Article: On-line survey results of techniques used for outdoor bronze conservation
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ON-LINE SURVEY RESULTS OF TECHNIQUES USED FOR OUTDOOR BRONZE CONSERVATION

Tara J. Shedlosky, Kimberly M. Stanek and Gordon Bierwagen

1. Introduction

A survey on the methods and materials used by outdoor bronze conservators was conducted to obtain a broad opinion of both practical information about the techniques and materials used to maintain outdoor sculptures and the future needs of the conservation community relating to coatings for outdoor bronze sculpture. Through this survey we hoped to develop specifications for formulating coatings for outdoor bronze which the authors of this paper will attempt to apply to novel coating ideas for outdoor bronze conservation.

The survey was conducted on-line to insure anonymity in the responses, as some of the questions could be interpreted as ethically challenging. The cost of addressing people on line was a more efficient use of time and funds verses sending out mass mailings to conservators. In addition, contacting people on-line allowed to easily communicate with conservators throughout the world.

A letter in the form of an e-mail was sent out to approximately 500 conservators including: sculpture conservators from the AIC Directory, people who participated in the Metals 2001 Conference and people on the Conservation On-line Distribution List (CoOL) who listed themselves as working with bronze. In addition a request was posted on CoOL. The letter included a password to enter the on-line survey to ensure only the targeted conservators would be able to fill out the survey. The entered data was stored on a controlled spreadsheet. This made the process efficient, avoiding having to reenter the results.

A total of 38 people answered the survey. Although this seems like a low percentage of participants, the following statistic indicate that those who did respond are very important to the preservation of bronze objects. Of these responders, 95% had cleaned, 87% had coated and 58% had repatinated an outdoor bronze. These statistics indicate that the people responding to the survey have relevant backgrounds that represent true practices of outdoor bronze conservation and maintenance. Throughout the remainder of this paper, these respondents will be referred to as the "conservators".

2. Survey Results

2.1 Cleaning

When asked about the materials used to clean outdoor bronze, 40% of the respondents use nylon brushes or scrub pads and 51% use natural brushes. The following chart represents the different detergents reportedly used by conservators and the percentage of conservators that report using each detergent.

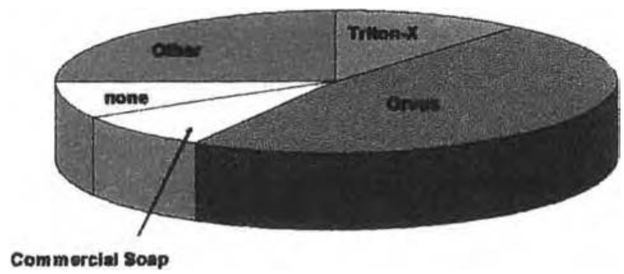

Figure 1. Different types of detergents used by conservators

Triton-X™ (a registered trademark formerly owned by Rohm and Haas Co., but now owned by Union Carbide) is a nonionic detergent. The "X" series of Triton detergents are produced from octylphenol polymerized with ethylene oxide. Orvus® WA Paste is produced by Proctor and Gamble it is reportedly an extremely gentle detergent designed to clean cattle and horses. In the "other" category detergents that are used are Vulpex, Teric 90, and the surfactant Synperonic N. Ivory® dish detergent was also reportedly used.

Blasting is sometime used to remove unwanted films and clean items. It was reported that 44 % of the conservators had used this technique to clean a bronze sculpture about 1.5 % of the time. The following graph represents the different materials used to blast sculptures and the number of conservators reportedly using them.

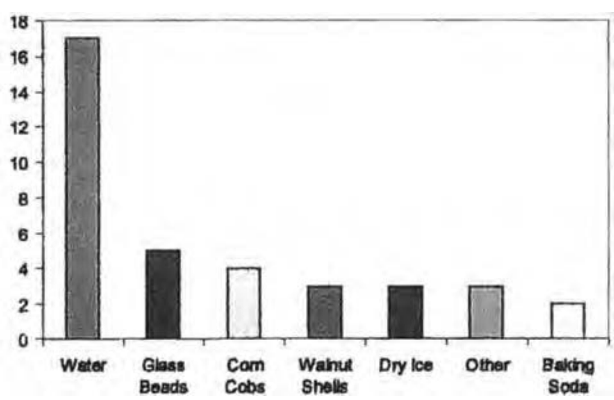

Figure 2. Blasting Media used to clean bronze sculptures.

