Coat of arms: Dovetailing the needs of outdoor sculpture and military assets to develop more durable and adaptable paint systems

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The requirements for paints used on outdoor sculpture and military vehicles are similar: overall protection for the underlying substrate, and the ability to withstand prolonged outdoor exposure and recurring physical contact. Aesthetic requirements are different but stringent for both categories of coatings and include maintaining appearance over time. Building on prior work undertaken by the United States Department of Defense (DoD) Army Research Laboratory (ARL) to modify military coating systems into a matte black paint suitable for outdoor sculpture, a long-term interdisciplinary collaboration is under way between the ARL, the Getty Conservation Institute, Mack Art Conservation, and NCP Coatings, that aims to develop and evaluate a wider range of robust paint systems with novel attributes for both the DoD and outdoor painted sculptures. For the latter, this includes coatings with a broader range of gloss, formulated with a much more varied palette. New low-gloss coatings used on military assets were used to paint sculptures by Alexander Calder, Tony Smith, and Louise Nevelson, designed to an aesthetic standard based on approved colour and gloss levels by the relevant artists' foundations and estates, and formulated to enhance durability. These new coatings offer the ability to match or meet a range of artists' aesthetic preferences, and to use a variety of polymeric flattening agents to control gloss levels, reduce marring, and eliminate volatile and hazardous pollutants. The use of low molecular weight (LMW) resins provides 4–8 hour pot life to assist in the application process. Compared to current resins, the LMW systems reduce organic solvent levels, are low viscosity, and permit far easier application. In addition, the replacement of typical pigments with low solar absorbing (LSA) pigmentation provides higher reflection which ‘shields’ the resin/binder system and reduces degradation. A particular advantage to conservators from this collaboration is that the coatings on DoD assets provide a convenient indicator of the paint's performance and durability. The outcome will be a unique coating system to provide enhanced durability and maintain the original coating properties for a period of 6–10 years.

Keywords: Outdoor sculpture, Camouflage coatings, Outdoor coatings, Matte paint, Low solar absorbing pigments

Introduction

The poor durability of matte or low-gloss coatings in an outdoor setting is well known. Such coatings are unavoidably overloaded with pigments and flattening agents to create a matte appearance, and the minimal amount of resin — along with poor choices of pigments and flattening agents — typically lead to fading, streaking, easily marred surfaces, that become thinner with each passing season until they no longer resemble the unexposed coating (Fig. 1A and B). Disfiguring weathering has been documented after only 3 years in some climates.

The paint industry’s matte coatings are generally not well suited to outdoor exposure or longevity, and are also not readily available (with a few exceptions, such as for luxury automobiles and architectural projects). However, two quite disparate professions are reliant on matte coatings with equally stringent requirements; the military and art conservation. For the military, concealment and blending in with the background necessitates a matte coating, while for outdoor sculptures, appearance is essentially non-negotiable. Although at first glance these groups do not seem to have much in common, they do share important commonalities. Both have the basic needs of providing protection to the underlying substrate, withstanding prolonged deterioration, and maintaining the original appearance. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.
outdoor exposure and recurring physical contact, plus the ability to maintain the same matte appearance over time. Furthermore, both outdoor sculpture and vehicles are usually large in size, high in value, need a secure facility for treatment, and have narrow limits of acceptability for coatings. The main differences are the need for bright and more varied colours for some works of art, and volume: with artworks, usually only one or a limited number of editions exist, whereas the US Army owns a seemingly endless number of vehicles to which the coatings can be applied, varied, and assessed.

Nearly any tour of an outdoor sculpture garden, business headquarters, or city centre with a monumental sculpture will reveal artworks with matte coatings. This is especially true of sculptures from the 1960s, 1970s, and 1980s, where a matte appearance was ubiquitous within the aesthetic of many artists. These grand sculptures represent the giants of the mid-twentieth century, such as Clement Meadmore, Louise Nevelson, Ronald Bladen, Tony Smith, Alexander Calder, and Claes Oldenburg, and an era when art moved out of traditional museum environments into our cityscapes and landscapes. For the last 30–50 years these sculptures have been on a continuous carnival ride of painting and repainting in an attempt to maintain the artists’ intended appearance (Steele & Mack, 2013) (Fig. 2). Practically speaking, the sheer number of such artworks make it challenging to create standards for long-term preservation, especially since many of them are in non-museum environments. Fifty years is a very long time to maintain a large sculpture regularly. With economic changes and shifting priorities, visitors to cityscapes and sculpture gardens have more often witnessed short periods of the correct appearance followed by many years of visual disfigurement. The expertise and practical experience of the US Army is very relevant here, since caring for a large number of assets is not new to them.

