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USMMA Historic District Property Maintenance and Repair Manual

Volume 5 – Metal Elements

Sunny E. Adams and Adam D. Smith

June 2018

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Cover Photo: Observe need to repaint metal windows at USMMA, following guidelines and standards (ERDC-CERL, 2015).

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Volume 5 – Metal Elements

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Abstract

The U.S. Merchant Marine Academy is located in Kings Point, New York. The Academy is listed on the National Register of Historic Places (#14000538). The historic district contains contributing mansions constructed during the Gold Coast Era and the Academy buildings constructed in 1942 to 1969. All buildings require regular planned maintenance and repair. The most notable cause of historic building element failure and/or decay is not because the historic building is old, but rather it is caused by an incorrect or inappropriate repair and/or basic neglect of the historic building fabric. This document is a maintenance manual compiled with as-is conditions of building materials at the Academy. The *Secretary of the Interior's Standards for the Treatment of Historic Properties on Preservation, Rehabilitation, and Repair* are discussed per material. This 8-volume report includes an overview volume plus volumes on each of the following elements: concrete, wood, brick, metal, roofing, stucco, and mechanical systems. All mentioned repair procedures are from the U.S. General Services Administration (GSA): Historic Preservation Technical Procedures and/or the National Park Service's series of Preservation Briefs. This report satisfies Section 110 of the National Historic Preservation Act (NHPA) of 1966, as amended.

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Preface

This study was conducted for the U.S. Department of Transportation Maritime Administration (MARAD) under Project Number 450153, “Historic Preservation Plan for U.S. Merchant Marine Academy.” The technical monitor was Barbara Voulgaris, Federal Preservation Officer, U.S. Department of Transportation, MARAD.

The work was performed by the Land and Heritage Conservation Branch (CNC) of the Installations Division (CN), U.S. Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Dr. Michael Hargrave was Chief, CEERD-CNC; and Ms. Michelle Hanson was Chief, CEERD-CN. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti, and the Director was Dr. Lance D. Hansen.

COL Bryan S. Green was the Commander of ERDC, and Dr. David W. Pittman was the Director.

Foreword

ERDC-CERL's effort to put together a guide to proper maintenance and repair of the historic elements at the U.S. Merchant Marine Academy has been divided into multiple volumes for ease of use by installation personnel.

This is Volume 5 of 8, and it covers guidance for proper maintenance and repair of historic metal elements at USMMA.

Please see Volume 1 for an overview of the project and the USMMA's historic context, an explanation of the Secretary of the Interior's Standards and their application, and overviews and lists of immediate concerns for the USMMA's historic exteriors and interiors.

ADAM D. SMITH
Project Manager

1 Metal Elements

NOTE: Maintenance manuals such as those produced as part of this report are a general guide for the historic materials used throughout the USMMA. Do not assume that because a particular building or a particular material on a building is not mentioned in these manuals that the material in need of maintenance or repair does not need to follow the Standards.

1.1 Metal railings

Iron railings are commonly found along hand rails, along stoop sides, and as balustrades along porch and balcony edges. Historically, metal railing profiles, details, and sizes varied with building styles. Metal railing details are considered to be architecturally significant features.

Typical metal railing concerns include lack of regular maintenance, peeling paint, rust or deterioration, and loose or missing pieces. Whatever the causes of deterioration, careful analysis that is supplemented by testing is vital to the success of any metal railing repair project. Repair of metal railings may consist of either refinishing the historic material or filling in with new metal worked to match the historic material. If replacement is necessary, duplication of historic materials and detailing should be exact as possible to assure a repair that is functionally and aesthetically acceptable.

1.1.1 Immediate concerns for metal railings

Iron oxidizes (rusts) quickly when exposed to air and moisture. When pollutants are present (as in many urban environments), the amount of moisture in the air required to begin oxidation is lowered, which means that proper care of ironwork in urban environments is critical.

Examples of metal railings found within the USMMAHD are shown in Figure 1–Figure 5.

Figure 1. Metal handrails on steps on north side of Wiley Hall (ERDC-CERL, 2015).

Figure 2. Metal handrails at the front steps of Land Hall (ERDC-CERL, 2013).

Figure 3. Decorative painted metal railing on window of Melville Hall (ERDC-CERL, 2013).

Figure 4. Decorative painted metal balcony on Melville Hall (ERDC-CERL, 2013).

Figure 5. Rusting metal railings on the roof of Bowditch Hall (ERDC-CERL, 2015).

1.1.1 Guidelines, briefs, bulletins, and sources for metal

In addition to the information contained in this manual, the authors have compiled the following federal resource publications (reproduced here for convenience, with links for online access given in References) to inform managers about standards, guidelines, and procedures for understanding architecture, and caring for, preserving, and rehabilitating historic buildings with emphasis on historic metal features (see subsections 1.1.1.1–1.1.1.7).

1.1.1.1 Cast iron: characteristics, uses, and problems (GSA 2016a)

Cast Iron: Characteristics, Uses and Problems

Procedure code:

501004G

Source:

Outdoor Sculpture Manual - Center For Public Buildings

Division:

Metals

Section:

Metal Materials

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08/08/2016

Preface

This set of guidelines provides general information on the characteristics and common uses of cast iron and identifies typical problems associated with the material. See also: "Checklist for Inspecting Cast Iron Failures".

Introduction

Cast iron is one of the oldest ferrous metals used in construction and outdoor ornament. It is primarily composed of iron (Fe), carbon (C) and silicon (Si), but may also contain traces of sulphur (S), manganese (Mn) and phosphorus (P). It has a relatively high carbon content of 2% to 5%. It is hard, brittle, nonmalleable (i.e. it cannot be bent, stretched or hammered into shape) and more fusible than steel. Its structure is crystalline and it fractures under excessive tensile loading with little prior distortion. Cast iron is, however, very good in compression. The composition of cast iron and the method of manufacture are critical in determining its characteristics.

The most common traditional form is grey cast iron. Common or grey cast iron is easily cast but it cannot be forged or worked mechanically, either hot or cold.

In grey cast iron, the carbon content is in the form of flakes distributed throughout the metal. In white cast iron, the carbon content is combined chemically as carbide of iron. White cast iron has superior tensile strength and malleability. It is also known as 'malleable' or 'spheroidal graphite' iron.

Cast iron is still manufactured by much the same process as it was produced historically. Iron ore is heated in a blast furnace with coke and limestone. This process "deoxidizes" the ore and drives off impurities, producing molten iron. The molten iron is poured into molds of the desired shape and allowed to cool and crystallize.

Upon manufacture, cast iron develops a protective film or scale on the surface which makes it initially more resistant to corrosion than wrought iron or mild steel. Finishing may include bituminous coatings, waxes, paints, galvanizing and plating. In addition, there are a variety of treatments that can reduce rusting and corrosion caused by environmental factors. Factory preservative treatments are typically barrier coatings intended to prevent the castings from oxidizing (rusting) in the presence of humidity and oxygen in the air.

References

- Margot Gayle, David W. Look, John G. Waite. Metals in America's Historic Buildings. Washington, DC: National Park Service, 1992. (USGPO 1992-332-360)
- L. William Zahner. Architectural Metals: A Guide to Selection, Specification, and Performance. New York City: John Wiley & Sons, 1995.

Typical uses

Cast iron is used in a wide variety of structural and decorative applications, because it is relatively inexpensive, durable and easily cast into a variety of shapes. Most of the typical uses include:

1. Historic markers and plaques
2. Hardware: hinges, latches
3. Columns, balusters
4. Stairs
5. Structural connectors in buildings and monuments
6. Decorative features
7. Fences
8. Tools and utensils
9. Ordnance
10. Stoves and firebacks
11. Piping

The basic cast iron material in all of these applications may appear to be the same, or very similar. However, the component size, composition, use, condition, relationship to adjacent materials, exposure and other factors may dictate that different treatments be used to correct similar problems. Any material in question should be evaluated as a part of a larger system and treatment plans should be based upon consideration of all relevant factors.

Problems and Deterioration

Cast iron is extremely strong and durable when used appropriately and protected from adverse exposure. It is much stronger in compression than in tension, therefore it is commonly found in columns, but not in structural beams. It is, however, highly susceptible to corrosion (rusting) when exposed to moisture and it has several typical problems which usually can be identified by visual inspection. The following sections will identify and discuss the most common problems encountered with cast iron. For general guidance on inspecting for cast iron failures, see 05010-01-G.

Natural or Inherent Problems

The typical deterioration or corrosion process for cast iron is a one-step straight line process of oxidation (or rusting) which begins on exposure to air and moisture and will continue (unless interrupted) until the metal is gone. This process is described in the following section.

Rusting

Rusting, or oxidation, is the most frequent and easily recognizable form of cast iron deterioration. Cast iron is highly susceptible to rusting when the humidity is higher than 65%. Iron (Fe) combines with oxygen (O) in the presence of water vapor (H₂O) to become rust (Fe₂O₃). This process can take place at significantly different rates depending on the material composition, protective treatments applied and severity of exposure. If rusting occurs at a rapid rate, it can result in severe damage or total loss of a component in a short time; therefore, the presence of any rust on a cast iron artifact should alert the observer to the presence of a serious problem. Rusting can occur when the humidity is as low as 58% in the presence of certain pollutants, especially sulfur dioxide, ammonia sulfates or even the presence of body oils from touching. Reducing the humidity to 30% or below has been found to be effective in preventing rusting, however this is not a practical solution for outdoor cast iron.

Rusting is such a common problem that it is quite easily recognizable. Rust (Ferrous Oxide, Fe₂O₃, and Ferric Oxide, Fe₃O₄) is an orange colored surface coating, ranging in texture from scaly to powdery. It is loosely bound and the outer layers will usually come off when rubbed by hand or brushed against. It is not a deposit on the surface. Rust is the result of the combination of the iron (Fe) with oxygen (O) in the air, in the presence of moisture. The presence of rust means that some original iron material has been converted to iron oxide and irreversibly lost from the cast iron piece.

The probability of rust occurring is generally dependent upon two factors:

1. The degree of protection (usually a protective coating) provided to keep moisture from contact with the metal, and
2. The degree of moisture present in the air.

Protective coatings used on iron include bituminous coatings (such as tars), waxes, paints and sophisticated metallic coatings. Effective coatings, well maintained, provide the most reliable protection against rust and corrosion of cast iron, however, there are a wide variety of coatings available, and these can be confusing to users not thoroughly versed in the technical data for each type.

Humidity is the second factor affecting the rate of oxidation (rusting) of iron. It is generally accepted that rusting cannot begin unless the relative humidity is at or above 65% (this figure can be lower, however, in the presence of pollutants). Relative humidity is, however, not the only factor to be considered. Once rusting has started, at least two other phenomena may occur:

1. Some rust or ferrous oxide can become hydrated, i.e. it can contain moisture within its chemical structure, thereby exposing the iron to additional moisture, and
2. The porous rust may act as a reservoir for liquid water, keeping it in contact with the iron and perpetuating the rusting process.

Both of these conditions are microscopic in nature and invisible to casual inspection. Maintenance staff and trained personnel, however, should be aware of the processes, and the potential for the processes to damage the cast iron. The presence of visible rust is the symptom indicating that a problem exists. Appropriate action should be taken to prevent rusting, and where it does occur, to correct it with an appropriate treatment. See individual repair or preventive maintenance procedures for specific guidance as needed.

Many other factors can affect both corrosion and the rate of corrosion. Sea water, salt air, cements, plasters, ashes, sulphur, soils and acids can accelerate the corrosion of iron. Corrosion rates can also be accelerated where the detailing of the cast iron provides pockets which can collect and hold moisture and corrosive agents. Preventive maintenance plans should consider detailing, such as crevices and recessed areas, in establishing routine inspection techniques and frequency of inspection.

Graphitization

Cast iron contains carbon, in the form of graphite, in its molecular structure. It is composed of a crystalline structure as are all metals; i.e. it is a heterogeneous mass of crystals of its major elements (Iron, Manganese, Carbon, Sulphur and Silicon). One condition which can occur in the presence of acid rain and/or sea water is "graphitization." The stable graphite crystals remain in place, but the less stable iron becomes converted to insoluble iron oxide (rust). The result is that the cast iron piece retains its shape and appearance but becomes weaker mechanically because of the loss of iron. Graphitization is not, however, a common problem. It generally will occur only after bare metal is left exposed for extended periods, or where failed joints allow the penetration of acidic rainwater to interior surfaces.

This corrosion process is galvanic, with the carbon present acting as the most noble (least corrosive) element and the iron acting as the least noble (most corrosive) element. The composition or microstructure of the iron affects the durability of the object because the rate of corrosion is dependent upon the amount and structure of the graphite present in the iron.

Coatings Failure

Barrier coatings are the most commonly used protective mechanisms for cast iron. Some type of coating (such as a wax, paint or metallic coating) should probably be considered an integral feature of cast iron in service. The absence of such a coating, or a failure in an existing coating should be corrected. Inspection should include a visual examination of all surfaces to determine if a coating exists, a fact which may be very apparent for opaque paints and coatings but substantially less apparent for clear lacquers, waxes or oils. Surfaces having the appearance of raw metal should be carefully examined for signs of rusting. Absence of a coating should be considered a major problem and corrective action should be undertaken. See individual repair or preventive maintenance procedures for specific guidance as needed.

Failure of a coating should also be identified and corrected. Coatings can wear away, crack, flake, blister, or peel away, indicating that the coating has failed and is no longer protecting the cast iron from moisture. Failed coatings can, in fact, trap moisture beneath the film and accelerate corrosion at certain points on the surface. Inspection of the surface should include a careful check for all of these types of coating failures. A record should be made of any coating failures observed so that corrective action may be taken.

Mechanical Failure

Mechanical failures of cast iron are typically of two types and are relatively common problems.

1. Structural Failure:

Cast iron may contain various imperfections due to the manufacturing process. These may occur due to air holes, interrupted pouring, uneven cooling (cold sheets), cracks and cinders. Where such imperfections occur, the piece may be weakened mechanically, sometimes severely. These manufacturing problems are not generally visible upon inspection; however, there are several non-destructive techniques of identifying these types of problems, such as the use of fluorescent fluids and ultraviolet lamps, or x-ray. These non-destructive techniques require specialized knowledge and equipment, and are not generally feasible for use by maintenance staff. They should be undertaken by specialists with experience.

Visible inspection may, however, enable detection of mechanical failures after the failure has occurred or begun to occur. Stress cracks in paint or metal may be symptomatic of this problem. Failures may begin as gradual separations which are visible upon inspection, and may be detected and corrected prior to a total, catastrophic failure of the piece. Linear cracks in paint film or metal should be investigated and/or monitored to determine if they are active. Non-destructive techniques may be used if symptoms exist, but the Regional Historic Preservation Officer (RHPO) should be consulted in the solicitation of professionals who are experienced in use of these techniques.

2. Mechanical Failure of Connections:

Larger cast iron pieces are generally systems composed of smaller castings, mechanically connected. This can even be the case for a simple baluster or historical marker. One of the most common failures that occurs with such systems is the failure of the connectors or joints. Loose, missing or broken screws, clamps or bolts may result in loose, failed or missing components. Visual inspection should include examination of cast iron pieces for sections which are loose and/or disoriented, and which have loose or missing screws or bolts. Further manipulation by hand, with probes, may indicate whether a casting is a discrete piece, mechanically attached, and whether or not it is in the early stages of working loose. It is especially important to detect connectors which are in danger of imminent failure if not corrected. Corrective action should be undertaken in either case, but the treatment plan should take into account the severity of the problem, consequences of failure and nature of the intervention required to correct the problem. See individual repair procedures for specific guidance as needed.

Another mechanical problem can be caused by inappropriate mechanical repairs to broken pieces. Some repairs may create openings that allow water penetration and "pockets" that collect water, both of which can cause problems. Castings which have been filled with concrete are also a potential problem since they may promote "crevice corrosion" due to entrapped water. Visual inspections should check for such conditions and where they exist, maintenance staff should plan to correct the problems and/or be vigilant for signs of deterioration.

Cast Iron Alloys for Replacements

Cast iron problems, especially corrosion problems, may be reduced or eliminated in cast iron that is an alloy of silicon, nickel, chromium and/or copper. For example, silicon is often present in cast iron to some degree, but it is not considered an alloy until the percentage exceeds the 3% upper range of non-alloy cast iron. Where silicon is present, a protective surface film develops during oxidation.

There are three main categories of cast iron alloys:

1. High silicon
2. High chromium
3. High nickel (frequently containing copper or chromium)

All of these alloys, plus copper alloys, have been tested and found to have increased corrosion resistance. The degree of increased resistance is dependent on many factors, primarily the alloying metal and the percentage of alloy relative to the carbon content of the cast iron. While a discussion of alloy durability and formulation is beyond the scope of this standard, users should be aware of the effect of alloying and consider the implications when ordering new cast iron replacement objects. Such consideration may involve experienced metallurgists, foundrymen, conservators, and historical architects.

Maintenance of Cast Iron

The maintenance principles for cast iron are, in order of appearance:

1. Prevent rust and corrosion.
2. Paint and plug holes.
3. Maintain structural soundness.
4. Keep it together with binding and bolts, welding, etc., and brace loose elements by resetting.
5. Recreate missing pieces using casting replacement parts (iron, aluminum, fiberglass, or epoxy), or wooden replacements, with appropriate composition and/or coatings to provide for color blending.

Cast iron requires continual maintenance. Check periodically for water collection spots and dry as necessary. Signs of corrosion are when rusty looking stain marks appear on the metal. If these areas are rubbed the metal surface is revealed as well as traces of perforation. Check for small chips in the coating surface and peeling of the coating surface.

Replace or repair as necessary if the damage is minimal missing and deteriorated pieces of metal prior to cleaning. If deteriorated condition is left unrepaired, perforation of the metal will occur and as a result structural failure.

Structural iron maintenance may require the services of a structural engineer when severe erosion or distortion occurs, to assist in the development of repair techniques when material loss is involved. For these repairs use only a professional iron worker. Before installation of new material verify the metal type and thickness. Prior to installation, remove all oil, dirt, and other debris from the surface. All surfaces shall be dry and free from frost.

1.1.1.2 Wrought iron: characteristics, uses and problems (GSA 2016b)

Wrought Iron: Characteristics, Uses and Problems

Procedure code:

501011G

Source:

Developed For HSPG (NPS- SERO)

Division:

Metals

Section:

Metal Materials

Last Modified:

07/15/2016

References

Gayle, Margot, Look, David, and Waite, John. Metals in America's Historic Buildings: Uses and Preservation Treatments. Washington, DC: National Park Service, 1992.

Zahner, L. William. Architectural Metal Surfaces. New York: Wiley 2004.

Introduction

Iron is a dark grey metal and is the major constituent of a range of materials including wrought iron, cast iron, carbonized iron (carbon steel) and steel, each of which has its own unique properties. Iron was first used as a material for tools and weapons. Its uses have since grown to include items for domestic use to architectural building components. The presence of iron in a feature may be detected with a magnet.

Wrought iron differs from cast iron and steel in that it contains less carbon. The three metals are ranked as follows in terms of their carbon content:

- A. Wrought iron: Contains the smallest amount of carbon (less than .035%).
- B. Steel: Contains a moderate amount of carbon (between .06% and 2%).
- C. Cast Iron: Contains the largest amount of carbon (between 2% and 4%).

Characteristics of Wrought Iron

- Soft.

- Ductile.
- Magnetic.
- Strong - high elasticity and tensile strength.
- Malleable - can be heated and reheated and worked into various shapes.
- Becomes stronger the more it is worked.
- Suitable for members in tension or compression (whereas cast iron is suitable for members in compression only).

Stages of the Indirect Reduction Process for Making Wrought Iron

Stage 1: Preparation of puddled iron.

1. Pig iron was first smelted in blast furnaces and subjected to a reducing condition when it apparently 'boiled'.
2. The boiling iron was worked continuously by the iron puddler and more impurities were removed from the iron, making the iron stiffer.
3. The iron was boiled until virtually no carbon remained, leaving a pasty mass of iron. This was evident when the carbon monoxide would stop bubbling through the iron.
4. The iron was then formed into balls to be molded.

Stage 2: Iron balls were hammered with a shingling hammer, to expel surplus slag or cinder (shingled).