2.2 Coatings

Atmospheric corrosion is becoming more prevalent throughout the world and results from an increasing production of corrodants such as SO_x, NO_x, CO_2, and chlorides. These corrodants affect various materials including bronze. Unprotected outdoor bronze corrodes readily when an electrolyte comes in contact with the metal. The metal, acting as the anode, readily oxidizes while a cathodic reduction reaction of O_2 and H_2O occurs. Protection from bronze corrosion is thus very important when trying to conserve bronze sculpture situated in a hostile environment. In attempting to maintain the original intent of the artist one must protect the bronze with the least intrusive means possible. The primary method of protecting bronze from elements found outdoors is using a protective coating. In developing a protective coating it is important to understand what is wanted and needed by the conservation community.

The surveyed conservators were asked to rate various potential properties of a coating on a sliding scale and report where the feature lay between very important and not important. The following figure graphically represents the results.

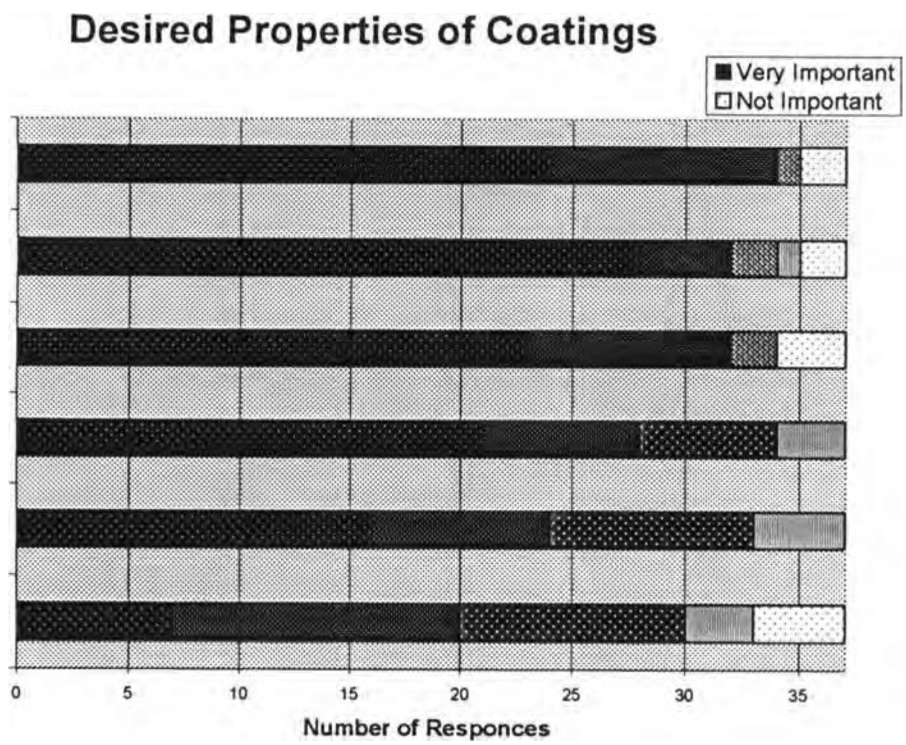

Figure 3. Coating features rated on a sliding scale.

The above results indicate that the three most significant features to build into a coating are weather resistance, the appearance of a coating on a bronze and the ability of a coating to be removable. The three other features as well are indicated as important to a majority of the surveyed. It was pointed out in the comments section of the survey that cost and availability of the coating system are issues that also must be addressed.

