant monitoring, improvement and feedback plan into the program is explained. An object in the collection of the NMA is examined after a decade on display under this regime. We conclude that ability to function is one of the significant attributes of an object that should be conserved wherever practically possible.

DOSIMETRY FOR MONITORING IN ORGAN PIPES AND IN MICROCLIMATE FRAMES FOR PAINTINGS

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Abstract

Lead-coated piezoelectric quartz crystals (PQC) were used for the first time to evaluate the quality of microclimates within organ pipes and within microclimate frames (mc–frames) for paintings. A continuous monitoring system was developed for the use within organ pipes, and this system was adapted for measuring within frames. Exposures took place within the organ pipes of St. Botolph Aldgate, London, and in Oergryte New Church, Sweden. It was found that the response of lead-PQC dosimeters within selected pipes was higher in the latter and occurred more rapidly, which correlated with the presence of higher levels of ethanoic (acetic) acid and relative humidity. In the case of mc-frames, it was found that the dosimeter response was higher within the frames than in the rooms, and this was consistent with higher levels of organic acids, which were measured within the frames using passive diffusive samplers.

PATINAS, POWDERS, AND PRIMERS: SAFETY WITH A MUSEUM COLLECTION OF SMALL ARMS AMMUNITION

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Abstract

Examination of a collection of unfired small arms ammunition from two late 19th century sites in southern Arizona has brought to light safety concerns involved with handling, deactivation, and storing items of this nature. These objects contain black powder (gunpowder) — potassium nitrate, charcoal, and sulfur — with mixed mercury fulminate and potassium chlorate primers. Mercury fulminate is highly explosive, and it poses potential safety concerns when exhibition, research access to collections, preservation treatments, and long-term storage schemes are considered. Non-destructive methods of analysis were used to screen for the presence of mercury and to assign the bullet classifications. Standard thermodynamics calculations, as well as comparison to empirical data reported in explosives and engineering literature, have allowed us to confirm the chemical form and determine the likelihood of stability for all hazardous compounds. This study contributes to the conservation literature by offering a protocol for identifying risk and determining deactivation treatment and storage plans for similar artifacts in museum collections.

Friday, October 15

SESSION 2

Innovative Techniques

QUALITATIVE ANALYSIS OF HISTORIC COPPER ALLOY OBJECTS BY MEASURING CORROSION POTENTIAL VERSUS TIME

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Abstract

This paper describes an electrochemical tool developed to measure the corrosion potential of metal surfaces, often expressed as Ecorr, versus time, as a technique used in the qualitative analysis of copper alloys. The instrument is easy to use and transport, and is ideally adapted to the work of conservators during on-site condition survey. Along with the tool, a database was created that contains the electrochemical plots of 66 reference alloys, representative of the materials typically found in collections containing technical and scientific objects, (for example, those found in industrial heritage, technology and army museums). The plots were obtained in three different solutions; mineral water, potassium nitrate and sodium sesquicarbonate. The electrochemical tool was used to study several objects in the collections of the Historical Swiss Army Material Foundation (HSAM Foundation), and, after confirmation of their composition by energy dispersive spectroscopy, has allowed the authors to validate the appropriateness of the tool and the associated database, as well as to determine their limitations.

COMPUTED TOMOGRAPHY: A POWERFUL TOOL FOR NON-DESTRUCTIVE MASS DOCUMENTATION OF ARCHAEOLOGICAL METALS

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Abstract

The use of X-ray computed tomography (XCT) as a non-destructive method for mass documentation of archaeological objects encased within lifted blocks of soil was investigated by the Landesamt für Denkmalpflege Baden-Württemberg in southwestern Germany. The main advantages of XCT over two-dimensional (2D) X-ray and conventional excavation techniques, are the three-dimensional (3D) view, the ability to visualise exterior and interior features of objects within the blocks, for example, the damascene structure of a sword blade with polychromatic metal inlays, and the relative speed with which large amounts of material can be processed. The results have confirmed the effectiveness of this method as an additional documentation and virtual excavation tool for use by conservators and archaeologists faced with large volumes of material and fragile finds.