1. Shingling was completed in minutes and the finished product was a bloom of approximately 5 inches x 5 inches x 3 feet.
2. The bloom, still at bright red heat, was then passed through rolling mills, becoming more elongated and thinner in section after each pass, and finished as puddled iron bar.

Stage 3: The bars were reheated and reworked as required to achieve the desired grades.

1. This stage increased the ductility and tensile strength of the puddled iron.
2. The more times the metal was reheated and reworked, the stronger were its mechanical properties.

Typical Uses

Historical uses during the seventeenth and eighteenth centuries were typically decorative and included:

- Fences, gates and railings.
- Balconies.
- Porches and verandas.
- Canopies.
- Roof cresting.
- Lamps.
- Grilles.
- Hardware.

Historical uses during the nineteenth century were more structural and included:

- Nails.
- Iron cramps (i.e. to secure masonry veneer building frames).
- Structural members in tension such as tie rods, bulb-tees and I-beams. The standard sections of wrought iron included bar iron, angle irons, T irons, channel iron (half H iron), rolled girder iron (rolled joist iron, beam iron, I iron, or H iron), various special sections (sash bar, beading iron, cross iron, quadrant iron), iron bars, rivet iron, chain iron, horseshoe iron, nail iron, plate iron, coated iron (tin or lead), and corrugated sheet iron (generally galvanized).

Note: By the end of the nineteenth century, the use of wrought iron for structural purposes had been superseded by steel.

Problems and Deterioration

Problems may be classified into two broad categories: 1) Natural or inherent problems based on the characteristics of the material and the conditions of the exposure, and 2) Vandalism and human-induced problems.

Although there is some overlap between the two categories, the inherent material deterioration problems generally occur gradually over long periods of time, at predictable rates and require appropriate routine or preventive maintenance to control. Conversely, many human induced problems, (especially vandalism), are random in occurrence; can produce catastrophic results; are difficult to prevent, and require emergency action to mitigate. Some human induced problems, however, are predictable and occur routinely.

Natural or Inherent Problems

Chemical corrosion can attack decorative and structural wrought iron features in several ways:

- A. Uniform Attack: Corrosion attacks the metal surface evenly.
- B. Pitting: Attacks the metal surface in selected areas.
- C. Selective Attack: When a metal is not homogenous throughout, certain areas may be attacked in preference to others.
- D. Stress corrosion cracking: Attacks areas in a metal which were stressed during metal working and were later exposed to a corrosive environment. Old, hand wrought iron items are more likely to be affected than are machine rolled wrought iron pieces.
- E. Rust: Probably the most common form of chemical corrosion of wrought iron. It occurs when unprotected metal is exposed to oxygen in the atmosphere in the presence of moisture. Moisture can be in the form of normal humidity, rain, dew, condensation, etc. Other gases, such as carbon dioxide, sulfur compounds, soot and fly ash will exacerbate the corrosion of the iron, as will airborne salts.
- F. Galvanic (or Electro-Chemical) Corrosion: Galvanic corrosion occurs when two dissimilar metals are in contact with one another and an electrolyte, such as rainwater, condensation, dew, fog, etc. is present. Such a reaction will cause one or the other of the metals to corrode. In the case of wrought iron, direct contact with copper or zinc, and to a lesser extent galvanized iron or steel, will cause galvanic corrosion.

Vandalism or Human-Induced Problems

- A. Mechanical or physical deterioration:
 1. Fatigue: Failure of metal that has been repeatedly stressed beyond its elastic limit.

- a. Wrought iron is generally fatigue resistant because it is so tough. It will deform considerably, within its elastic limit, without failure.
 - b. Even if past overloading has caused deformation, wrought iron fixings will usually continue to function.
 - c. Defects in the wrought iron itself, or stress points can cause a feature to fracture.
 2. Heat: Usually in the form of fire, will cause wrought iron features to become plastic, distort, and fail.
 3. Distortion: Permanent deformation or failure may occur when a metal is overloaded beyond its yield point because of increased live or dead loads, thermal stresses, or structural modifications altering a stress regime.
- B. Connection failure:
1. Chemical and mechanical processes can breakdown or reduce the effectiveness of structural metal fixings such as bolts, rivets, and pins.
 2. Stress failure is often a contributor to breakdown situations. Iron water traps are particularly susceptible.

1.1.1.3 Maintenance and repair of cast iron – Preservation Brief #27 (Waite and Gayle 1991)

PRESERVATION BRIEFS

27

The Maintenance and Repair of Architectural Cast Iron

John G. Waite, AIA, Historical Overview by Margot Gayle

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Cast iron feature in need of cleaning and painting. Photo: Courtesy, New York Landmarks Conservancy.

The preservation of cast-iron architectural elements, including entire facades, has gained increasing attention in recent years as commercial districts are recognized for their historic significance and revitalized. This Brief provides general guidance on approaches to the preservation and restoration of historic cast iron.

Cast iron played a pre-eminent role in the industrial development of our country during the 19th century. Cast-iron machinery filled America's factories and made possible the growth of railroad transportation. Cast iron was used extensively in our cities for water systems and street lighting. As an architectural metal, it made possible bold new advances in architectural designs and building technology, while providing a richness in ornamentation.

This age-old metal, an iron alloy with a high carbon content, had been too costly to make in large quantities until the mid-18th century, when new furnace technology in England made it more economical for use in construction. Known for its great strength in compression, cast iron in the form of slender, nonflammable pillars, was introduced in the 1790s in English cotton mills, where fires were endemic. In the United States, similar thin columns were first employed in the 1820s in theaters and churches to support balconies.

This shows a detail of a polychromed cast-iron facade in Petaluma, California, 1886 (O'Connell and Lewis, Architectural Iron Works, San Francisco). Photo: Don Meacham.

By the mid-1820's, one-story iron storefronts were being advertised in New York City. Daniel Badger, the Boston foundryman who later moved to New York, asserted that in 1842 he fabricated and installed the first rolling iron shutters for iron storefronts, which provided protection against theft and external fire. In the years ahead, and into the 1920s, the practical cast-iron storefront would become a favorite in towns and cities from coast to coast. Not only did it help support the load of the upper floors, but it provided large show windows for the display of wares and allowed natural light to flood the interiors of the shops. Most importantly, cast-iron storefronts were inexpensive to assemble, requiring little onsite labor.

A tireless advocate for the use of cast iron in buildings was an inventive New Yorker, the self-taught architect/engineer James Bogardus. From 1840 on, Bogardus extolled its virtues of strength, structural stability, durability, relative lightness, ability to be cast in almost any shape and, above all, the fire-resistant qualities so sought after in an age of serious urban conflagrations. He also stressed that the foundry casting processes, by which cast iron was made into building elements, were thoroughly compatible with the new concepts of prefabrication, mass production, and use of identical interchangeable parts.

In 1849 Bogardus created something uniquely American when he erected the first structure with self-supporting, multi-storied exterior walls of iron. Known as the Edgar Laing Stores, this corner row of small four-story warehouses that looked like one building was constructed in lower Manhattan in only two months. Its rear, side, and interior bearing walls were of brick; the floor framing consisted of timber joists and girders. One of the cast-iron walls was load-bearing, supporting the wood floor joists. The innovation was its two street facades of self-supporting cast iron, consisting of multiples of only a few pieces—Doric-style engaged columns, panels, sills, and plates, along with some applied ornaments. Each component of the facades had been cast individually in a sand mold in a foundry, machined smooth, tested for fit, and finally trundled on horse-drawn drays to the building site. There they were hoisted into position, then bolted together and fastened to the conventional structure of timber and brick with iron spikes and straps.

The second iron-front building erected was a quantum leap beyond the Laing Stores in size and complexity. Begun in April 1850 by Bogardus, with architect Robert Hatfield, the five-story Sun newspaper building in Baltimore was both cast-iron-fronted and cast-iron-framed. In Philadelphia, several iron-fronts were begun in 1850: The Inquirer Building, the Brock Stores, and the Penn Mutual Building (all three have been demolished). The St. Charles Hotel of 1851 at 60 N. Third Street is the oldest iron-front in America. Framing with cast-iron columns and wrought-iron beams and trusses was visible on a vast scale in the New York Crystal Palace of 1853.

In the second half of the 19th century, the United States was in an era of tremendous economic and territorial growth. The use of iron in commercial and public buildings spread rapidly, and hundreds of iron-fronted buildings were erected in cities across the country from 1849 to beyond the turn of the century. Outstanding examples of iron-fronts exist in Baltimore, Galveston, Louisville, Milwaukee, New Orleans, Philadelphia, Richmond, Rochester (N.Y.), and especially New York City where the SoHo Cast Iron Historic District alone has 139 iron-fronted buildings. Regrettably, a large proportion of iron-fronts nationwide have been demolished in downtown redevelopment projects, especially since World War II.

In addition to these exterior uses, many public buildings display magnificent exposed interior ironwork, at once ornamental and structural. Remarkable examples have survived across the country, including the Peabody Library in Baltimore; the Old Executive Office Building in Washington, D.C.; the Bradbury Building in Los Angeles; the former Louisiana State Capitol; the former City Hall in Richmond; Tweed Courthouse in New York; and the state capitols of California, Georgia, Michigan, Tennessee, and Texas. And it is iron, of course, that forms the great dome of the United States Capitol, completed during the Civil War. Ornamental cast iron was a popular material in the landscape as well, appearing as fences, fountains with statuary, lampposts, furniture, urns, gazebos, gates, and enclosures for cemetery plots. With such widespread demand, many American foundries that had been casting machine parts, bank safes, iron pipe, or cookstoves added architectural iron departments. These called for patternmakers with sophisticated design capabilities, as well as knowledge of metal shrinkage and other technical aspects of casting. Major companies included the Hayward Bartlett Co. in Baltimore; James L. Jackson, Cornell Brothers, J. L. Mott, and Daniel D. Badger's Architectural Iron Works in Manhattan; Heda Ironworks in Brooklyn; Wood and Perot of Philadelphia; Leeds and Co., the Shakspeare (sic) Foundry, and Miltenberger in New Orleans; Winslow Brothers in Chicago; and James McKinney in Albany, N.Y.

Cast iron was the metal of choice throughout the second half of the 19th century. Not only was it a fire-resistant material in a period of major urban fires, but also large facades could be produced with cast iron at less cost than comparable stone

The Slater Family Tomb in Mobile, Alabama, consisting of a cast-iron mausoleum and fence, exhibits the wide range of uses of the material in the 19th century. Photo: Jack E. Boucher, HAB S Collection.

fronts, and iron buildings could be erected with speed and efficiency. The largest standing example of framing with cast-iron columns and wrought-iron beams is Chicago's sixteen-story Manhattan Building, the world's tallest skyscraper when built in 1890 by William LeBaron Jenney. By this time, however, steel was becoming available nationally, and was structurally more versatile and cost-competitive. Its increased use is one reason why building with cast iron diminished around the turn of the century after having been so eagerly adopted only fifty years before. Nonetheless, cast iron continued to be used in substantial quantities for many other structural and ornamental purposes well into the 20th century: storefronts; marquees; bays and large window frames for steel-framed, masonry-clad buildings; and street and landscape furnishings, including subway kiosks.

The 19th century left us with a rich heritage of new building methods, especially construction on an altogether new scale that was made possible by the use of metals. Of these, cast iron was the pioneer, although its period of intensive use lasted but a half century. Now the surviving legacy of cast-iron architecture, much of which continues to be threatened, merits renewed appreciation and appropriate preservation and restoration treatments.

What is Cast Iron?

Cast iron is an alloy with a high carbon content (at least 1.7% and usually 3.0 to 3.7%) that makes it more resistant to corrosion than either wrought iron or steel. In addition to carbon, cast iron contains varying amounts of silicon, sulfur, manganese, and phosphorus.

While molten, cast iron is easily poured into molds, making it possible to create nearly unlimited decorative and structural forms. Unlike wrought iron and steel, cast iron is too hard and brittle to be shaped by hammering, rolling, or pressing. However, because it is more rigid and more resistant to buckling than other forms of iron, it can withstand great compression loads. Cast iron is relatively weak in tension, however and fails under tensile loading with little prior warning.

The characteristics of various types of cast iron are determined by their composition and the techniques used in melting, casting, and heat treatment. Metallurgical constituents of cast iron that affect its brittleness, toughness, and strength include ferrite, cementite, pearlite, and graphite carbon. Cast iron with flakes of carbon is called gray cast iron. The "gray fracture" associated with cast iron was probably named for the gray, grainy appearance of its broken edge caused by the presence of flakes of free graphite, which account for the brittleness of cast iron. This brittleness is the important distinguishing characteristic between cast iron and mild steel.

The risers on these cast iron steps feature a highly decorative pattern. Photo: NPS files.

Compared with cast iron, wrought iron is relatively soft, malleable, tough, fatigue-resistant, and readily worked by forging, bending, and drawing. It is almost pure iron, with less than 1% (usually 0.02 to 0.03%) carbon. Slag varies between 1% and 4% of its content and exists in a purely physical association, that is, it is not alloyed. This gives wrought iron its characteristic laminated (layered) or fibrous structure.

Wrought iron can be distinguished from cast iron in several ways. Wrought-iron elements generally are simpler in form and less uniform in appearance than cast-iron elements, and contain evidence of rolling or hand working. Cast iron often contains mold lines, flashing, casting flaws, and air holes. Cast-iron elements are very uniform in appearance and are frequently used repetitively. Cast-iron elements are often bolted or screwed together, whereas wrought-iron pieces are either riveted or forge-molded (heat welded) together.

Mild steel is now used to fabricate new hand-worked metal work and to repair old wrought-iron elements. Mild steel is an alloy of iron and is not more than 2% carbon, which is strong but easily worked in block or ingot form. Mild steel is not as resistant to corrosion as either wrought iron or cast iron.

Maintenance and Repair

Many of the maintenance and repair techniques described in the Brief, particularly those relating to cleaning and painting, are potentially dangerous and should be carried out only by experienced and qualified workmen using protective equipment suitable to the task. In all but the most simple repairs, it is best to involve a preservation architect or building conservator to assess the condition of the iron and prepare contract documents for its treatment.

As with any preservation project, the work must be preceded by a review of local building codes and environmental protection regulations to determine whether any conflicts exist with the proposed treatments. If there are conflicts, particularly with cleaning techniques or painting materials, then waivers or variances need to be negotiated, or alternative treatments or materials adopted.

Deterioration

Common problems encountered today with cast-iron construction include badly rusted or missing elements, impact damage, structural failures, broken joints, damage to connections, and loss of anchorage in masonry.

Oxidation, or rusting, occurs rapidly when cast iron is exposed to moisture and air. The minimum relative humidity necessary to promote rusting is 65%, but this figure can be lower in the presence of corrosive agents, such as sea water, salt air, acids, acid precipitation, soils, and some sulfur compounds present in the atmosphere, which act as catalysts in the oxidation process. Rusting is accelerated in situations where architectural details provide pockets or crevices to trap and hold liquid corrosive agents. Furthermore, once a rust film forms, its porous surface acts as a reservoir for liquids, which in turn causes further corrosion. If this process is not arrested, it will continue until the iron is entirely consumed by corrosion, leaving nothing but rust.

Structural crack, gaps at joints between components, and a large opening where part of the console bracket is missing are the problems evident in this cast-iron assembly. Photo: Ford, Powell & Carson.

Galvanic corrosion is an electrochemical action that results when two dissimilar metals react together in the presence of an electrolyte, such as water containing salts or hydrogen ions. The severity of the galvanic corrosion is based on the difference in potential between the two metals, their relative surface areas, and time. If the more noble metal (higher position in electrochemical series) is much larger in area than the baser, or less noble, metal, the deterioration of the baser metal will be more rapid and severe. If the more noble metal is much smaller in area than the baser metal, the deterioration of the baser metal will be much less significant. Cast iron will be attacked and corroded when it is adjacent to more noble metals such as lead or copper.

Graphitization of cast iron, a less common problem, occurs in the presence of acid precipitation or seawater. As the iron corrodes, the porous graphite (soft carbon) corrosion residue is impregnated with insoluble corrosion products. As a result, the cast-iron element retains its appearance and shape but is weaker structurally. Graphitization occurs where cast iron is left unpainted for long periods or where caulked joints have failed and acidic rainwater has corroded pieces from the backside. Testing and identification of graphitization is accomplished by scraping through the surface with a knife to reveal the crumbling of the iron beneath. Where extensive graphitization occurs, usually the only solution is replacement of the damaged element.

Castings may also be fractured or flawed as a result of imperfections in the original manufacturing process, such as air holes, cracks, and cinders, or cold shuts (caused by the "freezing" of the surface of the molten iron during casting because of improper or interrupted pouring). Brittleness is another problem occasionally found in old cast-iron elements. It may be a result of excessive phosphorus in the iron, or of chilling during the casting process.

Condition Assessment

Before establishing the appropriate treatment for cast-iron elements in a building or structure, an evaluation should be made of the property's historical and architectural significance and alterations, along with its present condition. If the work involves more than routine maintenance, a qualified professional should be engaged to develop a historic structure report which sets forth the historical development of the property, documents its existing condition, identifies problems of repair, and provides a detailed listing of recommended work items with priorities. Through this process the significance and condition of the cast iron can be evaluated and appropriate treatments proposed. For fences, or for single components of a building such as a facade, a similar but less extensive analytical procedure should be followed.

The nature and extent of the problems with the cast-iron elements must be well understood before proceeding with work. If the problems are minor, such as surface corrosion, flaking paint, and failed caulking, the property owner may be able to undertake the repairs by working directly with a knowledgeable contractor. If there are major problems or extensive damage to the cast iron, it is best to secure the services of an architect or conservator who specializes in the conservation of historic buildings. Depending on the scope of work, contract documents can range from outline specifications to complete working drawings with annotated photographs and specifications.

To thoroughly assess the condition of the ironwork, a close physical inspection must be undertaken of every section of the iron construction including bolts, fasteners, and brackets. Typically, scaffolding or a mechanical lift is employed for close inspection of a cast-iron facade or other large structures. Removal of select areas of paint may be the only means to determine the exact condition of connections, metal fasteners, and intersections or crevices that might trap water.

An investigation of load-bearing elements, such as columns and beams, will establish whether these components are performing as they were originally designed, or the stress patterns have been redistributed. Areas that are abnormally stressed must be examined to ascertain whether they have suffered damage or have been displaced. Damage to a primary structural member is obviously critical to identify and evaluate; attention should not be given only to decorative features.

The condition of the building, structure, or object; diagnosis of its problems; and recommendations for its repair should be recorded by drawings, photographs, and written descriptions, to aid those who will be responsible for its conservation in the future.

Whether minor or major work is required, the retention and repair of historic ironwork is the recommended preservation approach over replacement. All repairs and restoration work should be reversible, when possible, so that modifications or treatments that may turn out to be harmful to the long-term preservation of the iron can be corrected with the least amount of damage to the historic ironwork.

Cleaning and Paint Removal

When there is extensive failure of the protective coating and/or when heavy corrosion exists, the rust and most or all of the paint must be removed to prepare the surfaces for new protective coatings. The techniques available range from physical processes, such as wire brushing and grit blasting, to flame cleaning and chemical methods. The selection of an appropriate technique depends upon how much paint failure and corrosion has occurred, the fineness of the surface detailing, and the type of new protective coating to be applied. Local environmental regulations may restrict the options for cleaning and paint removal methods, as well as the disposal of materials.

Many of these techniques are potentially dangerous and should be carried out only by experienced and qualified workers using proper eye protection, protective clothing, and other workplace safety conditions. Before selecting a process, test panels should be prepared on the iron to be cleaned to determine the relative effectiveness of various techniques. The cleaning process will most likely expose additional coating defects, cracks, and corrosion that have not been obvious before.

There are a number of techniques that can be used to remove paint and corrosion from cast iron: Hand scraping, chipping, and wire brushing are the most common and least expensive methods of removing paint and light rust from cast iron. However, they do not remove all corrosion or paint as effectively as other methods. Experienced craftsmen should carry out the work to reduce the likelihood that surfaces may be scored or fragile detail damaged.