2.2.1 Wax

Wax is by far the most popular coating system used on outdoor bronzes. Wax is assumed to be protective, and fully removable. Although comments from a surveyed conservator say, "...wax can build up and change the appearance from multi-colored to a thick and glossy uniform brown. Further, it is very difficult to remove a wax coating and raised areas of bronze on the surface still become worn down and turn green. The wax can also assist harmful materials such as stray fertilizer pellets, in damaging the surface of the bronze by eating through via small openings and spreading under the layers of wax." Nevertheless, wax is a cost effective material and is easily applied and thus readily used. This same conservator went on to say that, "most curators and museum visitors, etc. aren't bothered by the change in appearance. Like so many (preventive) conservation treatments, protective wax coatings seem more beneficial than most other coatings at this time." The survey results indicate the popularity of wax, as 92% of the surveyed conservators have applied wax coatings. Brushing and cloth applications of wax are the most popular; only 9% had used spraying methods to apply the wax. Application of a hot wax technique was used by 62% of the surveyed and 70% of conservators have tinted the wax. The graph below in Fig. 4 represents the average wax reapplication.

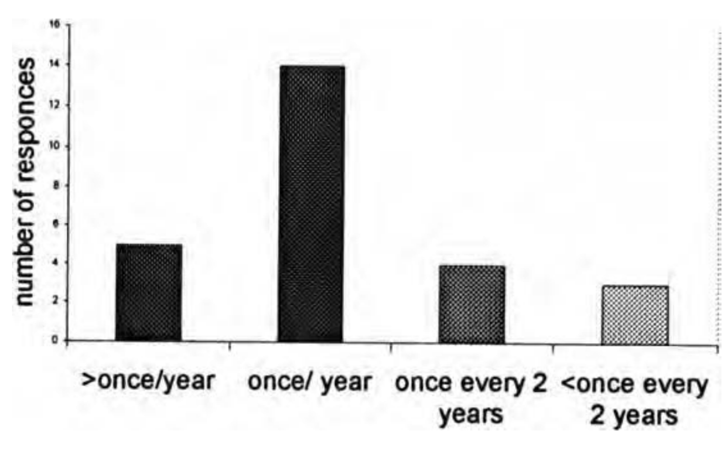

Figure 4. Average wax reapplication.

Typically wax is applied once per year. It was pointed out by a conservator that, "post-conservation maintenance of outdoor sculpture is often the responsibility of the institutional owner" and therefore out of control of the conservator. The following figure graphically represents the types of waxes and their frequency of use by conservators.

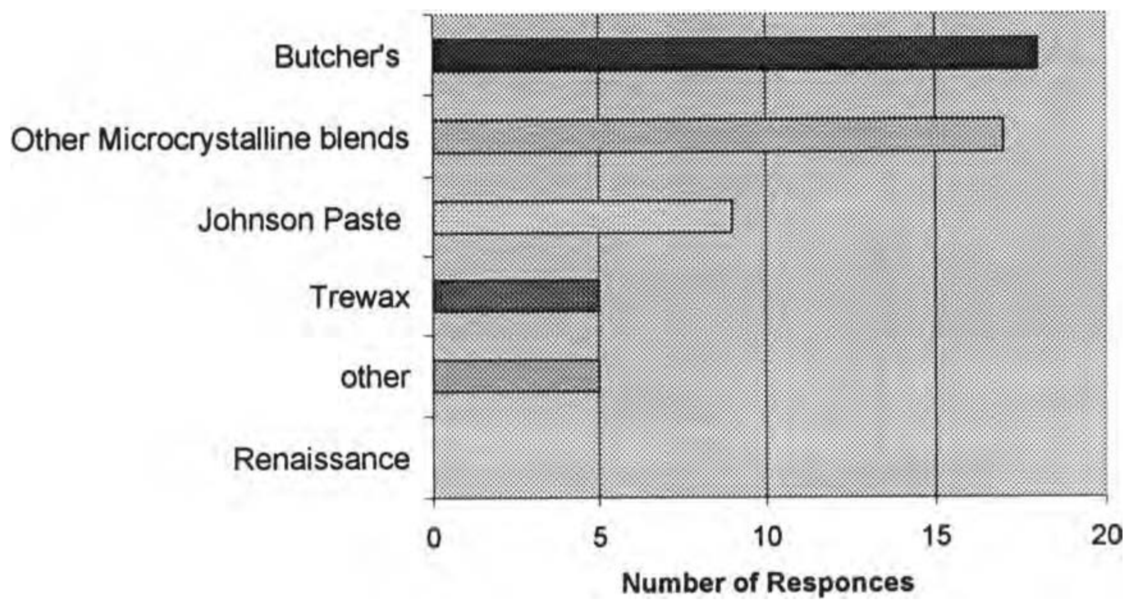

Figure 5. Types of Waxes and frequency of use.

