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Photograph: Detail from 'Bridge No. 2' from the series *Rust Never Sleeps*, John Moore, 1996

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.

Keywords: zinc, zinc sculpture, bronze paint, metal powders, American, nineteenth century

Introduction

Zinc is a dull gray metal that became available in large quantities in Europe during the early 19th century and quickly became one of the least expensive metals. By 1825, supply had exceeded demand to the point that a prize was offered by a Prussian industry association for new uses of zinc (Smith 1918). Zinc's first documented sculptural use in Europe followed in 1832 in Berlin (Hierath 2004). The metal's availability, relative low cost and low melting point (420°C) contributed to production of several thousand statues in the United States during the half-century following the American Civil War (1861-1865) (Grissom 2009). These statues filled an increasing demand for low-cost war memorials and for the decoration of civic fountains, county courthouses and grounds of private homes as the nation expanded.

Surfaces of zinc statues were invariably treated to resemble other materials. Bare zinc statues would have been unattractive on account of the dull luster of the metal and multi-piece assembly, which left most criss-crossed by disfiguring lead-tin solder seams. Treatments imitated stone and polychromed wood, but most often bronze. Methods for imitating bronze consisted primarily of paints, sometimes colored only with pigments, but more often incorporating brass or copper powders. For centuries, the latter have been referred to as bronze powders, although they never included copper-tin alloys (Rogers et al. 1973, Schiessl 1983); rather, the term referred to the metal that they imitated.

'Bronzed' statues cost about 10% above base prices for statues with 'one coat of paint' according to trade catalogues of the principal purveyors, the New York-based J.L. Mott Iron Works, J.W. Fiske, Wm. Demuth

& Co., and M.J. Seelig & Co. In a rare statement, one catalogue spelled out subjects suitable for bronzing:

Mythological subjects, such as the Sphinx, Griffin, Dragons, larger Dogs such as the Antique and St. Bernard, also Lions and Horses, should either be painted a stone color, or bronzed; large emblematic figures such as Industry, Justice, Commerce, and other figures used chiefly for buildings, look well bronzed... Figures representing the best works of art, ancient and modern, can either be bronzed or painted white...Such figures as Kiss' Amazon... should always be bronzed, in fact, nearly all the Statuary herein represented look well bronzed... Some of the most elaborate designs in Fountains and Vases look beautifully bronzed, which can be done at a very little extra cost, and will last and look well for a long time (Mott 1873).

Today, the original appearances of many statues have been forgotten, often leading to inappropriate surface treatments, such as painting statues a silver color in imitation of zinc. This paper attempts to aid conservators who seek guidance in applying replacement coatings. To accomplish this goal, historical information on bronze paints will be reviewed, samples of original paints detailed, and examples of recently applied imitation-bronze coatings surveyed.

Historic bronze paints

Nineteenth-century European coating literature described bronze powders and paints, and British and translated

French references were reprinted in the United States, e.g., Roseleur's *Galvanoplastic Manipulations* (Roseleur 1855, 1872). German-made bronze powders dominated commerce from at least the 17th century (Stalker and Parker 1688), however, and were generally referred to in English as Dutch metal, a corruption of *Deutsch* (German). Three companies from historical brassmaking centers of Fürth and Nuremberg were the exclusive exhibitors of bronze powders at the New York Crystal Palace Exhibition in 1853-54 (Association 1853). Eight other German firms exhibited at the Centennial Exhibition in Philadelphia in 1876, as well as one of the Fürth firms that had exhibited earlier, but was now listed in New York, presumably a branch of the German company (U.S. Centennial Commission 1880). The only other exhibitor was the American Bronze Powder Co., started by a pair of German 'meisters' in Brooklyn in 1873 (Rogers et al. 1973).

Structurally, imitation-bronze powders consist of metal platelets that 'float' in media parallel to the surface, maximizing coverage and brilliance. The color of bronze powders becomes more golden as the percentage of zinc to copper increases, up to about 30%. Heat also alters coloration.

Production methods for making metal powders were in transition during the 19th century. Still in use were traditional manual methods that made powders costly on account of the work involved: reduction of metal to foil (requiring pickling and annealing), grinding the foil into flakes with a muller, and polishing. Around 1845, Henry Bessemer invented an all-mechanical process that produced flakes much less expensively, but since he kept it a secret for the next 35 years, traditional production no doubt continued (Bessemer 1989). Manuals also describe dissolution of copper in acid followed by precipitation (Debonliez and Fink 1870), but this would not have produced the requisite plate-like structures.