Low-pressure grit blasting (commonly called abrasive cleaning or sandblasting) is often the most effective approach to removing excessive paint buildup or substantial corrosion. Grit blasting is fast, thorough, and economical, and it allows the iron to be cleaned in place. The aggregate can be iron slag or sand; copper slag should not be used on iron because of the potential for electrolytic reactions. Some sharpness in the aggregate is beneficial in that it gives the metal surface a "tooth" that will result in better paint adhesion. The use of a very sharp or hard aggregate and/or excessively high pressure (over 100 pounds per square inch) is unnecessary and should be avoided. Adjacent materials, such as brick, stone, wood, and glass, must be protected to prevent damage. Some local building codes and environmental authorities prohibit or limit dry sandblasting because of the problem of airborne dust.

Wet sandblasting is more problematic than dry sandblasting for cleaning cast iron because the water will cause instantaneous surface rusting and will penetrate deep into open joints. Therefore, it is generally not considered an effective technique. Wet sandblasting reduces the amount of airborne dust when removing a heavy paint buildup, but disposal of effluent containing lead or other toxic substances is restricted by environmental regulations in most areas.

Flame cleaning of rust from metal with a special multi-flame head oxyacetylene torch requires specially skilled operators, and is expensive and potentially dangerous. However, it can be very effective on lightly to moderately corroded iron. Wire brushing is usually necessary to finish the surface after flame cleaning.

Chemical rust removal, by acid pickling, is an effective method of removing rust from iron elements that can be easily removed and taken to a shop for submerging in vats of dilute phosphoric or sulfuric acid. This method does not damage the surface of iron, providing that the iron is neutralized to pH level 7 after cleaning. Other chemical rust removal agents include ammonium citrate, oxalic acid, or hydrochloric acid-based products.

Chemical paint removal using alkaline compounds, such as methylene chloride or potassium hydroxide, can be an effective alternative to abrasive blasting for removal of heavy paint buildup. These agents are often available as slow-acting gels or pastes. Because they can cause burns, protective clothing and eye protection must be worn. Chemicals applied to a non-watertight facade can seep through crevices and holes, resulting in damage to the building's interior finishes and corrosion to the backside of the iron components. If not thoroughly neutralized, residual traces of cleaning compounds on the surface

Where chemical paint stripping is involved, careful planning of the sequence of work and inspection by an architect or conservator to ensure strict compliance with the contract documents is important to minimize the risk of problems. Photo: Raymond M. Pepl, Building Conservation Associates.

of the iron can cause paint failures in the future. For these reasons, field application of alkaline paint removers and acidic cleaners is not generally recommended.

Following any of these methods of clearing and paint removal, the newly cleaned iron should be painted immediately with a corrosion-inhibiting primer before new rust begins to form. This time period may vary from minutes to hours depending on environmental conditions. If priming is delayed, any surface rust that has developed should be removed with a clean wire brush just before priming, because the rust prevents good bonding between the primer and the cast-iron surface and prevents the primer from completely filling the pores of the metal.

Painting and Coating Systems

The most common and effective way to preserve architectural cast iron is to maintain a protective coating of paint on the metal. Paint can also be decorative, where historically appropriate.

Before removing paint from historic architectural cast iron, a microscopic analysis of samples of the historic paint sequencing is recommended. Called paint seriation analysis, this process must be carried out by an experienced architectural conservator. The analysis will identify the historic paint colors, and other conditions, such as whether the paint was matte or gloss, whether sand was added to the paint for texture, and whether the building was polychromed or marbled. Traditionally, many cast-iron elements were painted to resemble other materials, such as limestone or sandstone. Occasionally, features were faux-painted so that the iron appeared to be veined marble.

Thorough surface preparation is necessary for the adhesion of new protective coatings. All loose, flaking, and deteriorated paint must be removed from the iron, as well as dirt and mud, water-soluble salts, oil, and grease. Old paint that is tightly adhered may be left on the surface of the iron if it is compatible with the proposed coatings. The retention of old paint also preserves the historic paint sequence of the building and avoids the hazards of removal and disposal of old lead paint.

It is advisable to consult manufacturer's specifications or technical representatives to ensure compatibility between the surface conditions, primer and finish coats, and application methods.

For the paint to adhere properly, the metal surfaces must be absolutely dry before painting. Unless the paint selected is specifically designed for exceptional conditions, painting should not take place when the temperature is expected to fall below 50 degrees Fahrenheit within 24 hours or when the relative humidity is above 80 per cent; paint should not be applied when there is fog, mist, or rain in the air. Poorly prepared surfaces will cause the failure of even the best paints, while even moderately priced paints can be effective if applied over well-prepared surfaces.

Selection of Paints and Coatings

The types of paints available for protecting iron have changed dramatically in recent years due to federal, state, and local regulations that prohibit or restrict the manufacture and use of products containing toxic substances such as lead and zinc chromate, as well as volatile organic compounds and substances (VOC or VOS). Availability of paint types varies from state to state, and manufacturers continue to change product formulations to comply with new regulations.

Traditionally, red lead has been used as an anticorrosive pigment for priming iron. Red lead has a strong affinity for linseed oil and forms lead soaps, which become a tough and elastic film impervious to water that is highly effective as a protective coating for iron. At least two slow-drying linseed oil-based finish coats have traditionally been used over a red lead primer, and this combination is effective on old or partially deteriorated surfaces. Today, in most areas, the use of paints containing lead is prohibited, except for some commercial and industrial purposes.

Today, alkyd paints are very widely used and have largely replaced lead-containing linseed oil paints. They dry faster than oil paint, with a thinner film, but they do not protect the metal as long. Alkyd rust-inhibitive primers contain pigments such as iron oxide, zinc oxide, and zinc phosphate. These primers are suitable for previously painted surfaces cleaned by hand tools. At least two coats of primer should be applied, followed by alkyd enamel finish coats.

Latex and other water-based paints are not recommended for use as primers on cast iron because they cause immediate oxidation if applied on bare metal. Vinyl acrylic latex or acrylic latex paints may be used as finish coats over alkyd rust-inhibitive primers, but if the primer coats are imperfectly applied or are damaged, the latex paint will cause oxidation of the iron. Therefore, alkyd finish coats are recommended.

On this building, a strong alkaline paint remover was used, and apparently was not adequately rinsed or neutralized. Over a period of months, the newly applied paint began to peel and streaks of rust appeared on the iron. Photo: Kim Lovejoy.

High-performance coatings, such as zinc-rich primers containing zinc dust, and modern epoxy coatings, can be used on cast iron to provide longer-lasting protection. These coatings typically require highly clean surfaces and special application conditions which can be difficult to achieve in the field on large buildings. These coatings are used most effectively on elements which have been removed to a shop, or newly cast iron.

One particularly effective system has been first to coat commercially blast-cleaned iron with a zinc-rich primer, followed by an epoxy base coat, and two urethane finish coats. Some epoxy coatings can be used as primers on clean metal or applied to previously-painted surfaces in sound condition. Epoxies are particularly susceptible to degradation under ultraviolet radiation and must be protected by finish coats which are more resistant. There have been problems with epoxy paints which have been shop-applied to iron where the coatings have been nicked prior to installation. Field touching-up of epoxy paints is very difficult, if not impossible. This is a concern since iron exposed by imperfections in the base coat will be more likely to rust and more frequent maintenance will be required.

A key factor to take into account in selection of coatings is the variety of conditions on existing and new materials on a particular building or structure. One primer may be needed for surfaces with existing paint; another for newly cast, chemically stripped, or blast-cleaned cast iron; and a third for flashings or substitute materials; all three followed by compatible finish coats.

Application Methods

Brushing is the traditional and most effective technique for applying paint to cast iron. It provides good contact between the paint and the iron, as well as the effective filling of pits, cracks, and other blemishes in the metal. The use of spray guns to apply paint is economical, but does not always produce adequate and uniform coverage. For best results, airless sprayers should be used by skilled operators. To fully cover fine detailing and reach recesses, spraying of the primer coat, used in conjunction with brushing, may be effective.

Rollers should never be used for primer coat applications on metal, and are effective for subsequent coats only on large, flat areas. The appearance of spray-applied and roller-applied finish coats is not historically appropriate and should be avoided on areas such as storefronts which are viewed close at hand.

Caulking, Patching, and Mechanical Repairs

Most architectural cast iron is made of many small castings assembled by bolts or screws. Joints between pieces were caulked to prevent water from seeping in and causing rusting from the inside out. Historically, the seams were often caulked with white lead paste and sometimes backed with cotton or hemp rope; even the bolt and screw heads were caulked to protect them from the elements and to hide them from view. Although old caulking is sometimes found in good condition, it is typically crumbled from weathering, cracked from the structural settlement, or destroyed by mechanical cleaning. It is essential to replace deteriorated caulking to prevent water penetration. For good adhesion and performance, an architectural-grade polyurethane sealant or traditional white lead paste is preferred.

Water that penetrates the hollow parts of a cast-iron architectural element causes rust that may streak down over other architectural elements. The water may freeze, causing the ice to crack the cast iron. Cracks reduce the strength of the total castiron assembly and provide another point of entry for water. Thus, it is important that cracks be made weathertight by using caulks or fillers, depending on the width of the crack.

Fiberglass columns and aluminum capitals were installed to replicate the ornamental features on the

Filler compounds containing iron particles in an epoxy resin binder can be used to patch superficial, nonstructural cracks and small defects in cast iron. The thermal expansion rate of epoxy resin alone is different from that of iron, requiring the addition of iron particles to ensure compatibility and to control shrinkage. Although the repaired piece of metal does not have the same strength as a homogeneous piece of iron, epoxy-repaired members do have some strength. Polyester-based putties, such as those used on auto bodies, are also acceptable fillers for small holes.

In rare instances, major cracks can be repaired by brazing or welding with special nickel-alloy welding rods. Brazing or welding of cast iron is very difficult to carry out in the field and should be undertaken only by very experienced welders.

In some cases, mechanical repairs can be made to cast iron using iron bars and screws or bolts. In extreme cases, deteriorated cast iron can be cut out and new cast iron spliced in

In an effort to repair the stair railing, concrete was poured around the wood spacer inside the railing ceiling. Water penetrated the railing and reacted with the concrete to accelerate the corrosion of the iron. Photo: John G. Waite.

east facade of the New Market Theater in Portland, Oregon.
Photo: William J. Hawkins, III.

place by welding or brazing. However, it is frequently less expensive to replace a deteriorated cast-iron section with a new casting rather than to splice or reinforce it. Cast-iron structural elements that have failed must either be reinforced with iron and steel or replaced entirely.

A wobbly cast-iron balustrade or railing can often be fixed by tightening all bolts and screws. Screws with stripped threads and seriously rusted bolts must be replaced. To compensate for corroded metal around the bolt or screw holes, new stainless steel bolts or screws with a larger diameter need to be used. In extreme cases, new holes may need to be tapped.

The internal voids of balusters, newel posts, statuary, and other elements should not be filled with concrete; it is an inappropriate treatment that causes further problems. As the concrete cures, it shrinks, leaving a space between the concrete and cast iron. Water penetrating this space does not evaporate quickly, thus promoting further rusting. The corrosion of the iron is further accelerated by the alkaline nature of concrete. Where cast-iron elements have been previously filled with concrete, they need to be taken apart, the concrete and rust removed, and the interior surfaces primed and painted before the elements are reassembled.

Duplication and Replacement

The replacement of cast-iron components is often the only practical solution when such features are missing, severely corroded, or damaged beyond repair, or where repairs would be only marginally useful in extending the functional life of an iron element.

Sometimes it is possible to replace small, decorative, nonstructural elements using intact sections of the original as a casting pattern. For large sections, new patterns of wood or plastic made slightly larger in size than the original will need to be made in order to compensate for the shrinkage of the iron during casting (cast iron shrinks approximately 1/8 inch per foot as it cools from a liquid into a solid). Occasionally, a matching replacement can be obtained from the existing catalogs of iron foundries. Small elements can be custom cast in iron at small local foundries, often at a cost comparable to substitute materials. Large elements and complex patterns will usually require the skills and facilities of a larger firm that specializes in replication.

The Casting Process

Architectural elements were traditionally cast in sand molds. The quality of the special sands used by foundries is extremely important; unlike most sands they must be moist. Foundries have their own formulas for sand and its admixtures, such as clay, which makes the sand cohesive even when the mold is turned upside down.

A two-part mold (with a top and a bottom, or cope and drag) is used for making a casting with relief on both sides, whereas an open-top mold produces a flat surface on one side. For hollow elements, a third pattern and mold are required for the void. Many hollow castings are made of two or more parts that are later bolted, screwed, or welded together, because of the difficulty of supporting an interior core between the top and bottom sand molds during the casting process.

The molding sand is compacted into flasks, or forms, around the pattern. The cope is then lifted off and the pattern is removed, leaving the imprint of the pattern in the small mold. Molten iron, heated to a temperature of approximately 2700 degrees Fahrenheit, is poured into the mold and then allowed to cool. The molds are then stripped from the casting; the tunnels to the mold (sprues) and risers that allowed release of air are cut off; and ragged edges (called "burrs") on the casting are ground smooth.

The castings are shop-primed to prevent rust, and laid out and preassembled at the foundry to ensure proper alignment and fit. When parts do not fit, the pieces are machined to remove irregularities caused by burrs, or are rejected and recast until all of the cast elements fit together properly. Most larger pieces then are taken apart before shipping to the job site, while some small ornamental parts may be left assembled.

Dismantling and Assembly

It is sometimes necessary to dismantle all or part of a cast-iron structure during restoration, if repairs cannot be successfully carried out in place. Dismantling should be done only under the direction of a preservation architect or architectural conservator who is experienced with historic cast iron. Extreme care must be taken since cast iron is very brittle, especially in cold weather.

Dismantling should follow the reverse order of construction and re-erection should occur, as much as possible, in the exact order of original assembly. Each piece should be numbered and keyed to record drawings. When work must be carried out in cold weather, care needs to be taken to avoid fracturing the iron elements by uneven heating of the members.

The west facade of the New Market Theater retains its original cast-iron features.
Photo: George McMath.

Both new castings and reused pieces should be painted with a shop-applied prime coat on all surfaces. All of the components should be laid out and preassembled to make sure that the alignment and fit are proper. Many of the original bolts, nuts, and screws may have to be replaced with similar fasteners of stainless steel.

After assembly at the site, joints that were historically caulked should be filled with an architectural-grade polyurethane sealant or the traditional white lead paste. White lead has the advantage of longevity, although its use is restricted in many areas.

Flashings

In some instances, it may be necessary to design and install flashings to protect areas vulnerable to water penetration. Flashings need to be designed and fabricated carefully so that they are effective, as well as unobtrusive in appearance. The most durable material for flashing iron isterne-coated stainless steel. Other compatible materials areterne-coated steel and galvanized steel; however, these require more frequent maintenance and are less durable. Copper and lead-coated copper are not recommended for use as flashings in contact with cast iron because of galvanic corrosion problems. Galvanic problems can also occur with the use of aluminum if certain types of electrolytes are present.

Substitute Materials

In recent years, a number of metallic and non-metallic materials have been used as substitutes for cast iron, although they were not used historically with cast iron. The most common have been aluminum, epoxies, reinforced polyester (fiberglass), and glass fiber-reinforced concrete (GFRC). Factors to consider in using substitute materials are addressed in Preservation Briefs 16, which emphasizes that "every means of repairing deteriorating historic materials or replacing them with identical materials should be examined before turning to substitute materials."

Cast aluminum has been used recently as a substitute for cast iron, particularly for ornately-detailed decorative elements. Aluminum is lighter in weight, more resistant to corrosion, and less brittle than cast iron. However, because it is dissimilar from iron, its placement in contact with or near cast iron may result in galvanic corrosion, and thus should be avoided. Special care must be taken in the application of paint coatings, particularly in the field. It is often difficult to achieve a durable coating after the original finish has failed. Because aluminum is weaker than iron, careful analysis is required whenever aluminum is being considered as a replacement material for structural cast-iron elements.

This lightweight fiberglass column at street level sustained damage from impact within a few years of installation. Photo: Building Conservation Associates.

Epoxies are two-part, thermo-setting, resinous materials which can be molded into virtually any form. When molded, the epoxy is usually mixed with fillers such as sand, glass balloons, or stone chips. Since it is not a metal, galvanic corrosion does not occur. When mixed with sand or stone, it is often termed epoxy concrete or polymer concrete, a misnomer because no cementitious materials are included. Epoxies are particularly effective for replicating small, ornamental sections of cast iron. Since it is not a metal, galvanic action does not occur. Epoxy elements must have a protective coating to shield them from ultraviolet degradation. They are also flammable and cannot be used as substitutes for structural cast-iron elements.

Reinforced polyester, commonly known as fiberglass, is often used as a lightweight substitute for historic materials, including cast iron, wood, and stone. In its most common form, fiberglass is a thin, rigid, laminate shell formed by pouring a polyester resin into a mold and then adding fiberglass for reinforcement. Like epoxies, fiberglass is non-corrosive, but is susceptible to ultraviolet degradation. Because of its rather flimsy nature, it cannot be used as a substitute for structural elements, cannot be assembled like cast iron and usually requires a separate anchorage system. It is unsuitable for locations where it is susceptible to damage by impact, and is also flammable.

Glass fiber-reinforced concrete, known as GFRC, is similar to fiberglass except that a lightweight concrete is substituted for the resin. GFRC elements are generally fabricated as thin shell panels by spraying concrete into forms. Usually a separate framing and anchorage system is required. GFRC elements are lightweight, inexpensive, and weather resistant. Because GFRC has a low shrinkage coefficient, molds can be made directly from historic elements. However, GFRC is very different physically and chemically from iron. If used adjacent to iron, it causes corrosion of the iron and will have a different moisture absorption rate. Also, it is not possible to achieve the crisp detail that is characteristic of cast iron.

Maintenance

A successful maintenance program is the key to the long-term preservation of architectural cast iron. Regular inspections and accurate record-keeping are essential. Biannual inspections, occurring ideally in the spring and fall, include the identification of major problems, such as missing elements and fractures, as well as minor items such as failed caulking, damaged paint, and surface dirt.

Records should be kept in the form of a permanent maintenance log which describes routine maintenance tasks and records the date a problem is first noted, when it was corrected, and the treatment method. Painting records are important for selecting compatible paints for touch-up and subsequent repainting. The location of the work and the type, manufacturer, and color of the paint should be noted in the log. The same information also should be assembled and recorded for caulking.

Superficial dirt can be washed off well-painted and caulked cast iron with low-pressure water. Non-ionic detergents may be used for the removal of heavy or tenacious dirt or stains, after testing to determine that they have no adverse effects on the painted surfaces. Thick grease deposits and residue can be removed by hand scraping. Water and detergents or non-caustic degreasing agents can be used to clean off the residue. Before repainting, oil and grease must be removed so that new coatings will adhere properly.

The primary purpose of the maintenance program is to control corrosion. As soon as rusting is noted, it should be carefully removed and the protective coating of the iron renewed in the affected area. Replacement of deteriorated caulking, and repair or replacement of failed flashings are also important preventive maintenance measures.

Summary and References

The successful conservation of cast-iron architectural elements and objects is dependent upon an accurate diagnosis of their condition and the problems affecting them, as well as the selection of appropriate repair, cleaning, and painting procedures. Frequently, it is necessary to undertake major repairs to individual elements and assemblies; in some cases badly damaged or missing components must be replicated. The long-term preservation of architectural cast iron is dependent upon both the undertaking of timely, appropriate repairs and the commitment to a regular schedule of maintenance.

Acknowledgements

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This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Technical Preservation Services (TPS), National Park Service prepares standards, guidelines, and other educational materials on responsible historic preservation treatments for a broad public.

October 1991

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EXPERIENCE YOUR AMERICA™

1.1.1.4 Primers and paints for wrought iron, cast iron, and steel (GSA 2018)

Primers and Paints for Wrought Iron, Cast Iron and Steel

Procedure code:

501013G

Source:

Maintenance, Repair and Alteration of Historic Buildings

Division:

Metals

Section:

Metal Materials

Last Modified:

01/03/2018

This document includes general information on primers and paints to be used on interior and exterior wrought iron, cast iron and steel surfaces.