Butcher's bowling-alley-paste wax, which is a carnauba wax, natural and synthetic waxes in mineral spirits and turpentine (or other hydrocarbon), is the most popular type of wax (Scott 2002). The microcrystalline blends are also commonly used and are often mixed by the conservator. Other waxes that were reported to be used are carnauba blends and synthetic beeswax. It was reported that Renaissance Wax was not used at all outdoors.

2.2.2 Pretreatments

Corrosion inhibitors retard the formation of corrosion through complex mechanisms, which are often more than simple barrier properties. The inhibitors suppress either the cathodic or anodic or both electrochemical reactions. In the case of benzotriazole (BTA), the molecule is chemisorbed on the metal substrate. This chemisorption is facilitated by the polar nitrogen molecules (Jones 1996). A total of 57 % of the surveyed conservators, have used a corrosion inhibitor, all report the corrosion inhibitor used as BTA. BTA pretreatments were used under both wax and non-wax coatings.

2.2.3 Non-wax Coatings

Synthetic resins are used to protect bronze instead of using a wax coating. The conservators report that 73% have used a non-wax coating. 90% of the conservators would find it valuable to be able to adjust the gloss of the system. The following figure represents the different coatings that are used and number of conservators who use each.

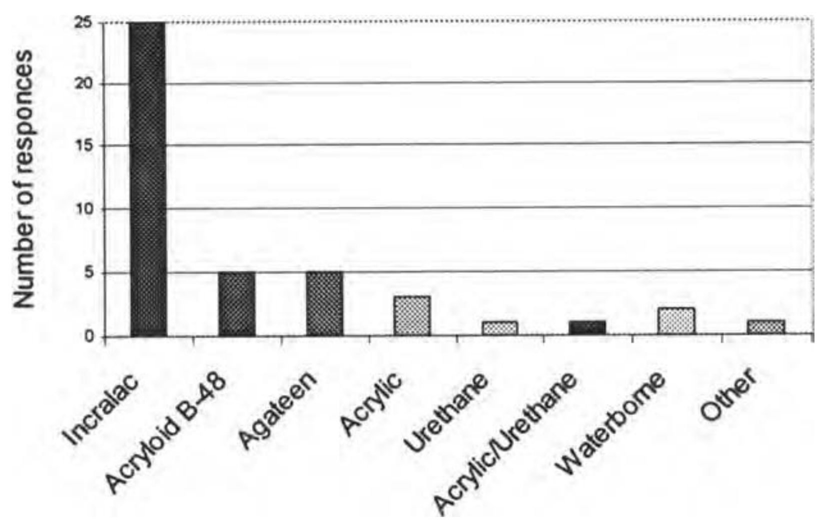

Figure 6. Types of resins that are used on outdoor bronze.

Incralac® is the most popular resin used to protect outdoor bronzes. Incralac® is an acrylic polymer-based coating that is soluble in toluene. Incralac® was developed in the 1960s by the International Copper Research and Development Corporation in New York (Scott 2002). The base of Incralac® is the resin Paraloid B-44 made by Rohm and Hass Inc, which is a ethyl methacrylate/methyl methacrylate copolymer. In addition to Paraloid B-44, Incralac® contains a leveling agent, epoxidized soybean oil, an ultraviolet stabilizer – benzotriazole (BTA), toluene and ethanol. BTA also functions as a corrosion inhibitor for the copper in the bronze and is present in the formulation. There have been several studies that have looked at the effectiveness of Incralac® and the conclusions of these studies indicate that Incralac® is an effective coating varying from 16 months to 5 years of outdoor exposure (Scott 2002; Weil 1980; Smith and Beale 1986; Brostoff et. al. 1998; Brostoff and de la Rie 1997; Bierwagen et. al. 1999). Thus every 2-5 years efforts must be made to remove the old coating system and then reapply a new coating. Minimizing this step of removing and then reapplying a new coating can be achieved by finding a better coating system to replace Incralac®.