The historic process for applying bronze paints was often described as beginning with a base coat similar in color to the bronze powder. Green, blue, and yellow ochre pigments were also named (Mussey 1987), and green base layers have been found in England (Bristow 1996).

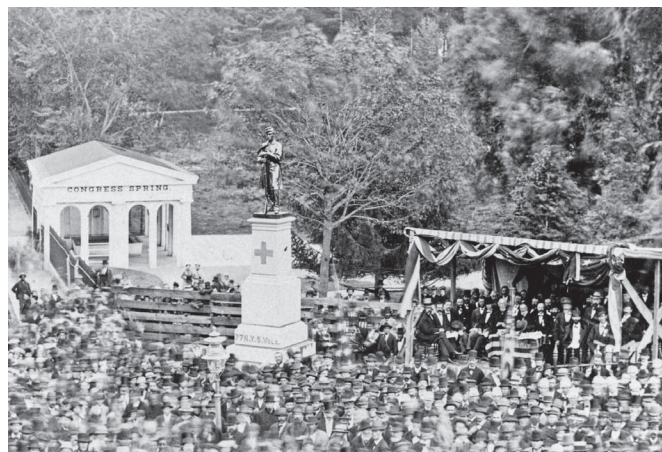


Figure 1. Dedication of the Civil War Monument, Saratoga Springs, NY, in 1875. Courtesy of the Saratoga Springs History Museum.

Two methods were described for application of bronze powders. By the first method, using velvet, soft leather, or a cotton ball, they were pounced onto a tacky oil varnish, gold size (probably an oil/resin mixture), or a mixture of asphaltum, boiled oil, and turpentine (*Painter's Manual* 1868). Alternatively, powders were mixed with a binder and applied as paint. Some manuals suggested limiting use of bronze powders to relief areas (Debonliez and Fink 1870, Mussey 1987). Finally, to prevent corrosion of the metal powders, manuals recommended use of varnish coatings, including shellac, spirit varnishes, and copal (Ure 1866, Hiorns 1892). However, these coatings would have been unsuitable for outdoor use. Documents identify 'spar' (marine) and 'carriage' varnishes as original coatings used on particular statues (Fiske 1893, Bazille & Partridge 1905). Since both coatings were meant for finishing exterior wood, they generally had elastic and weatherproof properties, but exact constituents cannot be known in the absence of analyses of paints from the statues.

Historical descriptions of bronze color on zinc statuary are absent from the literature, but representations provide evidence that most ranged from golden to dark brown, like contemporary bronze sculpture. For example, a photograph shows that a zinc Civil War statue in Saratoga Springs displayed a shiny, dark surface when it was unveiled (see Figure 1). Postcards of monuments were subjectively colored by print processes, but their copper and brown tones reflect perceptions of what was appropriate (see Figure 2). Also providing guidance are original coatings on indoor statues, which appear dark brown unless polychromed (see Figure 3). For gas fixtures made of zinc, 16 bronze colors are named in a catalogue of Cornelius & Sons (1876), including greens, lavenders, and silvers, but they almost certainly represent tints rather than strong colors. A mixture of 10 parts white, 5 parts raw umber, and 4 parts chrome yellow is suggested to imitate bronze without metal flakes in a 20th century manual (Pattou and Vaughn 1927).



Figure 2. Civil War Statue, New Jersey Home for Disabled Soldiers, Kearny, postcard, undated. Both the zinc statue and cast-iron fountain it rests on are toned brown on the postcard.



Figure 3. Departure statuette (ca. 1855-1870), Cornelius & Baker, 34 cm, private collection.

A survey of bronzing would not be complete without mentioning copper plating, used for imitating bronze in Germany and France soon after the discovery of electroplating around 1840 (Smith 1978). Copper plating was applied to statues made of zinc on the seminal *City of New York Civil War Monument* (1869) at Brooklyn's Green-Wood Cemetery. Probably because of the difficulty of electroplating entire sculptures, this instance of plating on outdoor statues was unique until the Daprato Statuary Company introduced its trademarked 'orbronze' in 1913 (Grissom 2009). Copper-plated statues have such poor durability outdoors, however, that they are frequently painted or replaced. Mosaic gold (SnS_2) is also mentioned for bronze coatings in historic literature alongside copper-alloy powders, but it has not been identified on any American zinc statues to date.