A SCIENTIFIC STUDY AND PRELIMINARY EXPERIMENTS FOR ELECTROLYTIC REDUCTION OF CORRODED LEAD INLAYS ON JAPANESE LACQUER OBJECTS

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Abstract

During assessment of the Japanese lacquer collection in the British Museum, problems with corroded lead inlays were observed. Some of the lead inlays were heavily corroded and have become brittle and friable. The inlays have been analysed by surface X-ray fluorescence spectroscopy and corrosion products identified by X-ray diffraction and Raman spectroscopy as cerussite or hydrocerussite, probably due to complete conversion from lead acetate or formate.
A detailed study of five cross-sections taken from three objects was made using microscopy and scanning electron microscopy with energy dispersive X-ray analysis. The study has revealed that some of the inlays are coated with multiple layers of lacquer dusted with tin, silver or gold particles. Some of the original inlays may have been replaced with modern lead. Preliminary experiments have been undertaken to adapt a consolidative electrolytic reduction treatment to enable the treatment of these friable and highly deformed lead inlays. The application of Paraloid B72® with polyaniline as a conductive consolidant has also been tested.

POSTER SESSION

NON TOXIC CORROSION INHIBITORS FOR THE CONSERVATION OF BRONZES AND GILDED BRONZES EXPOSED TO THE ATMOSPHERE

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Abstract

Corrosion inhibitors, associated or not with protective coatings, may be a good solution for planned conservation activities in the case of bronze and gilded bronze works of art. Studies in the cultural heritage area have been mainly focused on the use of Benzotriazole and its derivatives, but they are toxic for people and the environment. In this work, non-toxic corrosion inhibitors for bronzes and gilded bronze are investigated. The inhibitors have been tested both on non-patinated and patinated bronzes, reproducing Renaissance leaded bronzes. The experimentation includes electrochemical measurements in artificial rain and 3.5% NaCl solution, as well as short-circuit tests performed on gold/bronze couples. Materials and surfaces have been characterized with and without inhibitive treatments.

NON-INVASIVE INVESTIGATION OF POLIGEN®ES91009, A WATER-DISPERSIBLE ORGANIC COATING ON METALS, WITH REFLECTANCE-ABSORPTION INFRA RED SPECTROMETRY

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Abstract

Poligen® ES 91009 (BASF) is a material which has recently been tested as a coating in the field of conservation of metals. Ethylene-methacrylic acid copolymers can be partly neutralized and are commercially available as their sodium, potassium, ammonium or alkyl-ammonium *salts (which is the particular case of the material under study). Films of the coating material applied with the usual practices (brushing, immersion, spraying) on rough metal surfaces contain geometric irregularities responsible for certain distortions on reflectance FTIR spectra; this makes both qualitative and quantitative measurements from such samples difficult.*

DRY ICE DUSTING CLEANING TRIALS OF MUNTZ METAL SHEATHING FROM THE CLIPPER SHIP *SNOW SQUALL*

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Abstract

The American Clipper Ship Snow Squall's *(1851-1864) bow section retains 'Muntz's 24 Patent' brass and other brass alloy sheathing that varies in condition from good to very poor. The surfaces are heavily stained with copper alloy and iron corrosion products. Sheathing and wood samples were evaluated before and after systematic cleaning with the Dry Ice Dusting technique. Temperature, dwell time, nozzle shape, distance from surface and pre/post metallographic observations and application cautions are reported.*

COLORANDO AURO: EXPERIMENTS AND ANALYTICAL INVESTIGATION OF A MEDIEVAL COLOURING RECIPE ON GILDED PLATES

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Abstract

The issue of colouration of metals in medieval art objects has often been ignored, leading to inadequate, often unjustified and irreversible restoration treatments. The situation is the same for gilded silver objects. In conservation, a gilded artefact is considered a silver alloy covered with a gold layer. It is generally considered unlikely that gold would have been given a chemical surface treatment in order to change its colour or tone. At the Royal Institute for Cultural Heritage (KIK-IRPA), a study was undertaken of the Our Holy Lady Shrine of Huy (Belgium), a prestigious 13th century masterpiece of Mosan art and one of the four major shrines of the Colligiate of Huy. The study included establishing an appropriate method of conserving the gilding without altering the original colouration. It was discovered that by means of a special recipe, reported in Theophilus' (12th century) and Cellini's (15th century) writings, the colour of a gilded silver surface could indeed be changed into a warmer tone of gold. Based on these results, an extended project was set up with three aims: to rediscover all the details pertaining to these ancient colouring techniques; to investigate to what extent environmental parameters, such as relative humidity, temperature, ultra violet light and the presence of Chlorine and Sulphur influence the coloured surface; as well as to establish the most appropriate conservation approach for these materials.