2.2.4 New Coating Systems

The conservation community on a whole agrees that research needs to be continued to develop polymer coatings for the protection of outdoor bronze sculptures (Scott 2002). In attempting to develop a coating for outdoor sculpture, it is important to the authors to understand what type of coating would be accepted by the conservation community. The following statements refer to a fictional coating that would perform better than what is currently available. If a protective clear coating was developed and it was not removable by solvents, 29% of the surveyed conservators would use it. If the same coat was removable by mechanical means 31% would use it. If the means did not change the surface 63% would use it. If a different method was developed for removing the coating without changing the surface, 87% would use the coating. When asked about the need for a long term coating system, which was defined as longer that one year, 92% said there was a need for a long-term coating system. Fig. 7 represents the lifetime specifications for a model coating system as defined by the conservators.

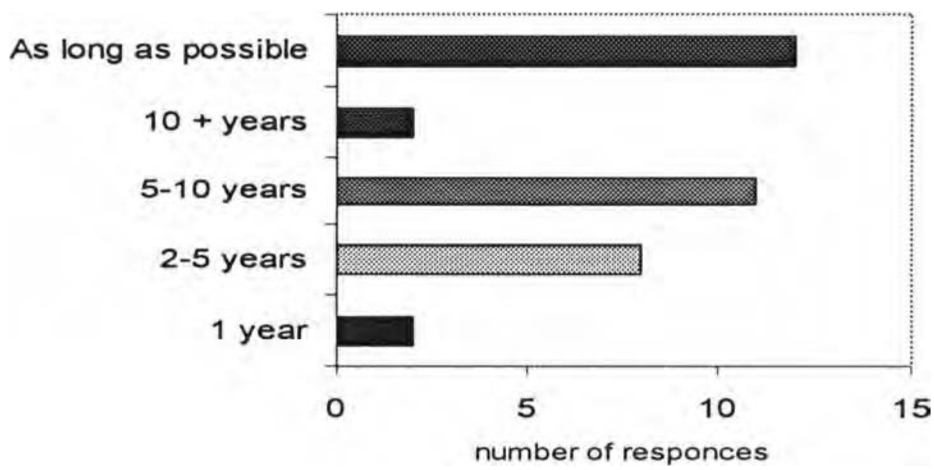

Figure 7. Lifetime Specifications for a model coating system as dictated by the surveyed conservators.

There seems to be a need for a long term protective system, especially if it is removable by a novel technique that does not disturb the surface. There was some concern that if a long term coating system were developed, annual inspections would not be upheld by the owners of the bronze.

The following represents the coating specifications of an *ideal* coating system, as defined by the survey questions and the comments that were submitted to the survey. The coatings must have the following characteristics:

- Protective against corrosion formation (provides a barrier against water, O2 , or ions)

- Clear (must be able to conform to the optical properties as the conservator and curators sees fit, gloss adjustable)
- Removable
- Easy to apply
- Non-toxic (as little as possible)
- Durable
- Not Degraded by ultra violet light
- Cost effective

3. Current Research

This research was recently reported at the 2002 Athens Conference on Coating Science and Technology (Bierwagen et. al. 2002). For a more in-depth analysis, please refer to the references.

A fluoropolymer is being studied as a protective coating on bronze when blended with an acrylic polymer. The acrylic used is Paraloid B-44, which is an acrylic resin made by Rohm and Haas. This acrylic also happens to be the base for Incralac®. We are currently studying another Rohm and Haas acrylic, Paraloid A-21, in hopes of furthering the adhesion of the fluorocarbon.

Electrochemical methods such as electrochemical impedance spectroscopy are techniques that provide a quantitative analysis of a corroding material (Bierwagen et. al. 1996; Wain et. al. 1996). Electro-chemical impedance spectroscopy (EIS) is one of the electrochemical methods that can be utilized to characterize the corrosion protection of coatings (Jones 1996; Skerry and Eden 1987; Bierwagen 1996). As the corrosion protection of the coating decreases so does the impedance. An increased amount of electrolyte penetrating into the coating is indicative of poor corrosion protection and increases the capacitance of the system. The capacitance increase shows its effects in the higher frequency portions of the EIS spectrum, but at low frequencies is identified with an increase in water uptake in the film and a decrease in film resistance.