Cross-sections

Representative examples of paints sampled from 25 zinc items and examined in cross-section are listed in Table 1, including three samples examined by other conservators. In addition to reflected-light microscopy (bright field,

dark field, and fluorescence), X-ray fluorescence spectroscopy (XRF) and scanning electron microscopy accompanied by energy dispersive spectroscopy (SEM EDS) were used for elemental analysis. SEM also proved useful for imaging metal flakes.

Original bronze paints were found below modern paints on most outdoor statues. In cross-section, the majority was applied in multi-layer systems: an undercoat (often reddish brown paint), followed by a layer containing copper or brass platelets in a transparent medium and a transparent coating (see Figure 4). Others consisted of a single layer containing copper-based flakes (see Figures 5, 6). In both cases, the copper-based flakes measured less than $1\ \mu\text{m}$ in thickness and from 5 to $65\ \mu\text{m}$ in diameter, oriented more or less parallel to the surface. We had hoped to differentiate pounced-on powders from those applied as paints according to flake locations, i.e., at the top or mixed throughout the film, respectively. However, we found that flakes were distributed throughout the layer or had settled to the bottom. Transparent media usually fluoresced, indicating the presence of natural resins or oils, although fluorescence was often difficult to see when non-fluorescing metal flakes were present. Zinc corrosion was observed below original paints, as well as penetrating into them and surrounding copper-based flakes (see Figure 6). In two cases, metal flakes were not found in the oldest paint layers, but it is possible that original layers were lost. Typically, paint samples showed numerous campaigns of repainting (20 or more), with many layers containing copper-based flakes. Flakes in subsequent paints tend to be larger and more regular than those in original paints.

We found some consistency in paints on outdoor statues, probably because Seelig's foundry produced statues sold by Fiske, Mott, and Demuth, as well its own. In some instances, customers must have exercised the option to purchase statues with one coat of paint and finish the statues themselves. On-site painting would have the advantage of precluding damage to foundry coatings during installation.

Original paints on Cornelius & Baker's zinc statuettes displayed indoors are thinner and contain more finely

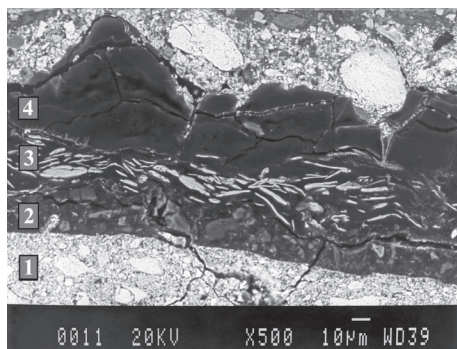


Figure 4. SEM of original bronze paint cross-section at 500x, showing (1) white-lead paint, (2) reddish brown paint, (3) brass-flake layer, and (4) varnish; Neptune (1892), Sailors Snug Harbor, NY.

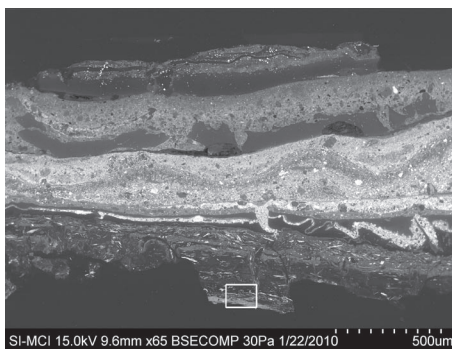


Figure 5. SEM of paint cross-section taken at 65x, showing many layers of paint; Memorial Arch Lion (1879), Princeton, NJ. Box indicates location of Figure 6.

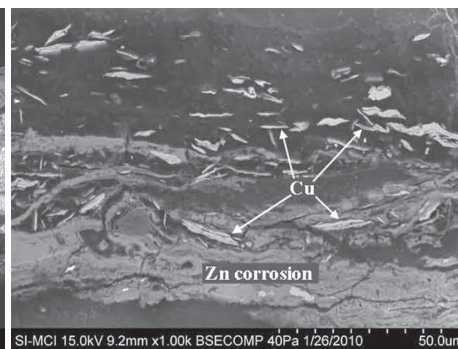


Figure 6. Detail of previous at 1000x, showing original paint layer: copper flakes (white) suspended in medium, penetrated by zinc corrosion (gray) from below.