THE TREATMENT AND DISPLAY OF A 16TH-17TH CENTURY WROUGHT IRON SWIVEL GUN RECOVERED FROM A MARINE ENVIRONMENT

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Abstract

Marine artefacts are often excavated to prevent looting. Therefore conservation procedures must be appropriately planned and budgets adequate for the labour and resource intensive processes required to keep marine artefacts stable in their post-excavation environment. This poster describes a low-budget re-treatment of a 16th-17th century iron swivel gun recovered from the Mediterranean off the coast of Malta. The practical steps of alkali washing, rinsing, accelerated drying, surface cleaning, surface consolidation, as well as environmental control and monitoring of the gun are outlined. Monitoring was carried out over a 21-month period at RH below 30%, and results suggest that preventive conservation measures, with a desiccated environment using silica gel, may provide sufficient stability for the artefact during display. A passive exhibition case with a pressure differential compensation device (PDCD) will provide a low air exchange rate, prolong desiccant life span, reduce intake of aerosol pollutants and minimize maintenance.

IRON FROM LONDON'S WATERLOGGED SITES: THIRTY YEARS ON

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Abstract

Museum of London conservators have worked on iron objects from excavations of waterlogged sites over the last 30 years. In the 1980s, treatments such as electrolytic reduction and alkaline washing were used for selected material. Suzanne Keene and others were instrumental in encouraging the treatment of iron from these sites which produced objects in excellent condition. Current practice in the UK is less interventive – most iron is not treated and dry storage is used to slow down corrosion. This poster outlines conservation policies and treatments of iron at the Museum of London since the 1980s, reflecting practice in the UK as a whole. There has also been an active programme at the Museum of surveying iron objects in our archaeological archive. Preliminary results suggest that a large proportion of untreated finds from waterfront sites are in good condition. Full results of the surveys will be published in due course.

NEW MATERIALS FOR TREATING FERROUS METAL OBJECTS: A CASE STUDY OF A 19TH CENTURY PAINTED, TINNED-IRON SPICE BOX FROM THE WINTERTHUR MUSEUM

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Abstract

This study focuses on the treatment of a spice box from the collection at the Winterthur Museum. Spice boxes, used to hold spices as well as trinkets, were once a common household item in America. The painted surfaces of the Winterthur spice box presented challenges for consolidation and cleaning. Flaking paint on the exterior was stabilized with an acrylic consolidant containing a corrosion inhibitor. The exterior surfaces were cleaned using a solvent based cleaning system constructed from a silicone crosspolymer that contained a small water phase. Corrosion on the interior was reduced using a combination of mechanical and chemical methods including a solvent-based gel containing a strong chelator for ferric ions. This treatment demonstrates the engineering of cleaning and corrosion reduction systems through the application of scientific analysis and materials science. It contributes to the field through the introduction of novel approaches for conservation treatment of degraded paint and corroded metal.

CONSERVATION AND RESTORATION OF A WWII CB-20 SUBMARINE

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Abstract

The CB-20 Submarine belongs to the class of pocket/midget submarines built for the Italian Navy in World War II. The submarine is designated CB-20 meaning 'corsiero tip B, number 20'. Manufactured in 1943, the submarine was seized and turned over to the Yugoslav Navy after the Second World War, after which it became a P-901 submarine. The CB-20 is the last surviving, complete submarine out of a series of 26 of this type ever produced. Other submarines of this class exist but are incomplete, and usually only the hull survives. In 1959, the CB-20 was donated to the Technical Museum in Zagreb, Croatia, and is the largest object on display in the museum's Transportation Gallery. This project describes the conservation and display of the CB-20 submarine.

TETRA ALKYL AMMONIUM HYDROXIDE SOLUTIONS – A BETTER WAY TO DESALINATE IRON FINDS?

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Abstract

Post excavation corrosion of terrestrial archaeological iron artifacts is a well-known problem in conservation [1]. Experience shows that the corrosion stability of iron finds can be significantly improved by the extraction of chloride ions from the corrosion layers [2]. To effectively improve long-term corrosion stability all chloride-containing phases, even the insoluble but metastable akaganéite, β-*FeO(OH), have to be removed. Currently, immersion treatments in aqueous, alkaline solutions are commonly used to achieve this goal. However, particularly long treatment times require further refinements of established methods. The desalination in aqueous and/or methanolic tetra methyl ammonium hydroxide (TMAH) solutions was tested on synthetic* akaganéite *as well as on Roman iron finds and compared to the common desalination treatments using aqueous sodium hydroxide solution with or without the addition of sodium sulphite. Results indicate that alcoholic TMAH solutions neither accelerate desalination nor improve overall chloride extraction efficiency. However, aqueous TMAH solutions promise higher extraction efficiency due to an accelerated decomposition of* akaganéite. *Nevertheless, the possible damage to treated artifacts by partial dissolution of the metal and corrosion layers requires further research.*

CONSERVATION OF LT. DIXON'S POCKET WATCH RECOVERED FROM THE *H.L. HUNLEY* SUBMARINE (1864)