Note: The selection of a suitable primer and paint for metals depends on many factors including the type of metal to be coated, the type of surface preparation to be used, environmental and surface conditions, desired appearance and performance requirements, method of application, and type and level of exposure. Consult a paint manufacturer along with the regional historic preservation officer before making the final selection.

The primary purpose of paint is to protect the metal from deterioration. To do so, paint manufacturers have developed paint systems which are made to work together to protect the metal substrate. These systems include primers and appropriate, compatible top coats which can vary depending on the substrate, environmental conditions, and can vary between manufacturers. As a result appropriate primers and compatible top coats, both from the same manufacturer should be used.

For information on paint removal from metal, surface preparation and application procedures, see the following:

For guidance on paint removal from iron and steel, see 05010-05-R "Cleaning/Removing Paint from Wrought Iron, Cast Iron and Steel Using Mechanical/Abrasive Methods," "Removing Paint from Wrought Iron, Cast Iron and Steel Using Thermal Methods" and "Removing Paint from Wrought Iron, Cast Iron and Steel Using Chemical Methods".

For additional information on the history, properties and uses of paint, see 09900-01-S. See 09900-07-S for general guidelines on painting interior and exterior surfaces.

PRIMERS FOR WROUGHT IRON, CAST IRON AND STEEL**Characteristics**

- Primary function is adhesion.
- Must bond well to substrate and intermediate coat.
- Should have enough chemical and weather resistance to protect the substrate before application of next coat.
- Should be compatible with intermediate and top coats.
- Should be compatible with paint/rust removal methods.

TYPES**OIL/ALKYD PRIMERS:****Advantages:**

- Bond well to most surfaces even if surface preparation is substandard.
- Compatible with oil finish coats.

Limitations:

- NOT compatible with finish coats of vinyl, epoxy or other synthetic polymer. Solvents in these systems attack and soften these primers.
- Limited corrosion resistance.

MIXED RESIN PRIMERS:**Advantages:**

- Bond well to most surfaces, though adequate surface preparation is important.
- Compatible with most finish coats.
- Good alkali resistance.
- Some corrosion resistance.

Limitations:

- Compatible with a specific range of top coats.

RESIN SAME AS TOPCOATS:**Advantages:**

- Effective when surface is properly prepared.
- Some corrosion resistance.

INORGANIC ZINC:**Advantages:**

- Outstanding bonding characteristics when surface is cleaned and roughened. Compatible with most finish coats.
- Effectively resists disbonding.
- Excellent resistance to underfilm corrosion.
- Effective in protecting the metal without the help of a finish coat.

Limitations:

- NOT acid or alkali-resistant.

WASH PRIMERS:

Suitable for use on steel, aluminum, zinc, cadmium, chromium, tinplate, and terneplate.

Advantages:

- Provides a smooth, durable, uniform base for finish coat application.
- Compatible with the following top coats: vinyls, phenolics, alkyds, nitrocellulose and oil-type products.

Limitations:

- NOT recommended for surfaces subject to temperatures above 150 degrees F. (66 degrees C.).

CONVERSION COATINGS:

Oxidizing solution Used on zinc, iron, aluminum and magnesium (formulation will vary depending on type of metal). This type of coating is usually factory-applied.

Advantages:

- Excellent corrosion resistance.
- Good adhesion to subsequent paint coats.

Limitations:

- Subject to deterioration if overheated.

ZINC CHROMATE:

Used on aluminum, magnesium and ferrous metals.

Advantages:

- Good corrosion resistance.

Limitations:

- Not suited to highly acidic environments.

ZINC-RICH COATINGS:**Advantages:**

- Good corrosion resistance.

PAINTS FOR WROUGHT IRON, CAST IRON AND STEEL**Characteristics**

- Should be compatible with primer.
- Intermediate coat should uniformly bond the primer with the top coat.
- Intermediate coat should have enough chemical and weather resistance to protect the primer and substrate.

TYPES**OIL-BASED/ALKYD ENAMEL:****Advantages:**

- For normal to severe weather conditions; provides good abrasion and dirt resistance.
- Suitable for both exterior and interior uses.
- Good bonding characteristics.

Limitations:

- Alkyds are not good in a continuously damp or chemically corrosive environment, nor are they solvent resistant.
- Limited alkali resistance.

BAKED PHENOLIC:**Advantages:**

- Excellent resistance to acidic environments.
- Excellent resistance to water.
- Excellent resistance to strong solvents.
- Low material cost.

Limitations:

- Low alkali resistance.
- High labor cost for application.

EPOXIES:**Advantages:**

- Good adhesion.
- Good chemical resistance.
- Good abrasion resistance.
- Good alkali resistance.

Limitations:

- Sensitive to chalking under exterior exposure.
- Sensitive to color fading.
- Weak in acid.

ACRYLICS (THERMOPLASTIC AND THERMOSETTING COATINGS):**Advantages:**

- Moderate cost
- Good resistance to degradation from ultraviolet light.
- Suitable for both interior and exterior use

VINYLS (USED PRIMARILY AS INTERMEDIATE COATS):**Advantages:**

- Good alkali and acid resistance.
- Excellent water resistance.
- Low chalking rate.

Limitations:

- Limited solvent and heat resistance.
- Inferior to alkyd and epoxy coatings - lower adhesive strength.
- Sensitive to intercoat contamination.

INORGANIC ZINC:

Advantages:

- Excellent weather and solvent resistance.
- Excellent resistance to underfilm corrosion.
- Resistant to petroleum products.

Limitations:

- Limited chemical resistance.
- Not suitable for strong acid or strong alkali environments.

ORGANIC ZINC:**Advantages:**

- Protects against corrosion.

FURAN:**Advantages:**

- One of the most versatile and resistant of organic films.

Limitations:

- Poor adhesion to steel and any primed surface.
- The film gets very hard after curing, making it extremely difficult to maintain them.

URETHANES:**Advantages:**

- Excellent gloss and color retention.
- Preferable to epoxy protective coatings or primers.
- Available in a wide variety of formulations for different surface types and conditions.

Limitations:

- Comparable to epoxies and vinyls in resistance to corrosion.
- Some tend to yellow when exposed to sunlight.
- Expensive.

SILICONES:**Advantages:**

- Excellent heat resistance.
- Excellent color and gloss retention.
- Available in pure or modified form (a mixture of 2 coating types)

Limitations:

- Expensive

REFERENCES:

- Margot Gayle, David Look, John Waite. Metals in America's Historic Buildings. Washington, DC: National Park Service, 1995.

1.1.1.5 Removing paint from wrought iron, cast iron and steel using chemical methods (GSA 2017)

U.S. General Services Administration

Removing Paint from Wrought Iron, Cast Iron and Steel Using Chemical Methods

Procedure code:

501017S

Source:

Developed by NPS Southeast Regional Office

Division:

Metals

Section:

Metal Materials

Last Modified:

12/26/2017

REMOVING PAINT FROM WROUGHT IRON, CAST IRON AND STEEL USING CHEMICAL METHODS

TAKE SPECIAL CARE TO PROTECT ALL ADJACENT MATERIALS, FROM DAMAGE BY SPLASHING OR RUN OFF THAT MAY CONTAIN CLEANING OR STRIPPING PRODUCTS AS WELL AS PAINT, FINISHES AND SOILING REMOVED FROM TREATED SURFACES. DO NOT USE THIS PROCEDURE ON METALS OTHER THAN THOSE SPECIFIED. REVIEW MANUFACTURER'S CAUTIONS AND APPLICABLE FEDERAL, STATE AND LOCAL REGULATIONS GOVERNING PRODUCT USE AND CONTROL OF HAZARDOUS MATERIALS BEFORE UNDERTAKING WORK INVOLVING REMOVAL OF PAINTS AND COATINGS; ADJUST PRODUCT SELECTION AND METHODS ACCORDINGLY. TEST MILDTEST, MOST ENVIRONMENTALLY BENIGN FORMULATIONS FIRST BEFORE PROCEEDING TO STRONGER CHEMICALS AND HARSHER METHODS.

PART 1---GENERAL

1.01 SUMMARY A. This procedure includes guidance on chemically removing paint from wrought iron, cast iron and steel. These metals should be repainted immediately following paint removal in order to prevent exposure to the atmosphere and subsequent corrosion.

B. For information on painting and coating these materials see 05010-13-S "Primers and Paints for Wrought Iron, Cast Iron and Steel", 05010-18-R "Applying a Sacrificial Coating to Wrought Iron, Cast Iron and Steel", and 09900-07-S "General Guidelines for Painting Exterior and Interior Surfaces".

C. Chemical methods as used herein shall apply to the use of commercial chemical paint strippers and rust removers.

D. There are several causes for paint failure on metal. Excess moisture can cause rusting. As metal rusts, the rust expands breaking the bond between the metal and the paint. Inadequate or improper surface preparation can interfere with the proper bonding of the new paint. The wrong primer can cause anything from pitting of the metal surface to peeling of the new paint.

E. It is not necessary to remove all previous coats of paint if:

1. they are adhering soundly,

2. the new painting system is compatible,
3. important design details are not being obscured by the paint layers.

F. An archives of the paint history of the building is to be maintained. This is to include the paint samples taken during research, samples of the new paint colors and the manufacturers technical information.

G. Safety Precautions:

1. No food or drink shall be allowed near any work station so as to prevent contamination from paint, paint chips or paint dust which may contain lead and other toxic substances.
2. Paint being removed most likely will contain lead. All workmen must wear protective clothing, (including hair), goggles and respirators with proper filters.
3. Protective clothing shall be removed at the end of each day and kept at the site to prevent workers from taking dust and paint chips to other parts of the site or to their homes.
4. Wash hands and face often, especially before eating and at the end of the day.
5. All waste material shall be collected at the end of each work day and disposed of in a manner consistent with local environmental regulations. It is considered Hazardous Waste.
6. Work area shall be sealed to prevent the spread of paint dust and debris beyond the work site.
7. After paint removal is complete, all areas around the building shall be cleaned of all paint dust and debris, and such debris shall be properly disposed of in a manner consistent with local environmental regulations.

H. See 01100-07-S for general project guidelines to be reviewed along with this procedure. These guidelines cover the following sections:

1. Safety Precautions
2. Historic Structures Precautions
3. Submittals
4. Quality Assurance
5. Delivery, Storage and Handling
6. Project/Site Conditions
7. Sequencing and Scheduling
8. General Protection (Surface and Surrounding)

I. For additional information on cast and wrought iron see the following procedures:

1. 05010-04-S, "Cast Iron: Characteristics, Uses and Problems."
2. 05010-11-S, "Wrought Iron: Characteristics, Uses and Problems."
3. 05010-01-S, "Checklist for Inspecting Cast Iron Failures."

PART 2---PRODUCTS

2.01 MANUFACTURERS

A. For Chemical Paint Removers:

1. ProSoCo, Inc
2. Star Bronze Co.
3. Savogran Company
4. Deidrich Technologies

2.02 MATERIALS

NOTE: Chemical products are sometimes sold under a common name. This usually means that the substance is not as pure as the same chemical sold under its chemical name, but the grade of purity of common name substances, is usually adequate for stain removal work, and these products tend to be less expensive. Common names are indicated below by an asterisk (*).

A. Chemical Paint/Lacquer Removers:

1. Manufacturer's standard thixotropic formulation for removing paint coatings from ornamental metal work. Review manufacturer's literature to identify least hazardous products that may be effective for initial testing. Examples include: "Envirestrip" (Diedrich Technologies), "EnviroKlean Safety Peel 1" (Prosoco, Inc.), Zip Strip 2 (Star Bronze Co.) and "Biodegradable Stripeeze" (Savogran Co.)
2. Semi-paste, water rinsing, nonbenzol remover such as "Stripeeze Semi-Paste" (Savogran Company), or approved equal.
 - a. Characteristic orange color.
 - b. Will work on both latex and oil-based paints, lacquers and varnishes.
 - c. Cling well to round or vertical surfaces.
 - d. Form an anti-evaporative film as they dry.
 - e. Clean-up by either washing or scraping off. All traces must be removed and a neutral pH achieved before repainting.
 - f. Use if milder formulations are not effective.
3. Non-flammable, heavy bodied, methylene-chloride based remover such as "Super Strip Non-flammable", "Zip-Strip" (Star Bronze Co.), or approved equal.
 - a. Good for interior use because they are non-flammable.
 - b. Will soften oil-based paints, lacquers, varnish and synthetic baked finishes.
 - c. Because they are so heavy bodied they will cling to vertical and irregular surfaces.
 - d. Use if milder formulations are not effective.
4. Non-flammable, water rinsing, liquid remover such as "H2O Off", or approved equal: Available from paint supply store.
 - a. Methylene-chloride based strippers excel in speed and effectiveness but produce toxic fumes and waste, limiting (in some locations prohibiting) their use. Test milder, non-hazardous formulations first.
 - b. Will soften oil-base paints, varnish, and synthetic baked finishes.
 - c. Will not work on vertical surfaces. Good for horizontal surfaces.

5. Liquid benzol remover such as "Kutzit", or approved equal: Available from paint supply store.

a. HIGHLY FLAMMABLE AND TOXIC. WEAR PROTECTIVE CLOTHING. USE IN WELL VENTILATED AREA, DO NOT USE NEAR FLAME, SPARKS, OR HEATERS.

b. Will remove oil-based paint, lacquer, varnish and synthetic baked finishes.

c. Work well on flat surfaces. Work quickly.

B. Chemical rust removers, such as "Navel Jelly", or approved equal.

C. Cornstarch or fumed silica to further thicken chemicals so they will adhere to vertical surfaces.

D. Liquid Strippable Masking Agent: Manufacturer's standard liquid, film forming, strippable masking material for protecting glass, and polished stone surfaces from damaging effect of acidic and alkaline cleaners, such as "Sure Klean Acid Stop" (ProSoCo, Inc.), or approved equal.

E. Mineral Spirits: (To remove chemical residue)

1. A petroleum distillate that is used especially as a paint or varnish thinner.

2. Other chemical or common names include Benzine* (not Benzene); Naphtha*; Petroleum spirits*; Solvent naphtha*.

3. Potential Hazards: TOXIC AND FLAMMABLE.

4. Safety Precautions:

a. AVOID REPEATED OR PROLONGED SKIN CONTACT.

b. ALWAYS wear rubber gloves when handling mineral spirits.

c. If any chemical is splashed onto the skin, wash immediately with soap and water.

5. Available from construction specialties distributor, hardware store, paint store, or printer's supply distributor.

F. Phenolphthalein: Used to test pH of a surface after stripping with chemicals or any alkaline product. Available at some drug stores or chemical supply houses.

G. Trisodium Phosphate and TSP Substitutes

DUE TO ENVIRONMENTAL HAZARDS OF PHOSPHATES, TSP IS PROHIBITED IN SOME LOCATIONS. USE ONLY AS NEEDED AFTER TESTING ALTERNATIVES FOR CLEANING EFFECTIVENESS.

1. Strong base-type powdered cleaning material sold under brand names.

2. Other chemical or common names include Sodium orthophosphate; Tribasic sodium phosphate; Trisodium orthophosphate; TSP*; Phosphate of soda*.

3. Potential Hazards: CORROSIVE TO SKIN.

4. Available from chemical supply house, grocery store or supermarket, hardware store or paint store.

5. Substitute products include Klean-Strip 0408 TSP Trisodium Phosphate Substitute No-Rinse (ProsoCo, Inc.) and water-based solutions containing baking soda or borax.

H. Soft cloths

I. Steel wool

J. Plastic sheeting and duct tape to cover the stripper during dwell time.

2.02 EQUIPMENT

- A. 000 steel wool or synthetic pads
- B. Scrapers and small picks to remove sludge
- C. Steel or brass wire brushes
- D. Fiber bristle brushes (1/2 to 3/4 inches long)
- E. Metal containers such as old coffee cans in which to dispose of sludge

PART 3---EXECUTION

3.01 EXAMINATION

- A. Before work is begun on removing the existing paint film or otherwise preparing the surface all sources of excess moisture shall be inspected and repaired or replaced as required.

3.02 PREPARATION

A. Protection:

1. Comply with recommendations of manufacturers of chemical cleaners for protecting building surfaces from exposure to their products.
2. Protect glass, unpainted metal trim and polished stone from contact with acidic chemical cleaners by covering them with liquid strippable masking agent or polyethylene film and waterproof masking tape. Apply masking agent to comply with manufacturer's recommendations. Do not apply liquid masking agent to painted or porous surfaces.
3. Protect unpainted metal from contact with alkali chemical cleaners by covering them either with liquid strippable masking agent or polyethylene film and waterproof masking tape.
4. Protect adjacent surfaces, including grass, shrubs and trees with paper, drop cloths and other means. Items not to be painted which are in contact with or adjacent to painted surfaces shall be removed or protected prior to surface preparation and painting operations.
5. All waste material shall be collected at the end of each work day and properly disposed of. It is considered Hazardous Waste.
6. Work area shall be sealed to prevent the spread of dust and debris beyond the work site.
7. If vacuums are used to clean area, machines shall be equipped with HEPA (High Efficiency Particulate Air) filters to insure all lead dust has been contained and removed.

3.03 ERECTION, INSTALLATION, APPLICATION

A. Rust Removal:

1. Brush apply commercially available chemical rust removers such as "Naval Jelly" (phosphoric acid), and allow to dwell according to manufacturer's instructions.

CAUTION: STAY AWAY FROM HYDROCHLORIC ACID BASED PRODUCTS AS THEY MAY LEAD TO FUTURE CORROSION.

2. Wipe off residue with mineral spirits and either steel wool or soft rags.
3. Dry immediately with clean soft cloths or using an industrial blow dryer. Follow direction of grain in metal. DO NOT TOUCH CLEANED ORNAMENTAL METAL SURFACE.

4. Prime immediately to prevent rust.

B. Clean small pieces which can be removed.

NOTE: REMOVE ONLY AS MUCH PAINT AND RUST EACH DAY AS CAN BE PRIMED THAT SAME DAY. BARE IRON AND STEEL WILL BEGIN TO RUST AGAIN WITHIN A MATTER OF HOURS. IT SHOULD NOT BE ALLOWED TO SIT UNPROTECTED OVERNIGHT.

1. Soak in a solution of hot water and TSP, TSP-Substitute, or sudsy ammonia to loosen the paint.
2. Remove paint with scrapers and/or a wire brush.
3. A final wipe down with mineral spirits may be necessary to help remove final traces of paint.
4. Dry immediately and prime to prevent rusting. A heat gun, set at the lowest temperature, can be used to hasten the drying time. DO NOT USE HIGH HEAT AS THIS MAY DISTORT THE METAL MEMBERS.

C. Remove any loose paint not already removed with the rust using a chemical paint remover.

NOTE: IF THE PAINT IS ADHERING SOUNDLY LEAVE IT ALONE-IT PROVIDES EXTRA PROTECTION. FEATHER THE EDGES OF THESE AREAS TO PROVIDE A SMOOTH FINISH AND APPEARANCE.

1. Brush the chemical onto the surface in the amount recommended by the manufacturer. Thicken if necessary with cornstarch or fumed silica.
2. Cover with plastic and allow to sit or "dwell" according to the manufacturer's instructions.
3. Remove sludge using scrapers and steel wool. A second application may be required on those areas where paint is especially thick or the detail is intricate.
4. After removal has been completed using chemicals rub all surfaces down with mineral spirits to remove all traces of chemical and waxy residue.
 - a. To test whether all chemicals have been removed and a neutral pH achieved, dissolve a 2" piece of phenolphthalein in denatured alcohol.
 - b. Brush the solution onto the surface. If it turns a shade from pink to magenta there is still chemical residue.
 - c. Treat the surface with additional mineral spirits and continue testing until there is no color change in the phenolphthalein solution.
5. Dry thoroughly and prime immediately to prevent rust.

D. Paint all surfaces. For guidance see 05010-13-S "Primers and Paints for Wrought Iron, Cast Iron and Steel", 05010-18-R "Applying a Sacrificial Coating to Wrought Iron, Cast Iron and Steel", and 09900-07-S "General Guidelines for Painting Exterior and Interior Surfaces".