**Prior efforts**

In 2001, the National Gallery of Art, Washington DC, USA, spearheaded a study to evaluate and identify more durable commercially available coatings for sculptures by Calder and Smith. The study included paints specified by the artists plus new coatings that contained high-performance resin systems. The durability of matte coatings is poor, regardless of the type of resin used, since there is simply too little of it to protect the paint film. However, the study also led to an unlikely allegiance between art conservation and...
the military, another sector that has no other alternative but to keep using matte coatings. At that time the ARL had already found a solution by considering the challenge holistically and formulating a matte coating with polyurethane-based resin systems with lower initial gloss (Even the base resin without pigments and flattening agents had a low initial gloss). Increased durability was effected by replacing the industry’s typical inorganic flattening agents such as talc and silica with polymeric beads similar in composition to the resin itself. The beads had free hydroxyl groups, which enabled seamless compatibility with the resin and also chemically reacted with the polyurethane chemistry for integration within the film. ARL’s formulation adjustments increased the durability of the paint film and, by extension, maintained its appearance. The study culminated in adapting military coatings for outdoor black sculpture by Calder (very matte) and Smith (dull semi-gloss) (Sturman et al., 2008). A number of case studies used a good match for the paint used by Calder. In 2013 the Calder paint was released for commercial use on his Gwenfritz (Fig. 3). Since then, Calder’s red, yellow, white, and blue colours have been made, based on the same resin and flattening agents. The paint modified for Smith’s surfaces, however, continues to present problems during application, and this continues to delay its commercial release. It is speculated that the success of the Calder paint and the continued challenges posed by the Smith paint are related to the former being closer to the very matte appearance of ARL’s original formula.

Over the last decade, through the trial use of adapted military paints for outdoor sculptures, there have been a number of issues, mainly with adhesion. This is thought to be due to a misunderstanding of the necessary preparation techniques, and the need for non-military painters to become familiar with the application methods. Of the sculptures painted, roughly one-third have exhibited adhesion problems between paint and substrate. It is clear that establishing guidelines and best practice is paramount, and that these problems stem from the importation of a material across industry boundaries.

The US Army has the ability to set detailed protocols on a very large scale, resulting in part from the high value placed on a culture of order, agreed-upon protocol, and precision. In contrast, conservators more often rely on ingenuity, personal skill, and consummate first-hand knowledge of materials to accomplish their work. Through experience it has been found that some master painters are unwilling to try new products, especially if it requires new equipment. Since appearance is critical, there is less focus on correct preparation. Conservators are also understandably cautious of blindly adapting industry standards to outdoor sculpture. For instance, the industry guidelines for a ‘paint-ready profile’ (creating tooth on a metal surface) for most high-performance coating systems would be viewed as aggressive by conservation standards. And rightly so, since sculptures should not be abrasive-blasted as if they were bridges, water towers, or tanks. This poses an ongoing challenge, since the industrial guidelines1 for an adequate paint-ready profile are a key factor in adhesion. Differing working styles is not the only challenge. There is general lack of understanding of new outdoor coatings technology within the conservation sector. The last decade has brought significant changes including the introduction of many previously unknown chemistries, in response to stronger US environmental restrictions.2

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1Surface Preparation Standards. Latest update 9/1/2015. Developed by the Society for Protective Coatings (SSPC) and National Association of Corrosion Engineers International (NACE).
2The US Toxic Substances Control Act (15 US. 2601-2692 11 Oct 1976) and US Consumer Product Safety Commission announced a final ban on lead-containing paint (September 2, 1977). The US Clean Air Act (42 U.S.C. 7401-7671) was effective from 17 December 1963, and is upheld by Public Health and Social Welfare.
Current efforts

The Getty Conservation Institute (GCI) launched a project on outdoor painted sculptures in recognition of the fact that this category of objects is both incredibly significant and poses major conservation issues — among them, the need for better coatings. In 2012, the GCI gathered a multi-disciplinary group that included conservators, scientists, curators, artists and artists’ estates, paint manufacturers, fabricators, and industrial painters, to discuss challenges and to define a way forward. A number of potential solutions were suggested, one of which was to build bridges between the coatings sector and the art world (Learner & Rivenc, 2015).

