& 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
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).

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 1889). 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).

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).

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IMITATION-BRONZE PAINTS ON AMERICAN ZINC SCULPTURE

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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 µm in thickness and from 5 to 65 µm 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

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,
<table>
<thead>
<tr>
<th>Statue</th>
<th>Seller</th>
<th>Original Layers(^1) (1=bottommost layer)</th>
<th>Fluor.(^2)</th>
<th>Avg. layer thickness</th>
<th>Predominant flake diameter</th>
<th>Flake morphology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OUTDOOR STATUES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Memorial Arch</em> (1879)</td>
<td>Princeton, NJ</td>
<td>copper flakes in clear medium</td>
<td>NF</td>
<td>70 µm</td>
<td>6 µm</td>
<td>irregular</td>
</tr>
<tr>
<td><em>Theo and Leo</em> (1920s)</td>
<td>Mott</td>
<td>copper flakes in clear medium</td>
<td>NF</td>
<td>40 µm</td>
<td>5 µm</td>
<td>irregular</td>
</tr>
<tr>
<td><strong>Fiske Civil War Infantryman statue:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>GAR Fountain</em> (1893)</td>
<td>Fiske</td>
<td>1: a few copper flakes in clear medium(^3)</td>
<td>50 µm</td>
<td>15 µm</td>
<td>regular</td>
<td></td>
</tr>
<tr>
<td><em>Soldiers’ Memorial Fountain</em> (1890)</td>
<td>Fiske</td>
<td>2: copper flakes in clear medium</td>
<td>30 µm</td>
<td>30 µm</td>
<td>regular</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: a few copper flakes in toned medium</td>
<td>25 µm</td>
<td>5 µm</td>
<td>regular</td>
<td></td>
</tr>
<tr>
<td><strong>Indian Chief statue:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Squantum</em> (1890)</td>
<td>Mott</td>
<td>dark gray brown oil/resin mixture (no metallic flakes)(^4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Hiawatha</em> (1920s)</td>
<td></td>
<td>copper flakes in clear medium</td>
<td>NF</td>
<td>15 µm</td>
<td>10 µm</td>
<td>irregular</td>
</tr>
<tr>
<td><strong>Neptune Fountain</strong> (1892), Sailors Snug Harbor, Staten Island, NY</td>
<td>Fiske</td>
<td>1: white lead paint</td>
<td>80 µm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2: reddish brown paint</td>
<td>25 µm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: brass flakes in clear medium</td>
<td>20 µm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4: varnish</td>
<td>40 µm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Psyche with Butterfly</em> James Graham, NY</td>
<td></td>
<td>1: reddish brown paint (Pb, Fe, Si, O)</td>
<td>NF</td>
<td>35 µm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2: brass flakes (95/5) in clear medium</td>
<td>NF</td>
<td>2 µm</td>
<td>15 µm</td>
<td>regular</td>
</tr>
<tr>
<td><strong>Justice</strong> (1889)</td>
<td></td>
<td>1: red lead paint</td>
<td>F</td>
<td>40 µm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2: brass flakes (90/10) in clear medium</td>
<td>NF</td>
<td>30 µm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3: varnish</td>
<td>F</td>
<td>10 µm</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>INDOOR ITEMS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Departure</em> statuette private collection</td>
<td>Cornelius &amp; Baker</td>
<td>1: brass flakes</td>
<td>PF</td>
<td>2 µm</td>
<td>&lt;2 µm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2: varnish</td>
<td>PF</td>
<td>10 µm</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Armorial gaselier</em> (1858), U.S. Capitol Washington, DC</td>
<td>Cornelius &amp; Baker</td>
<td>1: tin flakes in clear medium</td>
<td>PF</td>
<td>15 µm</td>
<td>10 µm</td>
<td>regular</td>
</tr>
</tbody>
</table>

\(^1\) Analyses were performed at the Smithsonian Museum Conservation Institute unless indicated otherwise.

\(^2\) F=fluorescence, PF=partial fluorescence, NF=no fluorescence


\(^4\) Susan Buck, private conservator, Williamsburg, VA, personal communication, December 2009.


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

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

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).

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

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

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).

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.

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.
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.

Acknowledgments

We would like to thank all those conservators who generously provided us with information about treatments, especially Andrew Lins.

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/

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253-255.


Authors

Carol Grissom has been Senior Objects Conservator at the Smithsonian since 1984.

Abigail Mack is an objects conservator in private practice with 17 years of museum conservation experience, most recently at the National Gallery of Art in Washington, DC. Email: abigailmack@gmail.com.

Melvin Wachowiak is Senior Conservator at the Smithsonian. Email: wachowiakm@si.edu.

Genevieve Bieniosek was a preprogram intern at the Smithsonian in 2009-2010, and she is a member of the Buffalo State College Art Conservation Department’s class of 2013. Email: gbieniosek@gmail.com.