1.1.1.6 Checklist for inspecting cast iron failures (GSA 2016c)

U.S. General Services Administration

Checklist For Inspecting Cast Iron Failures

Procedure code:

501001G

Source:

Outdoor Sculpture Manual - Center For Public Buildings

Division:

Metals

Section:

Metal Materials

Last Modified:

08/02/2016

This general checklist is an aid for inspecting the condition of cast iron. It should be used as a supplement to "Cast Iron: Characteristics, Uses and Problems".

- Examine the overall surface condition and appearance, paying particular attention to horizontal surfaces. Look for cracks, crevices, pockets, folds or details in the metal which may collect and hold water.
 - Examine and evaluate the coatings; determine the type and age of protective coating by visual or laboratory analysis.
- Look for:
- Cracks or breaks in the coating such as crazing, hairline cracks, cracks along seams, or other fractures in the surface, evidence of rust or rust stains at crazing, or blistering/flaking adjacent to cracks. Failures of this type may be one of the earliest warning signs of potential deterioration.
 - Bubbles or blisters on the surface of the coating. This type of failure results from the separation of the protective coating from the substrate. When left unrepaired, these air pockets may trap water or moisture and may accelerate deterioration or produce corrosion. Waxes and oil coatings are not susceptible to blistering.
 - Note extent of blistering and location of problem.
 - Is the problem localized or general?
 - Peeling and flaking of the surface. This usually results from unrepaired cracking or blistering (discussed above) and represents a more advanced stage of coatings failure. Areas left unprotected due to coatings loss may result in rust or corrosion.
 - Note extent of peeling/flaking and location of problem.
 - Is the problem localized or general?
 - Erosion and wear of the surface. Carefully examine the coating as well as the bare metal.
 - If possible, note all evidence of wear due to environmental or natural exposure.
 - If possible, note all evidence of wear due to human exposure or vandalism.
 - Graffiti on the surface.
 - Note basic types of graffiti material used such as paint, greasepaint, lipstick, marker, etc.
 - Note pattern of graffiti and location.

- Structural and mechanical deterioration. Look for rusting, cracks, breaks, etc. Monitor areas of concern to determine if they are active.
 - Identify locations of broken pieces. Note if they are missing or salvageable. Label all recovered material to location.
 - Identify locations of breaks at seams. Note whether connectors are missing or loose.

Reference

Margot Gayle, David W. Look, John G. Waite. *Metals in America's Historic Buildings*. Washington: National Park Service, 1992

L. William Zahner. *Architectural Metals: A Guide to Selection, Specification, and Performance*. New York City: John Wiley & Sons, 1995.

1.1.1.7 Installing new brass, cast-iron, and steel ornamental handrails and railing systems to match historic (GSA 2017b)

U.S. General Services Administration

Installing New Brass, Cast-Iron And Steel Ornamental Handrails And Railing Systems To Match Historic

Procedure code:

572002S

Source:

Tacoma Union Station Courthouse, Tacoma, Wa

Division:

Metals

Section:

Ornamental Handrails & Railings

Last Modified:

02/08/2017

PART 1---GENERAL

1.01 SUMMARY

A. This procedure includes guidance on replacing deteriorated handrails and railing systems with new or original factory refurbished brass, steel or iron ornamental rails to match the historic.

B. See 01100-07-S for general project guidelines to be reviewed along with this procedure. These guidelines cover the following sections:

1. Safety Precautions
2. Historic Structures Precautions
3. Submittals
4. Quality Assurance
5. Delivery, Storage and Handling
6. Project/Site Conditions
7. Sequencing and Scheduling
8. General Protection (Surface and Surrounding)

These guidelines should be reviewed prior to performing this procedure and should be followed, when applicable, along with recommendations from the Regional Historic Preservation Officer (RHPO).

1.02 REFERENCES

A. American Society for Testing and Materials (ASTM),

100 Barr Drive,
West Conshohocken, PA 19428,
(610) 832-9585 or FAX (610) 832-9555.

B. American Iron and Steel Institute (AISI),

1000 - 16th Street,
NW, Washington, DC 20036.

C. Copper Development Association (CDA),

Box 1840,
Greenwich Office Park 2,
Greenwich, CT 06836.

D. Steel Structures Painting Council,

4400 Fifth Avenue,
Pittsburgh, PA 15213.

E. National Association of Architectural Metal Manufacturers (NAAMM),

221 N. LaSalle Street,
Chicago, IL 60601.

1.03 DEFINITIONS

A. Definitions in ASTM E 985 for railing-related terms apply to this section.

1.04 SYSTEM DESCRIPTION

A. General: In engineering handrail and railing systems to withstand structural loads indicated, determine allowable design working stresses of railing materials based on the following:

B. For cold-formed structural steel: AISI "Specification for Design of Cold-Formed Steel Structural Members".

C. For copper alloys use a safety factor of 1.65 applied to minimum yield strength of alloy.

D. Structural Performance of Handrails and Railing Systems: Engineer, fabricate, and install handrails and railing systems to comply with requirements of ASTM E 985 for structural performance.

E. Control of Corrosion: Prevent galvanic action and other forms of corrosion by using metals that are compatible with one another. In some instances the corrosion can be prevented by inserting a plastic insulator between the dissimilar materials.

F. Thermal Movements: Allow for thermal movement resulting from the following maximum change (range) in ambient temperature in the design, fabrication, and installation of handrails and railings to prevent buckling, opening up of joints, and over-stressing of components, connections, and other detrimental effects. Base design calculation on actual surface temperatures of materials due to both solar heat gain and nighttime sky heat loss.

1.05 SUBMITTALS

- A. General: Submit the following in accordance with Conditions of Contract and Division 1 Specification Sections.
- B. Product data for each type of product specified.
- C. Shop drawings showing fabrication and installation of handrails and railings including plans, elevations, sections, details of components, and attachments to other units of Work.

1.06 QUALITY ASSURANCE

- A. Single-Source Responsibility: Obtain handrails and railing systems of each type and material from a single manufacturer.
- B. Engineering Responsibility: Engineer handrails and railing systems by qualified professional engineer legally authorized to practice in jurisdiction where Project is located.
- C. Engineer Qualifications: Professional engineer legally authorized to practice in jurisdiction where project is located and experienced in providing engineering services of the kind indicated for handrails and railings similar in material, design, and extent to that indicated for this Project and that have a record of successful in-service performance.
- D. Restoration Specialist: Work must be performed by a firm having not less than 5 years successful experience in comparable restoration projects and employing personnel skilled in the restoration processes and operations indicated.

1.07 DELIVERY, STORAGE AND HANDLING

- A. Storage and Protection: Store handrails and railing systems in clean, dry location, away from uncured concrete and masonry, protected against damage of any kind. Cover with waterproof paper, tarpaulin, or polyethylene sheeting; allow for air circulation inside the covering.

1.08 PROJECT/SITE CONDITIONS

- A. Field Measurements: Where handrails and railings are indicated to fit to other construction, check actual dimensions of other construction by accurate field measurements before fabrication; show recorded measurements on final shop drawings. Coordinate fabrication schedule with construction progress to avoid delay of Work.

1.09 SEQUENCING AND SCHEDULING

- A. Mount handrails only on completed surfaces. Do not support handrails temporarily by any means not satisfying structural performance requirements.

PART 2---PRODUCTS

2.01 MANUFACTURERS

A. Stan Chemical Company
01 Berlin Street
East Berlin, CT 06023
203/828-0571

2.02 MATERIALS

NOTE: Provide metal forms and types that comply with requirements of referenced standards and that are free from surface blemishes where exposed to view in the finished unit. Exposed-to-view surfaces exhibiting pitting, seam marks, roller marks, stains, discolorations, or other imperfections on finished units are not acceptable.

A. Copper Alloys: Provide CDA copper alloy of type and form indicated to comply with the following requirements:

1. Extruded Brass Shapes: Alloy suitable to produce US3 finish.
2. Seamless Brass Tube: Alloy suitable to produce US3 finish.
3. Composition Brass Castings: Alloy suitable to produce US3 finish.

B. Steel and Iron: Provide steel and iron in the form indicated complying with the following requirements:

1. Cold-Formed Steel Tubing: ASTM A 500, grade B, unless otherwise indicated or required by structural loads.
2. For exterior installations and as required, provide tubing with hot-dip galvanized coating per ASTM A 53.

C. Steel Plates, Shapes, and Bars: ASTM A 36.

D. Malleable Iron Castings: ASTM A 47, grade 32510.

2.03 ACCESSORIES

A. Grout and Anchoring Cement:

1. Non-shrink Nonmetallic Grout: Premixed, factory- packaged, nonstaining, noncorrosive, nongaseous grout. Provide grout specifically recommended by manufacturer for interior and exterior applications of type specified in this procedure such as "Bonsal Construction Grout" (W. R Bonsal Co.), "Diamond- Crete Grout" (Concrete Service Materials Co.), "Euco N-S Grout" (Euclid Chemical Co.), or approved equal.

B. Erosion-Resistant Anchoring Cement: Factory-packaged, nonstaining, hydraulic controlled expansion cement formulation for mixing with water at Project site to create pourable anchoring, patching, and grouting compound. Provide formulation that is resistant to erosion from water exposure without need for protection by a sealer or waterproof coating and is recommended for exterior use by manufacturer.

C. Paint:

1. Galvanizing Repair Paint: High-zinc-dust-content paint for reglazing welds in galvanized steel, with dry film containing not less than 94 percent zinc dust by weight, and complying with SSPC-Paint- 20.
2. Zinc Chromate Primer

D. Fasteners:

1. Fasteners for Anchoring Railings to Other Construction: Select fasteners of the type, grade, and class required to produce connections that are suitable for anchoring railing to other types of construction indicated and capable of withstanding design loadings.
 - For steel railings and fittings use plated fasteners complying with ASTM B 633, Class Fe/Zn 25 for electrodeposited zinc coating.

- For copper alloy railings provide fasteners fabricated from same base metal as railing components or from type 304.
- 2. Fasteners for Interconnecting Railing Components: Use fasteners of same basic metal as the fastened metal, unless otherwise indicated. Do not use metals that are corrosive or incompatible with materials joined.
 - Provide concealed fasteners for interconnection of handrail and railing components and for their attachment to other work except where exposed fasteners are unavoidable.
 - Provide Phillips flat-head machine screws for exposed fasteners, unless otherwise indicated.
- 3. Cast-In-Place and Post-installed Anchors in Concrete: Cast-in-place anchors and expansion anchors fabricated from corrosion-resistant materials with capability to sustain, without failure, load imposed within a safety factor of 4, as determined by testing per ASTM E 488, conducted by a qualified independent testing laboratory.

2.04 FABRICATION

A. General: Fabricate handrails and railing systems to comply with requirements indicated for design, dimensions, details, finish, and member sizes, including wall thickness of hollow members, post spacings, and anchorage, but not less than that required to support structural loads.

B. Preassemble railing systems in shop to greatest extent possible to minimize field splicing and assembly. Disassemble units only as necessary for shipping and handling limitations. Clearly mark units for reassembly and coordinated installation. Use connections that maintain structural value of joined pieces. Clearly mark units for reassembly and coordinated installation.

C. Form changes in direction of railing members by insertion of prefabricated elbow fittings, by radius bends of radius as designated, and by bending, as required.

D. Form simple and compound curves by bending members in jigs to produce uniform curvature for each repetitive configuration required; maintain profile of member throughout entire bend without buckling, twisting, cracking, or otherwise deforming exposed surfaces of handrail and railing components.

E. Welded Connections: Fabricate railing systems and handrails for connection of members by welding. For connections made during fabrication, weld corners and seams continuously to comply with the following:

1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
2. Obtain fusion without undercut or overlap.
3. Remove welding flux immediately.
4. At exposed connections, finish exposed welds and surfaces smooth and blended so that no roughness shows after finishing and contour of welded surface match those adjacent.

F. Non-welded Connections: Fabricate railing systems and handrails for connection of members by means of railing manufacturer's standard concealed mechanical fasteners and fittings unless otherwise indicated. Fabricate members and fittings to produce flush, smooth, rigid, hairline joints.

1. Fabricate splice joints for field connection using epoxy structural adhesive where this represents manufacturer's standard splicing method.

G. Brackets, Flanges, Fittings, and Anchors: Provide manufacturer's standard wall brackets, flanges, miscellaneous fittings, and anchors for connection of handrail and railing members to other construction.

H. Provide inserts and the anchorage devices for connecting handrails and railing systems to concrete or masonry work. Fabricate anchorage devices capable of withstanding loadings imposed by handrails and railing systems. Coordinate anchorage devices with supporting structure.

I. For existing cast iron posts to be reset in concrete: Examine existing anchors to determine if suitable for reuse. Do not reuse

unless in good condition. Provide new anchors where necessary of same configurations as existing.

J. Shear and punch metals cleanly and accurately. Remove burrs from exposed cut edges.

K. Ease exposed edges to a radius of approximately 1/32 inch, unless otherwise indicated. Form bent-metal corners to smallest radius possible without causing grain separation or otherwise impairing work.

L. Cut, reinforce, drill, and tap miscellaneous metal work as indicated to receive finish hardware, screws, and similar items.

M. For handrails and railing systems that are exposed to exterior or to moisture from condensation or other sources, provide weepholes or other means for evacuation of entrapped water in hollow sections of railing members.

N. Fabricate joints that will be exposed to weather in a manner to exclude water.

O. Close exposed ends of handrail and railing members by use of manufacturer's standard prefabricated end fittings.

P. Provide wall returns at ends of wall-mounted handrails, unless otherwise indicated. Close ends of returns unless clearance between end of the railing and wall is 1/4 inch or less.

Q. Fillers: Provide steel sheet or plate filler of thickness and size indicated or required to support structural loads of handrails where needed to transfer wall bracket loads through wall finishes to structural supports. Size fillers to suit wall finish thicknesses. Size fillers to produce adequate bearing to prevent bracket rotation and over-stressing of substrate.

R. Finishes:

1. Comply with NAAMM "Metal Finishes Manual" for recommendations relative to application and designations of finishes.
2. Appearance of Finished Work: Variations in appearance of abutting or adjacent pieces are not acceptable if they are within 1/2 of the range of approved samples. Noticeable variations in the same piece are not acceptable. Variations in appearance of other components are acceptable if they are within range of approved samples and they are assembled or installed to minimize contrast.

S. Copper Alloy Finishes: Finish designations prefixed by "CDA" conform with the system established by the Copper Development Association for designating copper alloy finish systems.

1. Buffed Finish: CDA M21 (Mechanical Finish: buffed, smooth specular).
2. Buffed Finish, Lacquered: CDA M21 Mechanical Finish: buffed, smooth specular; Coating: clear organic, air dry, such as "Incralac" (Stan Chemical Company), or approved equal.
 - Apply by air-spray in 2 coats per manufacturer's directions, with interim drying, to a total thickness of 1.0 mil.

T. Galvanized Finish:

1. General: Hot-dip galvanize items indicated to be galvanized to comply with ASTM A 123 for galvanizing iron and steel products made from rolled, pressed, and forged steel shapes, castings, plates, bars, and strips.
2. For exterior steel railings and handrails formed from steel tubing with galvanized finish, galvanize fittings, brackets, fasteners, sleeves, and other ferrous components.
3. Factory-Primed Finish: Apply air-dried primer immediately following cleaning and pretreatment, to provide a minimum dry film thickness of 2.0 mils per applied coat, to surfaces that will be exposed after assembly and installation and to concealed, non-galvanized surfaces.
4. Apply shop primer to uncoated surfaces of handrails and railing components, except those with galvanized finish or to be embedded in concrete or masonry, unless otherwise indicated. Comply with requirements of SSPC-PA 1 "Paint Application Specification No. 1" for shop painting.

Shop Primer: Manufacturer's or Fabricator's standard, fast-curing, lead-free, "universal" primer, selected for resistance to normal atmospheric corrosion, for compatibility with substrate and field-applied finish paint system indicated, and for capability to provide a sound foundation for field-applied topcoats despite prolonged exposure.

PART 3---EXECUTION

3.01 PREPARATION

A. Coordinate setting drawings, diagrams, templates, instructions, and directions for installation of anchorages, such as sleeves, concrete inserts, anchor bolts, and miscellaneous items having integral anchors, that are to be embedded in concrete as masonry construction. Coordinate delivery of such items to project site.

3.02 ERECTION, INSTALLATION, APPLICATION

A. General:

1. Fit exposed connections accurately together to form tight, hairline joints.
2. Cutting, Fitting, and Placement: Perform cutting, drilling, and fitting required for installation of handrails and railings. Set handrails and railing accurately in location, alignment, and elevation, measured from established lines and levels and free from rack. TAKE CARE SO AS NOT TO DAMAGE ADJACENT HISTORIC MATERIALS, SUCH AS MARBLE, GRANITE, OR LIMESTONE.
3. Do not weld, cut, or abrade surfaces of handrails and railing components that have been coated or finished after fabrication and are intended for field connection by mechanical or other means without further cutting or fitting.
4. Set posts plumb within a tolerance of 1/4 inch in 12 feet.
5. Align rails so that variations from level for horizontal members and from parallel with rake of steps and ramps for sloping members do not exceed 1/4 inch in 12 feet.
6. Field Welding: Comply with the following requirements:
 - Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
 - Obtain fusion without undercut or overlap.
 - Remove welding flux immediately.
 - At exposed connections, finish exposed welds and surfaces smooth and blended so that no roughness shows after finishing and contour of welded surface matches those adjacent.
7. Corrosion Protection: Coat concealed surfaces of concrete, masonry, wood, or dissimilar metals, which will be in contact with grout, with a heavy coat of bituminous paint or zinc chromate primer.
8. Adjust handrails and railing systems prior to anchoring to ensure matching alignment at abutting joints. Space posts at interval indicated but not less than that required by structural loads. MATCH ORIGINAL LOCATION AND SPACING TO AVOID GHOST MARKS.
9. Fastening to In-Place Construction: Use anchorage devices and fasteners where necessary for securing handrails and railing to in-place construction. INSPECT AND REUSE SOUND CONNECTIONS WHEN POSSIBLE.

B. Railing Connections:

1. Welded Connections: Use fully welded joints for permanently connecting railing components by welding. Cope or butt components to provide 100 percent contact or use manufacturer's standard fitting designed for this purpose.
2. Non-Welded Connections: Use manufacturer's standard mechanical or adhesive joints for permanently connecting railing components. Use wood blocks and padding to prevent damage to railing members and fittings. Seal recessed holes of exposed lock screws using plastic filler cement colored to match finish of handrails and railing systems.

C. Anchoring Posts:

1. Anchor posts in concrete by means of pipe sleeves preset and anchored into concrete. After posts have been inserted into sleeves, fill annular space between post and sleeve solid with the following anchoring material, mixed and placed to comply with anchoring material manufacturer's directions.
 - Non-shrink, nonmetallic grout: Exterior anchors, if in good condition, may be reused if suitable. To be set in new concrete stairs.
 - Interior posts may be set in existing anchor holes if suitable.
2. Cover interior anchorage joint with a flange of the same metal as post; attach to post by welding after placement of anchoring material.
3. Leave exterior anchorage joint exposed, wipe off surplus anchoring material, and leave 1/8-inch buildup, sloped away from post. For installations exposed on exterior or to flow of water, seal anchoring material to comply with grout manufacturer's directions.
4. For steel railings, weld flanges to post and bolt to metal supporting surfaces.

D. Anchoring Rail Ends:

1. Anchor rail ends to concrete and masonry with required flanges, connected to rail ends and anchored into wall construction with post-installed anchors and bolts.
2. Anchor rail ends to metal surfaces with required flanges. Weld flanges to rail ends, and bolt flanges to metal surfaces.

E. Attachment of Handrails to Walls:

INSPECT AND RE-USE SOUND CONNECTIONS WHEN POSSIBLE. ALSO WHEN POSSIBLE, MATCH ORIGINAL LOCATION AND SPACING TO AVOID GHOST MARKS.

1. Attach handrails to wall with wall brackets and end fittings. Provide bracket with not less than 1- 1/2-inch clearance from inside face of handrail and finished wall surface.
2. Locate brackets as indicated or, if not indicated, at spacing required to support structural loads.
3. Secure wall brackets and wall return fittings to building construction. Use type of bracket with flange tapped for concealed anchorage to threaded hanger bolt.
4. For concrete and solid masonry anchorage, use drilled-in expansion shield and either concealed hanger bolt or exposed lab bolt, as applicable.
5. For hollow masonry anchorage, use toggle bolts with square heads.
6. For steel framed gypsum board assemblies, fasten brackets directly to steel framing or concealed anchors using self-tapping screws of size and type required to support structural loads.