As another field with an ongoing commitment to matte coatings, ARL’s approach stood out as a viable alternative that offered a unique direction. GCI’s mission to advance conservation practices and to facilitate research led to building on the previous work done at the NGA by supporting continued collaboration with ARL. GCI provided John Escarsega — the driving force for the project on the ARL side — with a scholarly sabbatical away from the daily demands of running the DoD’s Chemical Agent Resistance Coatings (CARC) department for the US Army Research Laboratory. During this time he developed a new formula that incorporated the use of LMW resins and low solar loading pigments. The new formula has attributes that are tailored for the specific needs of outdoor sculpture and, as it turns out, are also very applicable to military vehicles.

For art conservation, being involved with the formulation of new paints has considerable and distinct advantages, such as choosing the initial gloss and colour through consultations with artists or artists’ estates, and tailoring the paint to these aesthetic needs, instead of modifying an existing coating which might affect the longevity or application characteristics. Other advantages include having input into the coating’s working properties, such as viscosity or drying time, to adapt to a variety of application environments, e.g. on site rather than in a spray booth. The goal is to expand the paints beyond the palettes of Calder and Smith to meet the aesthetic needs of as many outdoor sculptures as possible. To further that aim GCI, ARL, and the Louise Nevelson Foundation have developed parameters for the artist’s outdoor sculptures.

Crossover research at ARL

A unique and dynamic collaboration with the ARL developed followed suggestions from the 2012...
meeting. These came from a range of conservators and artists’ estates/foundations, and allowed ARL to further their efforts to improve upon existing formulations, and modify the coatings for specific works of art, to embrace the goals of both areas. Coatings for the military function on multiple levels that include providing camouflage for the vehicles and performing as a first line of defense against corrosion.

A current technology gap identified by the Army for its assets is the ability to lessen or reduce surface temperatures. Since the majority of equipment is operated and used outdoors and often in severe desert and desert-like environments, ARL sought to reduce the solar loading — effectively reflecting thermal energy not only reduce to the temperature of the coating, but also protect the resin from ultraviolet (UV) degradation. This also seemed an ideal solution for outdoor sculptures. The premise was to formulate coatings using low solar absorbing technology while maintaining all existing specification requirements found in military specification MIL-DTL-64159 (2010). These requirements include water, solvent, weather, and impact resistance; drying time parameters; and pot life. These are basic parameters for any coating system. Minimizing the absorption of solar energy and improving the life of the coatings through the incorporation of a new resin system was the primary focus, approached by attempting to improve the reflectance properties in the near infrared (IR) range while maintaining similar or identical colour in the visible range (400–700 nm) and selecting a resin system that best supported the pigment and flattening agents while enhancing mixing and application parameters and drying time.

The ARL has been able to formulate a novel coating that utilizes a recently-created water-dispersible CARC formulation and introduce LSA properties into it, resulting in reduced solar loading by providing higher reflectance in the near-IR range. This also maintains similar or identical appearance in the visible range. These elements are critical to address key technology challenges for military applications of camouflage coatings, but also serves to address durability issues for outdoor sculptures. The LSA CARC was applied to both metal and polymer composite test substrates with excellent results: it improved the lifetime of CARC from approximately 2–4 to 9–10 years. Mixing and application of the LSA CARC was performed in the same manner as conventional CARC. The technology was demonstrated at several sites with both high and low relative humidity, which included the coating of Blackhawk helicopter blades in one of the field demonstrations. The demonstrations were all successful in terms of ease of application, expedient drying times and appearance. The multiple users and field demonstrations permitted continued observations and insight into changing environmental and application parameters. The Army’s ability to work with outdoor sculptures and be able to crossover technologies affords even more insights and confidence in the development of high-performance coatings with enhanced properties, for multiple uses.