Statue	Seller	Original Layers ¹ (1=bottommost layer)	Fluor. ²	Avg. layer thickness	Predominant flake diameter	Flake morphology
OUTDOOR STATUES						
Pair of lion statues by A. Schiffelman:						
<i>Memorial Arch</i> (1879) Princeton, NJ		copper flakes in clear medium infiltrated by zinc corrosion	NF	70 µm	6 µm	irregular
<i>Theo and Leo</i> (1920s) National Park Seminary Silver Spring, MD	Mott	copper flakes in clear medium infiltrated by zinc corrosion	NF	40 µm	5 µm	irregular
Fiske Civil War Infantryman statue:						
<i>GAR Fountain</i> (1893) Pottstown, PA	Fiske	1: a few copper flakes in clear medium ³ 2: copper flakes in clear medium 3: a few copper flakes in toned medium		50 µm 30 µm 25 µm	15 µm 30 µm 5 µm	regular regular regular
<i>Soldiers' Memorial Fountain</i> (1890) Oak Bluffs, MA	Fiske	brown & green oil paints (no metallic flakes) ⁴				
Indian Chief statue:						
<i>Squantum</i> (1890) Tilton, NH	Mott	dark gray brown oil/resin mixture (no metallic flakes) ⁵				
<i>Hiawatha</i> (1920s) National Park Seminary Silver Spring, MD		copper flakes in clear medium	NF	15 µm	10 µm	irregular
<i>Neptune Fountain</i> (1892), Sailors Snug Harbor, Staten Island, NY	Fiske	1: white lead paint 2: reddish brown paint 3: brass flakes in clear medium 4: varnish		80 µm 25 µm 20 µm 40 µm	15 µm	irregular
<i>Psyche with Butterfly</i> James Graham, NY		1: reddish brown paint (Pb, Fe, Si, O) 2: brass flakes (95/5) in clear medium	NF NF	35 µm 2 µm	15 µm	regular
<i>Justice</i> (1889) Redding, CA		1: red lead paint 2: brass flakes (90/10) in clear medium 3: varnish	F NF F	40 µm 30 µm 10 µm	30 µm	regular
INDOOR ITEMS						
<i>Departure</i> statuette private collection	Cornelius & Baker	1: brass flakes 2: varnish	PF NF	2 µm 10 µm	<2 µm	
Armorial gaselier (1858), U.S. Capitol Washington, DC	Cornelius & Baker	1: tin flakes in clear medium	PF	15 µm	10 µm	regular

¹ Analyses were performed at the Smithsonian Museum Conservation Institute unless indicated otherwise.

² F=fluorescence, PF=partial fluorescence, NF=no fluorescence

³ Andrew Lins, 'Report on the Grand Army of the Republic Monument', 30 May 1996.

⁴ Susan Buck, private conservator, Williamsburg, VA, personal communication, December 2009.

⁵ Susan Buck, 'Cross-section microscopy analysis results,' 5 December 2001.

Table 1. Representative examples of historic metal paints on zinc artifacts examined in cross-section