3.03 PROTECTION

A. Protect finishes of railing systems and handrails from damage during cleaning period by use of temporary protective coverings approved by railing manufacturer. Remove protective covering at time of Substantial Completion.

B. Restore finishes damaged during installation and construction period so that no evidence remains of correction work. Return items that cannot be refinished in the field to the shop; make required alterations and refinish entire unit or provide new units.

1.2 Metal windows

The proportion, shape, pattern, and size of historic windows, and screens help convey the style and period of a building and contribute to its overall architectural character. In addition, the quality of construction of historic windows is generally much better than that of replacement windows and can be preserved through regular maintenance.

Historically, the original metal windows would have included multi-pane casement style, multi-pane awning style, hopper, and stationary.

1.2.1 Immediate concerns for metal windows

It is important to understand the type of metal used for the window (iron, steel, bronze, or aluminum) as this information will determine the right treatment. These are some of the problems to watch for when inspecting older metal windows:

- The original finish has been worn down or off due to age or weather exposing bare metal (Figure 6).
- The windows were painted at some point, and they were painted shut.
- The windows were painted at some point, and the paint has been worn down or off due to age or weather exposure (Figure 7–Figure 10).

Figure 6. Original steel multi-pane hopper-style window showing signs of rust (ERDC-CERL, 2015).

Figure 7. Repaint metal windows following guidelines and standards (ERDC-CERL, 2015).

Figure 8. Original metal frame casement windows need to be repainted following guidelines and standards (ERDC-CERL, 2015).

Figure 9. Bronze framing and windows on the sunroom at the American Merchant Marine Museum (Barstow Mansion) (ERDC-CERL, 2013).

Figure 10. Detail of the bronze framing and windows on the sunroom at the American Merchant Marine Museum (Barstow Mansion) (ERDC-CERL, 2013).

1.2.1 Guidelines, briefs, bulletins, and sources for metal windows

In addition to the information contained in this manual, the authors have compiled the following federal resource publications (reproduced here for convenience, with links for online access given in References) to inform managers about standards, guidelines, and procedures for understanding architecture, and caring for, preserving, and rehabilitating historic buildings with emphasis on historic metal windows material (see subsections 1.2.1.1–1.2.1.3).

1.2.1.1 Repair and thermal upgrading of historic steel windows – (Park 1984 – Preservation Brief #13)

Technical Preservation Services

National Park Service
U.S. Department of the Interior

[Home](#) > [How to Preserve](#) > [Preservation Briefs](#) > 13 Steel Windows

Some of the web versions of the Preservation Briefs differ somewhat from the printed versions. Many illustrations are new and in color; Captions are simplified and some complex charts are omitted. To order hard copies of the Briefs, see [Printed Publications](#)®.

PRESERVATION BRIEFS

13

The Repair and Thermal Upgrading of Historic Steel Windows

Sharon C. Park, AIA

[Historical Development](#)

[Evaluation](#)

[1890–Present: Typical Rolled Steel Windows](#)

[Routine Maintenance](#)

[Repair](#)

[Weatherization](#)

[Window Replacement](#)

[Summary and References](#)

[Reading List](#)

[Download the PDF](#)

Metal casement window from "Hope's Metal Windows and Casements, 1818-1926."
Photo: Courtesy, Hope's Windows, Inc.

The Secretary of the Interior's "Standards for Rehabilitation" require that where historic windows are individually significant features, or where they contribute to the character of significant facades, their distinguishing visual qualities must not be destroyed. Further, the rehabilitation guidelines recommend against changing the historic appearance of windows through the use of inappropriate designs, materials, finishes, or colors which radically change the sash, depth of reveal, and muntin configuration; the reflectivity and color of the glazing; or the appearance of the frame.

Windows are among the most vulnerable features of historic buildings undergoing rehabilitation. This is especially the case with rolled steel windows, which are often mistakenly not deemed worthy of preservation in the conversion of old buildings to new uses. The ease with which they can be replaced and the mistaken assumption that they cannot be made energy efficient except at great expense are factors that typically lead to the decision to remove them.

In many cases, however, repair and retrofit of the historic windows are more economical than wholesale replacement, and all too often, replacement units are unlike the originals in design and appearance. If the windows are important in establishing the historic character of the building, insensitively designed replacement windows may diminish—or destroy—the building's historic character.

This Brief identifies various types of historic steel windows that dominated the metal window market from 1890–1950. It then gives criteria for evaluating deterioration and

Maintaining historic steel windows for continued use is always recommended. Photo: NPS files.

for determining appropriate treatment, ranging from routine maintenance and weatherization to extensive repairs, so that replacement may be avoided where possible.¹ This information applies to do-it-yourself jobs and to large rehabilitations where the volume of work warrants the removal of all window units for complete overhaul by professional contractors.

This Brief is not intended to promote the repair of ferrous metal windows in every case, but rather to insure that preservation is always the first consideration in a rehabilitation project. Some windows are not important elements in defining a building's historic character; others are highly significant, but so deteriorated that repair is infeasible. In such cases, the Brief offers guidance in evaluating appropriate replacement windows.

Historical Development

Although metal windows were available as early as 1860 from catalogues published by architectural supply firms, they did not become popular until after 1890. Two factors combined to account for the shift from wooden to metal windows about that time. Technology borrowed from the rolling industry permitted the mass production of rolled steel windows. This technology made metal windows cost competitive with conventional wooden windows. In addition, a series of devastating urban fires in Boston, Baltimore, Philadelphia, and San Francisco led to the enactment of strict fire codes for industrial and multi-story commercial and office buildings.

As in the process of making rails for railroads, rolled steel windows were made by passing hot bars of steel through progressively smaller, shaped rollers until the appropriate angled configuration was achieved. The rolled steel sections, generally 1/8" thick and 1" - 1-1/2" wide, were used for all the components of the windows: sash, frame, and subframe. With the addition of wire glass, a fire-resistant window resulted. These rolled steel windows are almost exclusively found in masonry or concrete buildings.

A by-product of the fire-resistant window was the strong metal frame that permitted the installation of larger windows and windows in series. The ability to have expansive amounts of glass and increased ventilation dramatically changed the designs of late 19th and early 20th century industrial and commercial buildings.

The newly available, reasonably priced steel windows soon became popular for more than just their fire-resistant qualities. They were standardized, extremely durable, and easily transported. These qualities led to the use of steel windows in every type of construction, from simple industrial and institutional buildings to luxury commercial and apartment buildings. Casement, double-hung, pivot, projecting, austral, and continuous windows differed in operating and ventilating capacities. In addition, the thin profiles of metal windows contributed to the streamlined appearance of the Art Deco, Art Moderne, and International Styles, among others.

The extensive use of rolled steel metal windows continued until after World War II when cheaper, noncorroding aluminum windows became increasingly popular. While aluminum windows dominate the market today, steel windows are still fabricated. Should replacement of original windows become necessary, replacement windows may be available from the manufacturers of some of the earliest steel windows. Before an informed decision can be made whether to repair or replace metal windows, however, the significance of the windows must be determined and their physical condition assessed.

Evaluation

Historic and Architectural Considerations

An assessment of the significance of the windows should begin with a consideration of their function in relation to the building's historic use and its historic character. Windows that help define the building's historic character should be preserved even if the building is being converted to a new use. For example, projecting steel windows used to introduce light and an effect of spaciousness to a warehouse or industrial plant can be retained in the conversion of such a building to offices or residences.

Other elements in assessing the relative importance of the historic windows include the design of the windows and their relationship to the scale, proportion, detailing and architectural style of the building. While it may be easy to determine the aesthetic value of highly ornamented windows, or to recognize the importance of streamlined windows as an element of a style, less elaborate windows can also provide strong visual interest by their small panes or projecting planes when open, particularly in simple, unadorned industrial buildings.

Historic metal windows provide abundant natural light in this rehabilitated industrial space. Photo: NPS files.

One test of the importance of windows to a building is to ask if the overall appearance of the building would be changed noticeably if the windows were to be removed or radically altered. If so, the windows are important in defining the building's historic character, and should be repaired if their physical condition permits.

Physical Evaluation

Steel window repair should begin with a careful evaluation of the physical condition of each unit. Either drawings or photographs, liberally annotated, may be used to record the location of each window, the type of operability, the condition of all three parts—sash, frame and subframe—and the repairs essential to its continued use.

A severely deteriorated frame, such as this, can be replaced in kind. Photo: Henry Chambers, AIA

Specifically, the evaluation should include: presence and degree of corrosion; condition of paint; deterioration of the metal sections, including bowing, misalignment of the sash, or bent sections; condition of the glass and glazing compound; presence and condition of all hardware, screws, bolts, and hinges; and condition of the masonry or concrete surrounds, including need for caulking or resetting of improperly sloped sills.

Corrosion, principally rusting in the case of steel windows, is the controlling factor in window repair; therefore, the evaluator should first test for its presence. Corrosion can be light, medium, or heavy, depending on how much the rust has penetrated the metal sections. If the rusting is merely a surface accumulation or flaking, then the corrosion is light. If the rusting has penetrated the metal (indicated by a bubbling texture), but has not caused any structural damage, then the corrosion is medium. If the rust has penetrated deep into the metal, the corrosion is heavy. Heavy corrosion generally results in some form of structural damage, through delamination, to the metal section, which must then be patched or spliced.

A sharp probe or tool, such as an ice pick, can be used to determine the extent of corrosion in the metal. If the probe can penetrate the surface of the metal and brittle strands can be dug out, then

a high degree of corrosive deterioration is present.

In addition to corrosion, the condition of the paint, the presence of bowing or misalignment of metal sections, the amount of glass needing replacement, and the condition of the masonry or concrete surrounds must be assessed in the evaluation process. These are key factors in determining whether or not the windows can be repaired in place. The more complete the inventory of existing conditions, the easier it will be to determine whether repair is feasible or whether replacement is warranted.

Rehabilitation Work Plan

Following inspection and analysis, a plan for the rehabilitation can be formulated. The actions necessary to return windows to an efficient and effective working condition will fall into one or more of the following categories: routine maintenance, repair, and weatherization. The routine maintenance and weatherization measures described here are generally within the range of do-it-yourselfers. Other repairs, both moderate and major, require a professional contractor. Major repairs normally require the removal of the window units to a workshop, but even in the case of moderate repairs, the number of windows involved might warrant the removal of all the deteriorated units to a workshop in order to realize a more economical repair price. Replacement of windows should be considered only as a last resort.

Since moisture is the primary cause of corrosion in steel windows, it is essential that excess moisture be eliminated and that the building be made as weathertight as possible before any other work is undertaken. Moisture can accumulate from cracks in the masonry, from spalling mortar, from leaking gutters, from air conditioning condensation runoff, and from poorly ventilated interior spaces.

Finally, before beginning any work, it is important to be aware of health and safety risks involved. Steel windows have historically been coated with lead paint. The removal of such paint by abrasive methods will produce toxic dust. Therefore, safety goggles, a toxic dust respirator, and protective clothing should be worn. Similar protective measures should be taken when acid compounds are used. Local codes may govern the methods of removing lead paints and proper disposal of toxic residue.

Typical Rolled Steel Windows Available from 1890 to the Present

DOUBLE-HUNG industrial windows duplicated the look of traditional wooden windows. Metal double-hung windows were early examples of a building product adapted to meet stringent new fire code requirements for manufacturing and high-rise buildings in urban areas. Soon supplanted in industrial buildings by less expensive pivot windows, double-hung metal windows regained popularity in the 1940s for use in speculative suburban housing.

PIVOT windows were an early type of industrial window that combined inexpensive first cost and low maintenance. Pivot windows became standard for warehouses and power plants where the lack of screens was not a problem. The window shown here is a horizontal pivot. Windows that turned about a vertical axis were also manufactured (often of iron). Such vertical pivots are rare today.

PROJECTING windows, sometimes called awning or hopper windows, were perfected in the 1920s for industrial and institutional buildings. They were often used in "combination" windows, in which upper panels opened out and lower panels opened in. Since each movable panel projected to one side of the frame only, unlike pivot windows, for example, screens could be introduced.

AUSTRAL windows were also a product of the 1920s. They combined the appearance of the double-hung window with the increased ventilation and ease of operation of the projected window. (When fully opened, they provided 70% ventilation as compared to 50% ventilation for double-hung windows.) Austral windows were often used in schools, libraries and other public buildings.

CASEMENT windows adapted the English tradition of using wrought iron casements with leaded came for residential use. Rolled steel casements (either single, as shown, or paired) were popular in the 1920s for cottage style residences and Gothic style campus architecture. More streamlined casements were popular in the 1930s for institutional and small industrial buildings.

CONTINUOUS windows were almost exclusively used for industrial buildings requiring high overhead lighting. Long runs of clerestory windows operated by mechanical tension rod gears were typical. Long banks of continuous windows were possible because the frames for such windows were often structural elements of the building.

Routine Maintenance

A preliminary step in the routine maintenance of steel windows is to remove surface dirt and grease in order to ascertain the degree of deterioration, if any. Such minor cleaning can be accomplished using a brush or vacuum followed by wiping with a cloth dampened with mineral spirits or denatured alcohol.

If it is determined that the windows are in basically sound condition, the following steps can be taken:

1. removal of light rust, flaking and excessive paint;
2. priming of exposed metal with a rust-inhibiting primer;
3. replacement of cracked or broken glass and glazing compound;
4. replacement of missing screws or fasteners;
5. cleaning and lubrication of hinges;
6. repainting of all steel sections with two coats of finish paint compatible with the primer; and
7. caulking the masonry surrounds with a high quality elastomeric caulk.

Recommended methods for removing light rust include manual and mechanical abrasion or the application of chemicals. Burning off rust with an oxyacetylene or propane torch, or an inert gas welding gun, should never be attempted because the heat can distort the metal. In addition, such intense heat (often as high as 3800 deg. F) vaporizes the lead in old paint, resulting in highly toxic fumes. Furthermore, such heat will likely result in broken glass. Rust can best be removed using a wire brush, an aluminum oxide sandpaper, or a variety of power tools adapted for abrasive cleaning such as an electric drill with a wire brush or a rotary whip attachment. Adjacent sills and window jambs may need protective shielding.

Rust can also be removed from ferrous metals by using a number of commercially prepared anticorrosive acid compounds. Effective on light and medium corrosion, these compounds can be purchased either as liquids or gels. Several bases are available, including phosphoric acid, ammonium citrate, oxalic acid and hydrochloric acid. Hydrochloric acid is generally not recommended; it can leave chloride deposits, which cause future corrosion. Phosphoric acid-based compounds do not leave such deposits, and are therefore safer for steel windows. However, any chemical residue should be wiped off with damp cloths, then dried immediately. Industrial blow-dryers work well for thorough drying. The use of running water to remove chemical residue is never recommended because the water may spread the chemicals to adjacent surfaces, and drying of these surfaces may be more difficult. Acid cleaning compounds will stain masonry; therefore plastic sheets should be taped to the edge of the metal sections to protect the masonry surrounds. The same measure should be followed to protect the glazing from etching because of acid contact.

Measures that remove rust will ordinarily remove flaking paint as well. Remaining loose or flaking paint can be removed with a chemical paint remover or with a pneumatic needle scaler.

or gun, which comes with a series of chisel blades and has proven effective in removing flaking paint from metal windows. Well-bonded paint may serve to protect the metal further from corrosion, and need not be removed unless paint buildup prevents the window from closing tightly. The edges should be feathered by sanding to give a good surface for repainting.

Next, any **bare metal** should be wiped with a cleaning solvent such as denatured alcohol, and dried immediately in preparation for the application of an anticorrosive primer. Since corrosion can recur very soon after metal has been exposed to the air, the metal should be primed immediately after cleaning. Spot priming may be required periodically as other repairs are undertaken. Anticorrosive primers generally consist of oil-alkyd based paints rich in zinc or zinc chromate.⁴ Red lead is no longer available because of its toxicity. All metal primers, however, are toxic to some degree and should be handled carefully. Two coats of primer are recommended. Manufacturer's recommendations should be followed concerning application of primers.

Repair

Repair in Place

The maintenance procedures described above will be insufficient when corrosion is extensive, or when metal window sections are misaligned. Medium to heavy corrosion that has not done any structural damage to the metal sections can be removed either by using the chemical cleaning process described under "Routine Maintenance" or by sandblasting. Since sandblasting can damage the masonry surrounds and crack or cloud the glass, metal or plywood shields should be used to protect these materials. The sandblasting pressure should be low, 80-100 pounds per square inch, and the grit size should be in the range of #10-#45. Glass peening beads (glass pellets) have also been successfully used in cleaning steel sections. While sandblasting equipment comes with various nozzle sizes, pencil-point blasters are most useful because they give the operator more effective control over the direction of the spray. The small aperture of the pencil-point blaster is also useful in removing dried putty from the metal sections that hold the glass. As with any cleaning technique, once the bare metal is exposed to air, it should be primed as soon as possible. This includes the inside rabbeted section of sash where glazing putty has been removed. To reduce the dust, some local codes allow only wet blasting. In this case, the metal must be dried immediately, generally with a blowdrier (a step that the owner should consider when calculating the time and expense involved). Either form of sandblasting metal covered with lead paints produces toxic dust. Proper precautionary measures should be taken against toxic dust and silica particles.

Bent or bowed metal sections may be the result of damage to the window through an impact or corrosive expansion. If the distortion is not too great, it is possible to re-align the metal sections without removing the window to a metal fabricator's shop. The glazing is generally removed and pressure is applied to the bent or bowed section. In the case of a muntin, a protective 2 x 4 wooden bracing can be placed behind the bent portion and a wire cable with a winch can apply progressively more pressure over several days until the section is realigned. The 2 x 4 bracing is necessary to distribute the pressure evenly over the damaged section. Sometimes a section, such as the bottom of the frame, will bow out as a result of pressure exerted by corrosion and it is often necessary to cut the metal section to relieve this pressure prior to pressing the section back into shape and making a welded repair.

Once the metal sections have been cleaned of all corrosion and straightened, small holes and uneven areas resulting from rusting should be filled with a patching material and sanded smooth to eliminate pockets where water can accumulate. A patching material of steel fibers and an epoxy binder may be the easiest to apply. This steel-based epoxy is available for industrial steel repair; it can also be found in auto body patching compounds or in plumber's epoxy. As with any product, it is important to follow the manufacturer's instructions for proper use and best results. The traditional patching technique—melting steel welding rods to fill holes in the metal sections—may be difficult to apply in some situations; moreover, the window glass must be removed during the repair process, or it will crack from the expansion of the heated metal sections. After these repairs, glass replacement, hinge lubrication, painting, and other cosmetic repairs can be undertaken as necessary.

To complete the checklist for routine maintenance, cracked glass, deteriorated glazing compound, missing screws, and broken fasteners will have to be replaced; hinges cleaned and lubricated; the metal windows painted, and the masonry surrounds caulked. If the glazing must be replaced, all clips, glazing beads, and other fasteners that hold the glass to the sash should be retained, if possible, although replacements for these parts are still being fabricated. When bedding glass,

The historic steel sash is shown in place, prior to its removal and replacement with inappropriate aluminum sash (see below). Photo: NPS files.

The historic steel sash (see photo above) was removed and replaced with modern aluminum sash, resulting in a negative visual impact on the building's historic character. Photo: NPS files.

use only glazing compound formulated for metal windows. To clean the hinges (generally brass or bronze), a cleaning solvent and fine bronze wool should be used. The hinges should then be lubricated with a non-greasy lubricant specially formulated for metals and with an anticorrosive agent. These lubricants are available in a spray form and should be used periodically on frequently opened windows.

Final painting of the windows with a paint compatible with the anticorrosive primer should proceed on a dry day. (Paint and primer from the same manufacturer should be used.) Two coats of finish paint are recommended if the sections have been cleaned to bare metal. The paint should overlap the glass slightly to insure weathertightness at that connection. Once the paint dries thoroughly, a flexible exterior caulk can be applied to eliminate air and moisture infiltration where the window and the surrounding masonry meet.