**Technical background**

LSA pigmentation has been implemented in a number of applications such as coil roofing, roof shingles, and paints for architectural use. Now the automotive industry for luxury vehicles is investigating the use of LSA-type coatings to assist in cooling the interior of black or dark vehicles, to give a cost saving for air conditioning, enhance the longevity of the more sensitive electronic components, and obviously provide a more comfortable interior. The LSA pigments are a mixed metal iron oxides and contain reflective aluminium, and are processed at extremely high temperatures resulting in very reflective, UV-stable, and chemically resistant pigments. These characteristics are ideal for industrial outdoor use, outdoor sculptures, and military assets.

**Approach**

The technical approach involved modifying the existing water-dispersible CARC formulation to include new mixed metal oxides and a new LMW resin system. This enabled the use of less co-solvent and affording greater crosslink density while using a lower NCO to OH indexing (or molar ratio) compared to the original formula. Numerous studies were performed to investigate the appropriate raw materials, their quantity, and combinations (Fig. 4). Essentially, after multiple pigment loadings the highest reflectance values (Fig. 5) were obtained using 100% of the LSA pigments and a lower indexing of NCO to OH, which provided higher chemical resistance. Our research also concluded that with minimum dilution of conventional pigmentation the reflectance would drop significantly. This has proved beneficial in cases...
where reflectance can be modified to specific requirements or needs. Once homogeneous and robust films could be made, pigment substitutions using LSA pigments were performed, and two colours were formulated and utilized for the subsequent panel test evaluations. The project involved evaluation of both green and black formulations as well as some of other US military colours such as brown, grey, and aircraft green (known as 808 green), which were evaluated for all requirements. The other primary colours were evaluated only for gloss, colour, IR reflectance, and UV resistance via outdoor exposure in Arizona, USA. Coatings were sprayed and cured on cold rolled steel and subjected to numerous tests as detailed in MIL-DTL-64159 (2010).

**Summary of results and lessons learned**

The LSA formulation with the new resin system tested according to MIL-DTL-64159 (2010) met or exceeded the requirements. It has optimized reflectance properties and complies with EPA guidance for reducing volatile organic components (VOCs) and hazardous air pollutants (HAPs).

- LSA pigmentation provides a distinct advantage in terms of providing improved UV resistance. Initial estimates were 20% improvement. The results indicate 125% improvement, from 4 to 9 years during accelerated outdoor exposure.
- LSA pigments are nearly identical to the conventional mixed metal iron oxides in terms of formulation loading, compatibility within the coating and shelf life stability.
- The properties of higher reflectance are met by using nearly 100% of the LSA-type pigmentation in the formula. As an example using the black LSA pigment provided nearly 50% reflectance in the near IR, with only 4% doping (96% LSA and 4% of black iron oxide) the reflectance value dropped to 20%.

**Conclusion**

Short-term goals for this collaborative project include applying LSA-enhanced coatings with the new resin system to sculptures by artists for whom the specific aesthetic criteria have already been established. This will be followed by a monitoring programme for the coatings in real time, to compare to accelerated weathering. It is also now planned to expand this collaborative working model to address the needs of outdoor painted sculpture by living artists, and other artists’ estates/foundations.

GCI also recognizes the need for educating conservators, to facilitate the importation of new coatings technology across sectors. By embracing new coating systems, conservators who work on outdoor sculpture must develop a solid understanding of good industrial practices as they implement new high-performance coatings technology for outdoor environments, and will need to be familiar with the full range of options; understand the science behind good preparation and the various coatings systems; and be able to identify good technical work. It is also especially timely since hybrid waterborne chemistries are becoming the new cornerstone of the high-performance coatings industry, and are being adapted by artists, fabricators, and artists’ estates, which will lead to reduced access to many of the more familiar coating systems. While there is a need for better understanding by both painters and conservators, ongoing dialogue between coatings scientists and conservators needs to continue, to identify suitable alternative guidelines when standard preparation procedures are not desirable. It is clear that continued collaboration is critical to ensure that important crossover technology from the military and other sources present new chemistries for cultural heritage.

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