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Abstract

The confederate submarine H.L. Hunley *made history on the night of February 17, 1864 when it became the first submarine to sink an enemy ship in combat. After its successful mission, the* Hunley *mysteriously vanished with its crew of eight. The hand-cranked iron vessel was located in 1995, off the South Carolina coast, but was not raised from the ocean until the summer of 2000. In 2001, a multi-disciplinary team composed of archaeologists, conservators, and anthropologists excavated the crew compartment and uncovered the remains of the doomed crew along with numerous artifacts and personal belongings. Among those artifacts was an ornate gold pocket watch that belonged to the commander of the vessel, Lt. George Dixon. The conservation of Lt. Dixon's pocket watch represented a complex and challenging conservation task. Due to the presence of composite materials a very careful x-ray analysis was conducted prior to opening the watch. A plan to open the watch was devised in collaboration with Daniel Nied from the York Time Institute. Once the watch case was opened, it revealed that the hour, minute, and second hands were still in their original positions. Further disassembly of the watch's inner movement was initiated to provide archaeologists access to data that may reveal when the watch stopped, and allow treatment of its most fragile components. Thanks to an exemplary collaboration between archaeologists, clock specialists, and conservators it is now possible to exhibit this incredible artifact and allow it to be studied and interpreted.*

EVALUATION OF SODIUM NITRITE AS A CORROSION INHIBITOR FOR USS *MONITOR* ARTIFACTS

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Abstract

The treatment of 210 tons of material from the Civil War ironclad USS Monitor *at The Mariners' Museum (TMM, Newport News, VA) presents conservators with many challenges related to conserving industrial waterlogged composite materials. Sodium nitrite ($NaNO_2$) was suggested and evaluated for TMM by CCTechnologies /DNV Columbus (CCT), a corrosion engineering firm, as a replacement for highly alkaline sodium hydroxide storage and desalination solutions used for large artifacts.The advantages offered by sodium nitrite treatment as presented by CCT are:*

- *neutral pH (less aggressive to organics);*
- *low concentration of solution used (100ppm, i.e. 100mg/l or $1{,}45.10^{-3}$M), reducing cost and disposal factors;*
- *effective on multiple metals (iron, copper and lead).*

Conservators at TMM in conjunction with the Department of Biology, Chemistry and Environmental Sciences (BCES) of Christopher Newport University tested $NaNO_2$ to answer the following questions:

- *Is $NaNO_2$ an efficient corrosion inhibitor in the presence of chlorides and corrosion products, i.e. on real artifacts?*
- *Will O_2 oxidize NO_2 into NO_3 and lead to less efficiency?*
- *Does $NaNO_2$ help in extracting chlorides from the metal?*

HISTORIC IRON STABILISATION TREATMENTS: A PUBLIC SURVEY

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Abstract

This research project explores the influence conservation treatments can have on the appearance, perception, and interpretation of historic iron. There are a variety of materials available to conservators and according to the survey undertaken for this project the most common are:

- *Paraloid B72*
- *Microcrystalline wax*
- *Tannic acid*
- *Phosphoric acid Part of the project included testing the materials to evaluate their effectiveness at preventing iron from re-corroding in poor environments. The most effective materials were microcrystalline wax that had been applied hot and Paraloid B72.*

In conjunction with the testing of conservation techniques a public survey was undertaken in a social history museum, the Museum of London, to learn about how treatments affect the public's perception of objects. The stabilisation treatments were used as examples and the public's reaction illustrated that their perceptions were influenced by conservation treatments.

TESTING FOR LOCALIZED ELECTROCHEMICAL CLEANING OF TWO 17TH-CENTURY GILT SILVER DECORATIVE OBJECTS

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Abstract

A pair of amalgam gilt sterling silver Stags *(Augsburg, circa 1680-1700) by Johann Ludwig Biller the Elder from the collection of the J. Paul Getty Museum have been susceptible to active tarnishing and have been cleaned three times at the Museum since 1986. Treatment reports describe that acidic thiourea was applied locally by swabbing and water rinsing. After each treatment, the Stags re-tarnished rapidly on display, and for the past eight years they have been stored in a sealed Corrosion Intercept® zip-lock bag with dry silica gel and activated charcoal (10% RH, 21ºC), yet they continue to re-tarnish. The thiourea treatments are suspected to increase their susceptibility to rapid tarnish. As an alternative treatment, electrochemical reduction is being considered. Electrolytic techniques have been developed for tarnish removal of silver sulfide and the reduction potential has been previously studied. Described here is a study to test electrolytic cleaning of gilt metal coupons made out of the sterling alloy. Preliminary results from localized testing on the* Stags *have also been presented.*

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