MONUMENT	LOCATION	CONSERVATOR/ DATE OF PAINTING	PAINT SYSTEM	CONDITION	SIMULACRUM OF BRONZE
<i>GAR Fountain</i> (1893), Fiske	Pottstown, PA	Douglas Kwart 1997	phosphoric-acid wash primer PPG acrylic urethane primer NCP 250 PPG Deltron DAU (acrylic urethane) plus mica powders	fair: well-attached paint but possible color loss	fair (light)
<i>Soldier's Memorial Fountain</i> (1891), Fiske	Oak Bluffs, MA	Mark Rabinowitz 2000	acrylic urethane primer acrylic urethane paint	well attached paint, but dull	fair (unmodulated)
<i>Squantum</i> (1890), Mott	Tilton, NH	Ron Harvey 2002	phosphoric-acid wash primer Dupont zinc chromate paint Dupont clear acrylic urethane paint plus mica powders Dupont U-POL clear coat & wax	good	good (a bit dark)
<i>Hebe Fountain</i> (1909), Mott	Beacon, NY	Tallix Foundry 2000	unknown primer probably PPG acrylic urethane brown paint with flakes clear top coat	fair	fair (too dark & metallic)
<i>Soldier's Monument</i> (1893), Mott	Candia, NH	Rika Smith McNally 2007	Golden MSA (acrylic) Colors plus Sepp micro-bronze mica powder Incralac & wax	good	good
<i>Spirit of the Fighting Yank</i> (1958), E.M. Viquesney	Chicago, IL	Jane Foley 2009	Golden Gel (acrylic) plus pigments and mica powders Incralac & wax	good	good
<i>Benjamin Franklin</i>	Poughkeepsie, NY	Abigail Mack 2009	Golden GAC 200 (acrylic) paint plus pigments (phthalo green & blue) and sparing mica powder Golden Hard MSA varnish & wax	good	excellent
<i>Fireman's Memorial</i> (1892), Fiske	Trenton, NJ	Moorland Studios 2002	Randolph phosphoric-acid primer Randolph zinc chromate (yellow) primer Randolph acrylic paint plus mica powders	poor	good
<i>Volunteer Fireman Memorial</i> (1915), Fiske	Ottawa, OH	McKay Lodge 2004	Statuary Bronze Sheffield Gold Leaf Metallic Paint (alkyd), containing copper-alloy powders		fair (too glossy, unmodulated)
<i>Chief Hopocan</i> (1911), Fiske	Barberton, OH	Tom Podnar 2001	Statuary Bronze Sheffield Gold Leaf Metallic Paint (alkyd), containing copper-alloy powders		fair (too glossy, unmodulated)
<i>Benjamin Franklin</i> (1879)	San Francisco, CA	Genevieve Baird 2002?	red lead primer metallic grey paint	satisfactory	inaccurate

Table 2. Outdoor zinc statues recently painted with modern imitation-bronze paints (organized by paint type), evaluated in 2009

divided copper-based powders or consist simply of toned translucent coatings. A tin-flake powder was identified on zinc gaselier decorations made by the company, but has not been found on any statuettes to date. Coatings on the statuettes are visibly pockmarked by corrosion and cross-sections display thick layers of zinc corrosion, probably because of minimal protection afforded by the thin coatings.

When examined with the naked eye, plating could be mistaken for metallic paint. However, in cross-section its appearance is unmistakable as a continuous, solid layer rather than distinct flakes (see Figure 7).

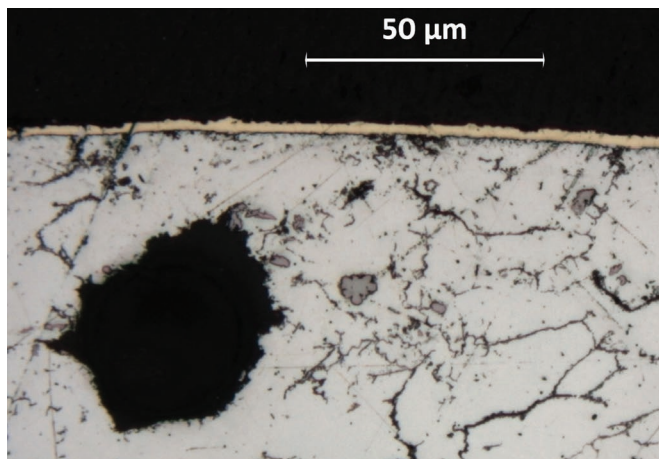


Figure 7. Cross-section of a twentieth-century zinc lamp part, showing copper-based plating.

Modern Replacement Paints

Foregoing surface treatment on outdoor zinc statues that were meant to be painted is an ahistorical and unsatisfactory option in several ways. The zinc was never intended to be seen, and sculptures without coatings are criss-crossed by the darker colored solder that joins the zinc sections. Finally, zinc should be protected from atmospheric corrosion, which occurs at roughly twice the rate of copper corrosion.

Complete understanding of the intended appearance of a particular sculpture may be hampered by the fact that, after more than a century outdoors, its original paint has been covered by later paint, or lost altogether. Thus, as an initial step in the treatment process, cross-sections of paint samples should be made, historic photographs and documents sought, and references consulted regarding typical treatments for particular statue types and manufacturers (Grissom 2009). Products of the Monumental Bronze Co. and its affiliates, for example, were sandblasted to imitate stone and should not be painted.