Caulking is generally undertaken after the windows have received at least one coat of finish paint. The perimeter of the masonry surround should be caulked with a flexible elastomeric compound that will adhere well to both metal and masonry. The caulking used should be a type intended for exterior application, have a high tolerance for material movement, be resistant to ultraviolet light, and have a minimum durability of 10 years. Three effective compounds (taking price and other factors into consideration) are polyurethane, vinyl acrylic, and butyl rubber. In selecting a caulking material for a window retrofit, it is important to remember that the caulking compound may be covering other materials in a substrate. In this case, some compounds, such as silicone, may not adhere well. Almost all modern caulking compounds can be painted after curing completely. Many come in a range of colors, which eliminates the need to paint. If colored caulking is used, the windows should have been given two coats of finish paint prior to caulking.

Repair in Workshop

Damage to windows may be so severe that the window sash and sometimes the frame must be removed for cleaning and extensive rust removal, straightening of bent sections, welding or splicing in of new sections, and reglazing. These major and expensive repairs are reserved for highly significant windows that cannot be replaced; the procedures involved should be carried out only by skilled workmen.

As part of the orderly removal of windows, each window should be numbered and the parts labeled. The operable metal sash should be dismantled by removing the hinges; the fixed sash and, if necessary, the frame can then be unbolted or unscrewed. (The subframe is usually left in place. Built into the masonry surrounds, it can only be cut out with a torch.) Hardware and hinges should be labeled and stored together.

The two major choices for removing flaking paint and corrosion from severely deteriorated windows are dipping in a chemical bath or sandblasting. Both treatments require removal of the glass. If the windows are to be dipped, a phosphoric acid solution is preferred, as mentioned earlier. While the dip tank method is good for fairly evenly distributed rust, deep set rust may remain after dipping. For that reason, sandblasting is more effective for heavy and uneven corrosion. Both methods leave the metal sections clean of residual paint. As already noted, after cleaning has exposed the metal to the air, it should be primed immediately after drying with an anticorrosive primer to prevent rust from recurring.

Sections that are seriously bent or bowed must be straightened with heat and applied pressure in a workshop. Structurally weakened sections must be cut out, generally with an oxyacetylene torch, and replaced with sections welded in place and the welds ground smooth. Finding replacement metal sections, however, may be difficult. While most rolling mills are producing modern sections suitable for total replacement, it may be difficult to find an exact profile match for a splicing repair. The best source of rolled metal sections is from salvaged windows, preferably from the same building. If no salvaged windows are available, two options remain. Either an ornamental metal fabricator can weld flat plates into a built-up section, or a steel plant can mill bar steel into the desired profile.

While the sash and frame are removed for repair, the subframe and masonry surrounds should be inspected. This is also the time to reset sills or to remove corrosion from the subframe, taking care to protect the masonry surrounds from damage.

Missing or broken hardware and hinges should be replaced on all windows that will be operable. Salvaged windows, again, are the best source of replacement parts. If matching parts cannot be found, it may be possible to adapt ready-made items. Such a substitution may require filling existing holes with steel epoxy or with plug welds and tapping in new screw holes. However, if the hardware is a highly significant element of the historic window, it may be worth having reproductions made.

Weatherization

Historic metal windows are generally not energy efficient; this has often led to their wholesale replacement. Metal windows can, however, be made more energy efficient in several ways, varying in complexity and cost. Caulking around the masonry openings and adding weatherstripping, for example, can be do-it-yourself projects and are important first steps in reducing

air infiltration around the windows. They usually have a rapid payback period. Other treatments include applying fixed layers of glazing over the historic windows, adding operable storm windows, or installing thermal glass in place of the existing glass. In combination with caulking and weatherstripping, these treatments can produce energy ratings rivaling those achieved by new units.³

Weatherstripping

The first step in any weatherization program, caulking, has been discussed above under "Routine Maintenance." The second step is the installation of weatherstripping where the operable portion of the sash, often called the ventilator, and the fixed frame come together to reduce perimeter air infiltration. Four types of weatherstripping appropriate for metal windows are spring-metal, vinyl strips, compressible foam tapes, and sealant beads. The spring-metal, with an integral friction fit mounting clip, is recommended for steel windows in good condition. The clip eliminates the need for an applied glue; the thinness of the material insures a tight closure. The weatherstripping is clipped to the inside channel of the rolled metal section of the fixed frame. To insure against galvanic corrosion between the weatherstripping (often bronze or brass), and the steel window, the window must be painted prior to the installation of the weatherstripping. This weatherstripping is usually applied to the entire perimeter of the window opening, but in some cases, such as casement windows, it may be best to avoid weatherstripping the hinge side. The natural wedging action of the weatherstripping on the three sides of the window often creates an adequate seal.

Vinyl weatherstripping can also be applied to metal windows. Folded into a "V" configuration, the material forms a barrier against the wind. Vinyl weatherstripping is usually glued to the frame, although some brands have an adhesive backing. As the vinyl material and the applied glue are relatively thick, this form of weatherstripping may not be appropriate for all situations.

Compressible foam tape weatherstripping is often best for large windows where there is a slight bending or distortion of the sash. In some very tall windows having closure hardware at the sash midpoint, the thin sections of the metal window will bow away from the frame near the top. If the gap is not more than 1/4", foam weatherstripping can normally fill the space. If the gap exceeds this, the window may need to be realigned to close more tightly. The foam weatherstripping comes either with an adhesive or plain back; the latter variety requires application with glue. Compressible foam requires more frequent replacement than either spring-metal or vinyl weatherstripping.

A fourth type of successful weatherstripping involves the use of a caulking or sealant bead and a polyethylene bond breaker tape. After the window frame has been thoroughly cleaned with solvent, permitted to dry, and primed, a neat bead of low modulus (firm setting) caulk, such as silicone, is applied. A bond breaker tape is then applied to the operable sash covering the metal section where contact will occur. The window is then closed until the sealant has set (27 days, depending on temperature and humidity). When the window is opened, the bead will have taken the shape of the air infiltration gap and the bond breaker tape can be removed. This weatherstripping method appears to be successful for all types of metal windows with varying degrees of air infiltration.

Since the several types of weatherstripping are appropriate for different circumstances, it may be necessary to use more than one type on any given building. Successful weatherstripping depends upon using the thinnest material adequate to fill the space through which air enters. Weatherstripping that is too thick can spring the hinges, thereby resulting in more gaps.

Appropriate Types of Weatherstripping for Metal Windows

SPRING-METAL comes in bronze, brass or stainless steel with an integral friction fit clip. The weatherstripping is applied after the repaired windows are painted to avoid galvanic corrosion. This type of thin weatherstripping is intended for windows in good condition.

VINYL STRIPS are scored and fold into a "V" configuration. Applied adhesive is necessary which will increase the thickness of the weatherstripping, making it inappropriate for some situations. The weatherstripping is generally applied to the window after painting.

Closed cell **FOAM TAPE** comes either with or without an adhesive backing. It is effective for windows with a gap of approximately 1/4" and is easy to install. However, this type of weatherstripping will need frequent replacement on windows in regular use. The metal section should be cleaned of all dirt and grease prior to its application.

SEALANT BEAD. This very effective type of weatherstripping involves the application of a clean bead of firm setting caulk on the primed frame with a polyethylene bond breaker tape on the operable sash. The window is then closed until the bead has set and takes the form of the gap. The sash is then opened and the tape is removed leaving the set caulk as the weatherstripping.

Thermal Glazing

Another weatherization treatment is to install an additional layer of glazing to improve the thermal efficiency of the existing window. The decision to pursue this treatment should proceed from careful analysis. Each of the most common techniques for adding a layer of glazing will effect approximately the same energy savings (approximately double the original insulating value of the windows); therefore, cost and aesthetic considerations usually determine the choice of method. Methods of adding a layer of glazing to improve thermal efficiency include adding a new layer of transparent material to the window; adding a separate storm window; and replacing the single layer of glass in the window with thermal glass.

Historic steel sash can be fitted with dual glazing to improve thermal efficiency. Photo: NPS files.

The least expensive of these options is to install a clear material (usually rigid sheets of acrylic or glass) over the original window. The choice between acrylic and glass is generally based on cost, ability of the window to support the material, and long-term maintenance outlook. If the material is placed over the entire window and secured to the frame, the sash will be inoperable. If the continued use of the window is important (for ventilation or for fire exits), separate panels should be affixed to the sash without obstructing operability. Glass or acrylic panels set in frames can be attached using magnetized gaskets, interlocking material strips, screws or adhesives. Acrylic panels can be screwed directly to the metal windows, but the holes in the acrylic panels should allow for the expansion and contraction of this material. A compressible gasket between the prime sash and the storm panel can be very effective in establishing a thermal cavity between glazing layers. To avoid condensation, 1/8" cuts in a top corner and diagonally opposite bottom corner of the gasket will provide a vapor bleed, through which moisture can evaporate. (Such cuts, however, reduce thermal performance slightly.) If condensation does occur, however, the panels should be easily removable in order to wipe away moisture before it causes corrosion.

The second method of adding a layer of glazing is to have independent storm windows fabricated. (Pivot and astral windows, however, which project on either side of the window frame when open, cannot easily be fitted with storm windows and remain operational.) The storm window should be compatible with the original sash configuration. For example, in paired casement windows, either specially fabricated storm casement windows or sliding units in which the vertical meeting rail of the slider reflects the configuration of the original window should be installed. The decision to place storm windows on the inside or outside of the window depends on whether the historic window opens in or out, and on the visual impact the addition of storm windows will have on the building. Exterior storm windows, however, can serve another purpose besides saving energy: they add a layer of protection against air pollutants and vandals, although they will partially obscure the prime window. For highly ornamental windows this protection can determine the choice of exterior rather than interior storm windows.

The third method of installing an added layer of glazing is to replace the original single glazing with thermal glass. Except in rare instances in which the original glass is of special interest (as with stained or figured glass), the glass can be replaced if the hinges can tolerate the weight of the additional glass. The rolled metal sections for steel windows are generally from 1" 1-1/2" thick. Sash of this thickness can normally tolerate thermal glass, which ranges from 3/8" 5/8". (Metal glazing beads, readily available, are used to reinforce the muntins, which hold the glass.) This treatment leaves the window fully operational while preserving the historic appearance. It is, however, the most expensive of the treatments discussed here.

Window Replacement

Repair of historic windows is always preferred within a rehabilitation project. Replacement should be considered only as a last resort. However, when the extent of deterioration or the unavailability of replacement sections renders repair impossible, replacement of the entire window may be justified.

In the case of significant windows, replacement in kind is essential in order to maintain the historic character of the building. However, for less significant windows, replacement with compatible new windows may be acceptable. In selecting compatible replacement windows, the material, configuration, color, operability, number and size of panes, profile and proportion of metal sections, and reflective quality of the original glass should be duplicated as closely as possible.

A number of metal window manufacturing companies produce rolled steel windows. While stock modern window designs do not share the multi-pane configuration of historic windows, most of these manufacturers can reproduce the historic configuration if requested, and the cost is not excessive for large orders. Some manufacturers still carry the standard pre-World War II multi-light windows using the traditional 12" x 18" or 14" x 20" glass sizes in industrial, commercial, security, and residential configurations. In addition, many of the modern steel windows have

integral weatherstripping, thermal break construction, durable vinyl coatings, insulating glass, and other desirable features.

Windows manufactured from other materials generally cannot match the thin profiles of the rolled steel sections. Aluminum, for example, is three times weaker than steel and must be extruded into a boxlike configuration that does not reflect the thin historic profiles of most steel windows. Wooden and vinyl replacement windows generally are not fabricated in the industrial style, nor can they reproduce the thin profiles of the rolled steel sections, and consequently are generally not acceptable replacements.

For product information on replacement windows, the owner, architect, or contractor should consult manufacturers' catalogues, building trade journals, or the Steel Window Institute, 1230 Keith Building, Cleveland, Ohio 44115.

This is a successful replacement in kind of the deteriorated frame shown above. Photo: Henry Chambers, AIA.

Summary and References

The National Park Service recommends the retention of significant historic metal windows whenever possible. Such windows, which can be a character-defining feature of a historic building, are too often replaced with inappropriate units that impair rather than complement the overall historic appearance. The repair and thermal upgrading of historic steel windows is more practicable than most people realize. Repaired and properly maintained metal windows have greatly extended service lives. They can be made energy efficient while maintaining their contribution to the historic character of the building.

Notes

1. The technical information given in this brief is intended for most ferrous (or magnetic) metals, particularly rolled steel. While stainless steel is a ferrous metal, the cleaning and repair techniques outlined here must not be used on it as the finish will be damaged. For information on cleaning stainless steel and nonferrous metals, such as bronze, Monel, or aluminum, refer to *Metals in America's Historic Buildings* (see bibliography).
2. Refer to Table IV. Types of Paint Used for Painting Metal in *Metals in America's Historic Buildings*, p. 139. (See bibliography).
3. One measure of energy efficiency is the U-value (the number of BTUs per hour transferred through a square foot of material). The lower the U-value, the better the performance. According to *ASHRAE HANDBOOK 1977 Fundamentals*, the U-value of historic rolled steel sash with single glazing is 1.3. Adding storm windows to the existing units or reglazing with 5/8" insulating glass produces a U-value of .69. These methods of weatherizing historic steel windows compare favorably with rolled steel replacement alternatives: with factory installed 1" insulating glass (.67 U-value); with added thermal break construction and factory finish coatings (.62 U-value).

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This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Technical Preservation Services (TPS), National Park Service prepares standards, guidelines, and other educational materials on responsible historic preservation treatments for a broad public.

September 1984

Reading List

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1.2.1.2 Cleaning and painting steel windows (GSA 2017c)

U.S. General Services Administration

Cleaning and Painting Steel Windows

Procedure code:

850002S

Source:

National Capitol Region Specifications

Division:

Doors And Windows

Section:

Metal Windows

Last Modified:

12/22/2017

CLEANING AND PAINTING STEEL WINDOWS

BEFORE UNDERTAKING ANY PROJECT INVOLVING PAINT REMOVAL, APPLICABLE STATE AND FEDERAL LAWS ON LEAD PAINT ABATEMENT AND DISPOSAL MUST BE TAKEN INTO ACCOUNT AND CAREFULLY FOLLOWED. STATE AND FEDERAL REQUIREMENTS MAY AFFECT OPTIONS AVAILABLE TO OWNERS ON BOTH PAINT REMOVAL AND REPAINTING. THESE LAWS, AS WELL AS ANY REQUIREMENTS PROHIBITING VOLATILE ORGANIC COMPOUNDS (VOCs), SHOULD BE REQUESTED FROM THE STATE HISTORIC PRESERVATION OFFICER IN EACH STATE. (From Preservation Brief 28, "Painting Historic Interiors").

REGULATORY INFORMATION MAY ALSO BE REQUESTED FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) REGIONAL OFFICE AND/OR THE STATE OFFICE OF ENVIRONMENTAL QUALITY.

PART 1---GENERAL

1.01 SUMMARY

A. This procedure includes guidance on the cleaning and painting of exterior steel windows. It also includes information on removing all deteriorated caulking and recaulking all joints between metal elements and masonry.

B. See 01100-07-S for general project guidelines to be reviewed along with this procedure. These guidelines cover the following sections:

1. Safety Precautions
2. Historic Structures Precautions
3. Submittals

4. Quality Assurance

5. Delivery, Storage and Handling

6. Project/Site Conditions

7. Sequencing and Scheduling

8. General Protection (Surface and Surrounding)

These guidelines should be reviewed prior to performing this procedure and should be followed, when applicable, along with recommendations from the Regional Historic Preservation Officer (RHPO).

PART 2---PRODUCTS

2.01 MANUFACTURERS

A. Devcon Corporation

2.02 MATERIALS

A. Metal Filler: Steel filled two-part epoxy metal filler, putty grade such as "Plastic Steel Putty A" (Devcon Corporation), or approved equal.

B. Dry Grit Blasting: Fine grit No. 16 at 80-100 psi.

C. Paint for Metal: Paint products shall be fresh and well ground; shall not settle readily, cake or thicken in the container; shall be broken up readily with a paddle to a smooth consistency and shall have easy application properties. Other painting materials such as linseed oil, turpentine, mineral spirits, and miscellaneous thickeners, shall be the highest quality of an approved manufacturer.

1. Colors: Each primer coat to be clearly different in color; base coat to be clearly different from primer and finish coat; finish coat to match existing or as approved by RHPO.

2. Dry Film Thickness: Primer, base and finish, each 2 mils.

D. Sealant Backer Rod: Polyethylene compressible rod 50% larger in diameter than joint.

E. Sealant: Polysulfide sealant, white or light grey in color.

F. Mineral Spirits:

1. A petroleum distillate that is used especially as a paint or varnish thinner.

2. Other chemical or common names include Benzine* (not Benzene); Naphtha*; Petroleum spirits*; Solvent naphtha*.

3. Potential Hazards: TOXIC AND FLAMMABLE.

4. Safety Precautions:

- a. AVOID REPEATED OR PROLONGED SKIN CONTACT.
 - b. ALWAYS wear rubber gloves when handling mineral spirits.
 - c. If any chemical is splashed onto the skin, wash immediately with soap and water.
5. Available from construction specialties distributor, hardware store, paint store, or printer's supply distributor.

2.03 EQUIPMENT

- A. Chisels
- B. Joint tools
- C. Putty knife
- D. Stiff, bristle brushes
- E. Paint brushes

PART 3---EXECUTION

3.01 PREPARATION

A. Protection:

- 1. Enclose any dry grit blasting work areas with temporary scaffolding or framework sufficient to support tarpaulin enclosure to prevent escape of abrasive.
- 2. Shield adjacent masonry and glass with a temporary covering of cardboard or fiberboard held in place with heavy-duty strapping tape or wood bracing.

B. Surface Preparation:

- 1. Determine surfaces to which paint is to be applied are even, smooth, sound, clean, dry and free from defects affecting proper application. Report defective surfaces to Contracting Officer.
- 2. All painting should be executed at a temperature range of 50 to 80 F, at a relative humidity below 60%.

3.02 ERECTION, INSTALLATION, APPLICATION

- A. Remove all paint to bare metal from the surface of the frames and sash. Restore sash to full operation.

- B. Paint removal may be done by dry grit blasting, scraping or sanding. See also 05010-05-R for additional guidance on paint removal from steel.

- C. Remove, by hand, all caulking between metal and masonry.
- D. Clean off dirt and grease by rubbing the surface with mineral spirits. Remove residual grit from all surfaces by air blasting.
- E. Seal all open joints between metal elements and masonry with backer rods and sealant. Joints shall be concave with smooth finish. Do not allow sealant to extend over the edges of the metal or the face of the stone. See also 07900-01-R for guidance on replacing joint sealants between window frames and masonry.
- F. Prime all metal within two hours of cleaning. Use color distinct from finish color.
- G. Paint to match color specified by the RHPO.
1. Brush-apply material evenly without runs, sags, or other defects. Work each coat onto the material being coated at an average rate of coverage recommended in manufacturer's printed instructions.
 2. Cover surfaces completely to provide uniform color and appearance with a minimum of dry, film thickness of 2 mils.
 3. Make edges of paint, adjoining other materials or colors, sharp and clean and without overlaps.
 4. Apply additional coats when undercoats, stains, or other conditions show through final coat of paint, until paint film is of uniform finish, color and appearance. Insure that corners, edges, crevices and exposed fasteners receive a dry film thickness equal to that of flat surfaces.
 5. Each coat of paint is to be slightly darker than the preceding coat with the final coat exactly matching the accepted samples.
- 3.03 ADJUSTING/CLEANING
- A. Cleanup: Remove all paint where it has spilled or spattered. Use paint thinner or solvent as necessary to effect complete removal.