EIS analysis of the protective coatings on monumental bronze was determined by application of an alternating current of 5mV to the cell. The electrochemical cell consisted of a saturated calomel reference electrode and a platinum mesh counter electrode that were immersed in dilute Harrison electrolyte solution. The electrolyte stayed in contact with the working electrode sample by using an o-ring clamp with an area of 7.0 cm^2. A Gamry PC3 potentiostat with CMS 100 software was used to collect the data over the frequency range of 5000 to 0.1 Hz.

The following is a Bode Plot of various coatings on bronze before any weathering occurred.

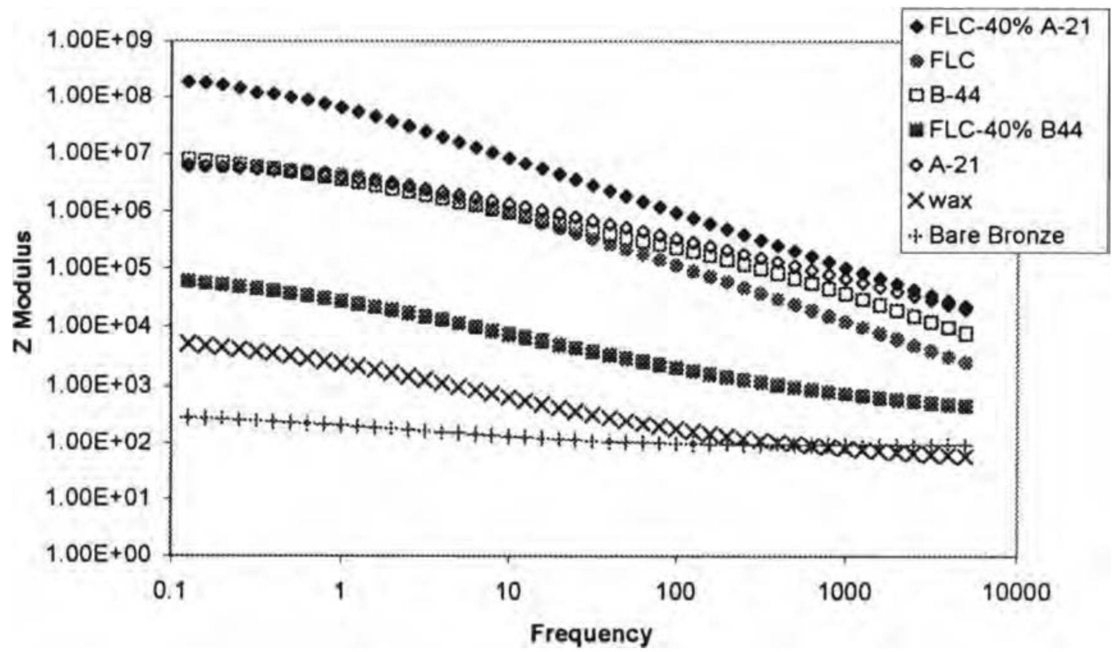

Figure 8. Bode plot of various coatings on bronze, at time zero.

Initial electrochemical studies indicate that the fluorocarbon-acrylic blend has the potential of being an excellent coating. The following figure, measured initially after the coating was cast over the bronze substrate, demonstrates the initial electrochemical impedance spectroscopy (EIS) results of the blend on rolled bronze. It indicates the greater barrier properties of the fluoropolymer-based coatings. The low frequency portion of this Bode plot, indicate that the fluoropolymer-acrylic blend is highly resistant coating. The authors would like to note the significant difference in resistance between that of the wax and the resistance of the acrylic and acrylic blends at low frequencies, even before weathering has occurred. Further studies will again look at increasing the adhesion of the coating, along with artificial weathering of the coating on cast bronze.

4. Conclusions

Through this on-line survey, a general overview of materials and methods used in outdoor bronze conservation was obtained. It was found that there seems to be a need for a long term protective system, especially if it is removable by a novel technique that does not disturb the surface. Coating specifications were generated as a goal when developing an ideal coating system. Initial results indicate that there is potentially a significant area of growth in coating systems.

Acknowledgments

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