Producing a satisfactory imitation-bronze paint can be a challenge, and to assist conservators in this endeavor, recently painted statues were surveyed; representative examples are listed in Table 2. From an aesthetic viewpoint, our admittedly subjective evaluations found that the most believable coatings were achieved

by applying slightly different colored layers of paint followed by sparing application of imitation-metal colorants. Given the premise that bronze paint was meant to imitate real bronze to which a brown chemical patina had been applied, variations of dark earth tones seemed to be most successful, especially with darker paints in recessed areas and lighter paints on highlights (Figures 8, 9). Also found to be useful in creating depth and variation was the application of cool-colored underlayers, such as phthalo green and blue, mimicking historic base layers. The least satisfactory coatings were commercial bronze paints applied without modulation, resulting in appearances reminiscent of radiator paint on account of high metallic flake content. Commercial dark brown paint without metal colorants would be a more satisfactory option than commercial bronze paints. In general, darker paints seemed to produce better results than lighter ones.

Greening of copper-alloy powder paints on iron objects was observed by Watin in 1755 and can be seen both on outdoor statues and in cross-sections. To avoid such changes, mica-based flakes rather than metal flakes were added to imitation-bronze coatings by most conservators. No changes were observed in the appearance of coatings containing mica-based powders. In fact, inclusion of mica may increase paint durability (Preston 1973). However, one conservator had difficulty getting sufficient color using mica-based flakes, and has reverted to using copper-alloy flakes (Kwart 2009). Application of both metallic and imitation-metallic flakes achieved a better appearance when sparing, but it is noteworthy that we did not find their inclusion essential. Many outdoor statues are viewed from a distance, where the subtleties provided by flakes may be lost.



Figure 8. Benjamin Franklin (1858) in its original location on the Franklin Lyceum, Providence, RI; now in the collection of Citizens Bank. The invoice for the statue stated that it was purchased 'bronzed' for \$300, and the statue appears dark in this historic photograph. From the Rhode Island Collection at the Providence Public Library.

While it is understood that outdoor paints have limited lifespans, good results for some paints were observed after a decade or more of exposure without maintenance (see Table 2 for specific paint systems). Given that zinc is difficult to coat, good surface preparation is crucial. This generally requires removal of all old paints, with the disadvantage that sampling of original paints will be precluded in the future. Most conservators used methylene chloride-based paint strippers to remove old paints, in one case assisted by walnut-shell-abrasive blasting. Application of a good quality primer is also important in an outdoor setting, but the best choice of primer requires additional research. Mixed results have been noted for phosphoric-acid-based primers (Mottner 1995). A phosphoric-acid-based wash primer may have contributed to excellent adhesion of coatings on the *GAR Fountain* statue in Pottstown after 13 years. On the other hand, the *Fireman's Memorial* in Trenton treated with this type of primer exhibits detachment of coatings at the primer/zinc interface after seven years.

In this limited study set, acrylic urethane paints have achieved excellent results to date. Illustrative is the *Soldier's Memorial Fountain* in Oak Bluffs, Massachusetts, standing in an aggressive saline atmosphere less than 50 meters from the Atlantic Ocean. Although somewhat dulled after 10 years, its coating remains intact, similar to the condition of the acrylic urethane coating observed in Pottstown after 13 years. Acrylic paints have the advantage of reversibility and easier reapplication compared to acrylic urethanes. However, since the longest any of the acrylic paint examples has been exposed is seven years, their durability compared to acrylic urethanes cannot be determined. A German laboratory study showed best adhesion on zinc for acrylic paints, followed by urethanes,



Figure 9. Benjamin Franklin, Vassar College, Poughkeepsie, NY, after repainting in 2009. Nothing remained of the original coating on this statue, a different cast of the statue shown in Figure 8, but the Providence statue provides guidance regarding a suitable treatment.

and poor results for epoxy resins and oil-based coatings (Mottner 1995). In practice, however, oil-based paints have performed well in Germany (Riederer 1997).

Conclusion

Sampling of historic coatings informs the conservator as to materials used during manufacture and repainting. In concert with an understanding of original surfaces of particular statue types, reasonable inference of intended appearance may be determined. Attractive and historically accurate imitation-bronze paints on zinc statues were found to be produced by brown paints modulated according to relief and containing sparing amounts of imitation-bronze flakes. Owing to the limited study set, the most durable coatings could not be determined with certainty, but acrylic urethane paints show excellent durability after as long as 13 years.

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Materials

Dupont
1007 N. Market Street
Wilmington, DE 19801
<http://pc.dupont.com/>

Golden Artist Colors
188 Bell Road
New Berlin, NY 13411-9527
www.goldenpaints.com

PPG Industries
19699 Progress Drive
Strongsville, OH 44149
www.ppg.com

Randolph Products
33 Haynes Circle
Chicopee, MA 01020
www.randolphproducts.com

Sepp Leaf Products
381 Park Avenue South
New York, NY 10016-8819
www.seppleaf.com

Sheffield Bronze Paint Corporation
17814 South Waterloo Road
Cleveland, Ohio 44119
www.sheffieldbronze.com/

References

Association for the Exhibition of the Industry of all Nations, *Official Awards of Juries*, New York: Bryant (1853) 7, 9.

Bazille & Partridge, St. Paul, invoices for painting (September 1889).

Bessemer, H., *Sir Henry Bessemer: An Autobiography*, London: Offices of Engineering (1905). Reprint, London: Institute of Metals (1989) 53-85.

Bristow, I., *Interior House-Painting Colours and Technology 1615-1840*, New Haven: Yale (1996) 140-141.

Buck, S., private conservator, Williamsburg (VA), personal communication (December 2009).

Cornelius & Sons, *Gas Fixtures* (1876).

Debonliez, G., and F. Fink, *Nouveau manuel complet du bronzage des métaux et du plâtre*, Paris: Roret (1870).

Fiske, J.W., to Gov. G.D.S. Trask, unpublished letter, inventory of Sailors' Snug Harbor City Park, Staten Island, New York City (29 June 1893).

Grissom, C.A., *Zinc Sculpture in America: 1850 to 1950*, Newark: University of Delaware Press (2009).

Hierath, S., *Berliner Zinkguss*, Cologne: Letter Stiftung (2004).

Hiorns, A.H., *Metal-Colouring and Bronzing*, London: Macmillan (1892) 317.

Mott, J.L., Iron Works, *Illustrated Catalogue of Statuary* (1873) preface.

Mottner, P., J. Freitag and H. Brückner, 'Condition and conservation of nineteenth century outdoor zinc sculptures', in *From Marble to Chocolate*, London: Archetype (1995) 39-45.

Mussey, R.D. (ed.), *The First American Furniture Finisher's Manual: A Reprint of 'The Cabinet-Makers Guide' of 1827*, New York: Dover (1987) 62-63.

The Painter's Manual, New York: Excelsior (1868) 32.

Pattou, A.B., and C.L. Vaughn, *Furniture Finishing Decoration and Patching*, Chicago: Drake (1927) 364-365.

Preston, J.A., 'Aluminum Potassium Silicate', in *Pigment Handbook: Volume 1 Properties and Economics*, ed. T.C. Patton, Wiley, New York (1973) 249-263.

Riederer, J., 'Korrosionsschäden an Zinkskulpturen', in *Korrosionsschäden an Zinkskulpturen*, Berliner Beiträge zur Archäometrie 14, Berlin: Staatliche Museen zu Berlin (1997) 153-163.

Rogers, P.E., F.S. Greenawald and W.L. Butters, 'Copper and copper alloy flake powders', in *Pigment Handbook*, ed. T.C. Patton, Wiley, New York (1973) vol. 1 807-817.

Roseleur, A., *Manipulations hydroplastiques*, Paris (1855)

253-255.

Roseleur, A., *Galvanoplastic Manipulations*, trans. A.A. Fesquet, Philadelphia: Baird (1872) 378-380.

Schiessl, U., *Techniken des Fassmalerei in Barock und Rokoko: dass alles von Bronze gemacht zu sein scheine*, Worms: Werner (1983).

Smith, C.S., 'The Beginnings of Industrial Metallurgy', *Proceedings of the Symposium on Selected Topics in the History of Electrometallurgy*, ed. G. Dubpernell and J. H. Westbrook, Electrochemical Society, Princeton, NJ (1978) 360-405.

Smith, E., *Zinc Industry*, London: Longmans, Green (1918), 13.

Stalker, J., and G. Parker, *A Treatise of Japanning and Varnishing 1688*, Oxford: by the authors (1688), Reprint, London: Tiranti (1960) 5.

U.S. Centennial Commission, *Reports and Awards*, Washington: Government Printing Office (1880) group 3 226-227.

Ure, A., *A Dictionary of Arts, Manufactures, and Mines*, New York: Appleton (1866) 282-85.

Watin, J.F., *Art du Peintre, Doreur et Vernisseur*, Paris: Chardon (1755), Reprint, Paris: Laget (1975) 176-178.

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