1.2.1.3 Treatment for condensation (GSA 2016d)

Treatment for Condensation on Historic Glass and Storm Sashes

Procedure code:

880001S

Division:

Doors and Windows

Section:

Glass & Glazing

Last Modified:

08/18/2016

PART 1---GENERAL

1.01 SUMMARY

- A. This specification provides guidance on cleaning and protection of glazing against condensation.
- B. This specification should NOT be used on wood windows with a shellac finish, as the alcohol mixture recommended for treating condensation will destroy shellac.
- C. Safety Precautions:
 - 1. DO NOT save unused portions of stain-removal materials.
 - 2. DO NOT store any chemicals in unmarked containers.
 - 3. The proper Personal Protective Equipment (PPE) must be used when utilizing the chemicals involved. The proper eye and skin protection, and respirators fitted with appropriate solvent filters must be used. See the manufacturer's MSDS for guidance.
 - 4. NOTE: SOME OF THE SOLVENTS LISTED ARE KNOWN CARCINOGENS AND MAY BE BANNED IN SOME STATES.
 - 5. NOTE: EXCELLENT VENTILATION MUST BE PROVIDED WHEREVER ANY SOLVENT IS USED.
 - a. No use of organic solvents indoors should be allowed without substantial air movement.
 - b. Use only spark-proof fans near operations involving flammable liquids.
 - 6. Before work is commenced, you must have available any antidote and accident treatment chemicals that are noted in the MSDS.
- D. Read "General Project Guidelines" along with this specification. These guidelines should be reviewed prior to performing this procedure and should be followed, when applicable, along with recommendations from the Regional Historic Preservation Officer (RHPO). The guidelines cover the following sections:

1. Safety Precautions
2. Historic Structures Precautions
3. Submittals
4. Quality Assurance
5. Delivery, Storage and Handling
6. Project/Site Conditions
7. Sequencing and Scheduling
8. General Protection (Surface and Surrounding)

1.02 DEFINITIONS

- A. Condensation in building terms is the process by which water vapor, a gas, changes to a liquid. There is always water vapor in the air, the amount depending upon the local climatic conditions.
1. Within a building, the amount of water vapor depends upon the amount of vapor generated by the users. Air can hold more water vapor in higher temperatures.
 2. When the air is saturated, it has reached the dew point. If the temperature drops, the air can no longer hold all the water, so the excess is changed back into liquid form.
- B. Surface condensation occurs on any building material whose temperature is lower than the dew point, but it is only visible on surfaces which are nonabsorbent, such as window glass in winter and exposed cold water pipes in basements in summer.
1. Just as each raindrop forms around a speck of dust, a dirty glazing surface will condense more readily than a clean one.
 2. The intent of this specification is to provide guidance for carrying out a regular maintenance regimen for removing a wide variety of surface contaminants from glazed surfaces.

PART 2---PRODUCTS

2.01 MATERIALS

NOTE: Not all the following chemicals will be needed for every application. Read the entire specification before moving forward.

NOTE: Chemical products are sometimes sold under a common name. This usually means that the substance is not as pure as the same chemical sold under its chemical name. The grade of purity of common name substances, however, is usually adequate for stain removal work, and these products should be purchased when available, as they tend to be less expensive. Common names are indicated below by an asterisk (*).

A. Xylol:

1. Any one of three specific, isomeric, aromatic hydrocarbons which are obtained from tar or petroleum distillates.
2. It can also be a mixture of xylenes and ethyl-benzene that is used chiefly as a solvent.
3. Other chemical or common names include Xylene; 1,4-dimethyl benzene.
4. Potential Hazards: TOXIC AND FLAMMABLE.
5. Available from chemical supply house, hardware store, paint store or printer's supply distributor.

-OR-

B. Toluol:

1. A liquid, aromatic hydrocarbon that resembles benzene but is less volatile, flammable and toxic.
2. It is produced commercially from coke- oven gas, coal tar, and from petroleum, and is used as a solvent, in organic synthesis and as an antiknock agent for gasoline.
3. Other chemical or common names include Toluene.
4. Potential Hazards: TOXIC AND FLAMMABLE.
5. Available from chemical supply house, hardware store, paint store or printer's supply distributor.

C. Glycerin (or Glycerine):

1. A sweet syrupy alcohol usually obtained from animal fats, and used especially as a solvent and plasticizer.
2. Other chemical or common names include Glycerol; Glyceryl hydroxide; Glycyl alcohol; 1,2,3-propanetriol; Propenyl alcohol.
3. Potential Hazards: FLAMMABLE.
4. Available from chemical supply house, drug store or hardware store.

D. Methyl Alcohol:

1. Other chemical or common names include Carbinol; Methanol; Methyl hydrate; Methyl hydroxide; Methyllic alcohol; Colonial spirits*; Columbian spirits*; Green wood spirits*; Manhattan spirits*; Pyroligneous spirit*; Pyroxylic spirit*; Standard wood spirits*; Wood alcohol*; Wood naphtha*; Wood spirit*.
2. Potential Hazards: TOXIC AND FLAMMABLE.
3. Available from automotive supply distributor, chemical supply house, dry cleaning supply distributor, drugstore or pharmaceutical supply distributor, hardware store, paint store, or photographic supply distributor (not a retail camera shop).

E. Caulk such as DAP "Seal 'N Peel Removable Caulk 18324" (not for glazing, see 3.03 D. 3. below for specific usage) or approved equal.

1. Type to match application:
 - a. Natural caulks are used for glazing most wood window members.
 - b. Synthetic caulks are often used for glazing steel, aluminum or vinyl coated window members.
2. For guidance on caulking, see also:
 - a. "Replacing Broken Glass in Wood and Metal Windows"
 - b. "Rehabilitating Wood Windows"
 - c. "Cleaning and Painting Steel Windows"

2.02 EQUIPMENT

- A. Clean cloths for drying
- B. Caulking gun

PART 3---EXECUTION

3.01 EXAMINATION

Before proceeding with steps to clean and protect glazing against condensation, first determine the cause and extent of the problem:

- A. Determine the age of the structure and of the glazing.
- B. Examine the condition of the window components.
- C. Is glass free of embedded dust? (Embedded dust increases condensation)
- D. Check for loose, cracked, broken, chipped, or otherwise damaged glass.
- E. Verify the putty is sound and complete.

3.02 PREPARATION

- A. Protection: Provide adequate wash solutions (i.e. water, soap and towels) before starting the job.
- B. Surface Preparation: Remove all oil, dirt, and other materials from the glass and any metal framing members by means of proper solvents (xylol or toluol).

3.03 ERECTION, INSTALLATION, APPLICATION

NOTE: APPLY TREATMENT EVERY TIME THE GLASS IS WASHED, IN ALL SEASONS. DO NOT USE THIS PROCEDURE ON WINDOWS WITH A SHELLAC FINISH, AS THE ALCOHOL MIXTURE WILL DESTROY THE FINISH.

- A. Apply mixture of equal parts of glycerin and methyl alcohol to the inside of the glass with a clean cloth.
- B. Clean excess solution from glass, frames and sash promptly.
- C. Clean adjacent surfaces immediately if spills have occurred.
- D. If storm windows are in place, identify location of condensation (interior sash or exterior sash) and make the necessary adjustments to reduce condensation as described below.
 - 1. Sweating on the inner face of the interior sash is the result of cold air infiltration around the exterior sash. Caulk around exterior sash to eliminate infiltration.
 - 2. Sweating on the inner face of the exterior sash indicates warm air infiltration around the interior sash. Caulk around interior sash to eliminate infiltration.
 - 3. If storm windows are to be removed and replaced each year, a removable sealant product, such as DAP "Seal 'N Peel Removable Caulk 18324" or approved equal, should be used instead of a more permanent caulk. Silicone-based caulk should be avoided as it may damage the finish, and its superior adhesion could cause loss of wood when the pieces are separated. If plausible for your situation, a better solution is to utilize a natural wool or felt weatherstrip, to be installed on the storm window once and reused year after year.

1.3 Metal doors

The location and appearance of doors are important character-defining features of historic buildings. Main entry doors, usually located on the front facades, often employ richer materials and more elaborate designs than do rear or service doors.

There are only a few original metal entry doors located on USMMA historic buildings; an example is shown in Figure 11.

1.3.1 Immediate concerns for metal doors

It is important to understand the type of metal used for the doors (iron, steel, bronze, or aluminum) as this will determine the correct treatment.

These are some of the problems to be looked out for when inspecting older metal windows:

- Doors are subject to various forms of deterioration. Metal doors and surrounds may corrode, or their anchoring systems may fail.
- Door hardware may no longer function properly.
- The original finish has been worn down or off due to age or weather exposing bare metal.
- Historic doors that have been inappropriately altered should be replaced with a door that duplicates, as closely as possible, the design and detailing of the original.

Figure 11. Original steel vestibule doors at Wiley Hall (ERDC-CERL, 2015).

1.3.2 Guidelines, briefs, bulletins, and sources for metal doors

In addition to the information contained in this manual, the authors have compiled the following federal resource publications (reproduced here for

convenience, with links for online access given in References) to inform managers about standards, guidelines, and procedures for understanding architecture, and caring for, preserving, and rehabilitating historic buildings with emphasis on historic metal doors (see subsection 1.3.2.1).

1.3.2.1 Stripping and repainting metal doors (GSA 2016e).

GSA U.S. General Services Administration

Stripping And Repainting Metal Doors

Procedure code:
810001S

Source:
National Capitol Region Specifications

Division:
Doors and Windows

Section:
Metal Doors & Frames

Last Modified:
06/08/2016

STRIPPING AND REPAINTING METAL DOORS

PROJECTS INVOLVING PAINT REMOVAL ARE SUBJECT TO STATE AND FEDERAL LAWS ON LEAD PAINT ABATEMENT, DISPOSAL AND USE OF VOLATILE ORGANIC COMPOUNDS (VOCs). SPECIFIED PRODUCTS MAY NOT BE PERMITTED OR APPROPRIATE FOR ALL LOCATIONS. PRODUCTS CONTAINING CHEMICALS KNOWN TO PRESENT HEALTH OR ENVIRONMENTAL HAZARDS SHOULD BE USED ONLY AS A LAST RESORT, WHERE PERMISSIBLE, IN ACCORDANCE WITH MANUFACTURER'S DIRECTIONS AND GOVERNMENT REQUIREMENTS. TEST Milder FORMULATIONS FOR EFFECTIVENESS BEFORE PROCEEDING TO STRONGER ALTERNATIVES.

PART 1---GENERAL

1.01 SUMMARY

A. This procedure includes guidance on stripping, surface preparation, priming and finishing of scratched painted metal doors.

B. See 01100-07-S for general project guidelines to be reviewed along with this procedure. These guidelines cover the following sections:

1. Safety Precautions
2. Historic Structures Precautions
3. Submittals
4. Quality Assurance

5. Delivery, Storage and Handling

6. Project/Site Conditions

7. Sequencing and Scheduling

8. General Protection (Surface and Surrounding)

1.02 DEFINITIONS

A. "Paint" as used herein means all coating systems materials, including primers, emulsions, enamels, sealers and fillers, and other applied materials whether used as prime, intermediate or finish coats.

1.03 SUBMITTALS

A. Product Data: Submit manufacturer's technical information including paint label analysis and application instructions for each material proposed for use.

1. Finish color and primer tints shall be as approved by the RHPO.

2. Prior to beginning work, the Contractor will submit two samples of each color with texture and gloss level to simulate actual conditions for review by the Contracting Officer. Resubmit samples as requested by the Contracting Officer until an acceptable sheen, color, and texture of the paint is achieved.

3. Base coats and undercoats of paint enamel shall be tinted or shaded as directed. Tinting and shading colors are not to be considered as separate colors and no extra or additional payment will be made for such tinting and shading work.

1.04 QUALITY ASSURANCE

A. Regulatory Requirements: Provide primers and other undercoat paint produced by same manufacturer as finish coats. Use only thinners approved by paint manufacturer, and use only within recommended limits.

B. Mock-Ups: Prior to beginning work, the Contractor shall prepare on-site color mock-ups for the Owner's approval.

1. One painted metal office door.

2. Mock-ups shall be prepared until a satisfactory sample is approved by the Contracting Officer. Retain acceptable mock-ups in undisturbed condition, suitably marked, during construction as a standard for judging completed work.

3. The colors and surface finishes of the approved mock-ups shall be matched in the completed work by the Contractor who shall do all mixing and blending necessary to achieve this result.

1.05 DELIVERY, STORAGE AND HANDLING

A. Storage and Protection:

1. Storage space for all materials used on the job shall be designated by the Contracting Officer. The Contractor shall provide a lock and key, and shall secure local Fire Department permit if needed for the storage and use of paint materials.

2. Paints and other flammable products shall not be stored in the building. Keep storage space neat and clean. Soiled or used rags, waste and trash shall be removed from the job site daily, at the end of each day's work, and every precaution shall be taken to avoid the danger of fire.

1.06 PROJECT/SITE CONDITIONS

A. Environmental Requirements:

1. Ventilation in mixing and application areas shall be suitable for application, drying, and curing of paint and safe dissipation of solvent fumes.

2. Air shall not be dust-laden prior to, during or after painting operations.

1.07 SEQUENCING AND SCHEDULING

A. Coordinating Work: Coordinate painting so that it will not conflict with the work of other trades and building

operations.

PART 2---PRODUCTS

2.01 Manufacturers

A: The Sherwin Williams Co.

B: Devcon Corporation

C: Benjamin Moore

D. Glidden Coatings and Resins

E. Klean Strip, Inc.

F. Govgeon Brothers, Inc.

G. Duron

H. ProSoCo, Inc.

755 Minnesota Avenue, P.O. Box 1578

Kansas City, KS 66117

800/255-4255 or 913/281-2700

Prosoco.com

I. Savogran Company

www.savogran.com

800/225-9872 or 617/762-5400

J. Diedrich Technologies, Inc.

www.diedrichtechnologies.com

K. Star Bronze Co.

P.O. Box 2206

Alliance, OH 44601

216/823-1550

email@starbronze.com

I. All painting specifications for General Services Administration historic properties shall include the following clause in the Special Conditions Section:

All paint will be custom tinted by computer matching. Color selection must follow the codes indicated on the finish schedule. Accurate color reproduction is accomplished by matching modern paints to the sample color chips corresponding to each code. There are two coding systems for describing color. They are the Munsell and Plochere color systems.

The contractor must obtain the coded color chips for each color indicated in the finish schedule. Chips are to be purchased directly from the following firm(s):

Munsell Color System

Plochere Color System

1. Chips each range around \$10. Coded color chips must be computer matched. Major paint manufacturers known to be capable of computer color matching include Sherwin Williams, Benjamin Moore, and Duron. Visual matching is not acceptable.

2. Written verification of having had coded color chips computer matched to paints will be submitted to the Contracting Officer 48 hours prior to painting. These verifications must be written on paint manufacturer's stationery and hand signed by the individual conducting the computer color matching. No substitution for coded colors will be accepted."

2.02 MATERIALS

A. Provide best quality grade of various types of coatings as regularly manufactured by acceptable paint materials manufacturers, such as Benjamin Moore, Sherwin Williams, Glidden Coatings and Resins, or approved equal. Materials not displaying manufacturer's identification as a standard, best-grade product will not be acceptable.

B. Color Pigments: Pure, non-fading, applicable types to suit substrates and service indicated.

1. Lead content in pigment of new paints you are to be applying is limited to not more than 0.5% lead, as lead metal based on the total non-volatile (dry-film) of paint by weight. This definition may be updated in the future, and regulations limiting lead in coatings may be even more stringent in certain localities. You need to properly research pertinent standards before utilizing any such product. Regulatory information as well as recommendations for alternative or equivalent chemicals may be requested from the Environmental Protection Agency (EPA) Regional Office and/or the State Office of Environmental Quality.

D. Paint Stripper: Thixotropic/alkaline formulation for removing paint coatings from metal, such as "Sure Klean Fast Acting Stripper," (ProSoCo, Inc.), "Kwick Superfast Paint and Varnish Remover" (Klean Strip, Inc.), or approved equal. Note: These products contain Methylene Chloride. Potential substitutes (following case-specific research and on-site testing to verify applicability and effectiveness) include "Envirestrip" (Diedrich Technologies), "EnviroKlean Safety Peel 1" (ProsoCo, Inc), "Zip Strip 2" (Star Bronze Co.) and "Biodegradable Stripeeze" (Savogran Co.).

E. Epoxy Based Filler (for scratched metal doors): Govgeon Brothers, Inc. #407 Low Density Filler mixed with #105/205 Resin-Hardener system, or approved equal.

2.03 MIXES

A. Mix and prepare painting materials in accordance with manufacturer's directions.

B. Maintain containers used in mixing and application of paint in a clean condition, free of foreign materials and residue.

C. Stir materials before application to produce a mixture of uniform density, and stir as required during application. Do not stir surface film into material. Remove film and, if necessary, strain material before using.

PART 3---EXECUTION

3.01 EXAMINATION

A. Verification of Conditions:

1. Inspect the work for any serious defects or conditions which would interfere or prevent a

satisfactory application of materials under this Section.

2. Do not proceed with the work until corrections have been made. Application shall be deemed acceptance of the related surfaces.

3. No painting shall be performed until surfaces have been properly prepared. Beginning work shall constitute acceptance of base surfaces as found and any subsequent failure or development of defects in the painting work shall be corrected at no additional expense to the Government.

3.02 PREPARATION

A. Protection:

1. Do not paint over any code-required labels, such as Underwriters' Laboratories and Factory Mutual, or any equipment identification, performance rating, name, or nomenclature plates.

2. Caution shall be observed in painting not to daub any bright or plated work adjacent to painted areas and not to spatter marble or other finished work.

3. Protect work of other trades, whether to be painted or not, against damage by painting and finishing work. Correct any damage by cleaning, repainting, repairing or replacing, as acceptable to the Contracting Officer.

4. Provide "Wet Paint" signs as required to protect newly painted finishes. Remove temporary protective wrappings provided by others for protection of their work, after completion of painting operations.

5. At completion of work of other trades, touch-up and restore all damaged or defaced painting work specified herein.

B. Surface Preparation:

1. Perform preparation and cleaning procedures in accordance with paint manufacturer's instructions and as herein specified, for each particular substrate condition.

CAUTION: PAINT MAY CONTAIN LEAD. PAINT REMOVAL ON SURFACES TESTED POSITIVE FOR LEAD MUST BE PERFORMED BY

CERTIFIED LEAD ABATEMENT FIRMS. For additional guidance, see

2. Provide barrier coats over incompatible primers or remove and reprime as required. Notify Contracting Officer in writing of any anticipated problems in using the specified coating systems with substrates primed by others.

3. Remove hardware, hardware accessories, machined surfaces, plates, lighting fixtures, and similar items in place and not to be finish-painted, or provide surface-applied protection prior to surface preparation and painting operations. Remove, if necessary, for complete painting of items and adjacent surfaces. Following completion of painting of each space or area, reinstall removed items.

4. Clean surfaces to be painted before applying paint or surface treatments. Remove oil and grease prior to mechanical cleaning. Prior to painting, surfaces shall be clean, dry and free of foreign materials which will adversely affect adhesion of appearance of the applied coating.

5. Program cleaning and painting so that contaminants from cleaning process will not fall onto wet, newly-painted surfaces.

3.03 ERECTION, INSTALLATION, APPLICATION

A. Stripping Scratched Painted Metal Interior Doors:

1. Apply stripping materials to entire surface in accordance with manufacturer's recommendations and to match the results obtained in the approved test applications. Provide neutralizers, cleaning agents and other related materials recommended by the stripper manufacturer.

2. Perform stripping in a manner which results in uniform stripping of all surfaces without streaking or damage to substrate. Use tools that will not gouge or disfigure the substrate.

3. On completion of stripping, clean all residue from treated surfaces with damp sponge and neutralize

area as required. Surface shall be free of oil and containments that may affect the adhesion of filler and paint.

4. If substrate exhibits superficial scratches, polish out in an even plane with successively finer grades of wet and dry sandpaper (#180-#400). Fill gouges and deep scratches with epoxy filler prior to sanding in accordance with manufacturer's recommendations.

5. Upon completion of filling and sanding, wipe surfaces with a tack cloth.

B. Repainting Metal Doors:

1. General: Apply paint in accordance with manufacturer's directions. Use applicators and techniques best suited for substrate and type of material being applied.

a. Paint colors, surface treatments, and finishes, to be approved by RHPO.

b. Provide finish coats which are compatible with prime paints used.

c. Apply additional coats when undercoats, stains or other conditions show through final coat of paint, until paint film is of uniform finish, color and appearance. Give special attention to ensure that surfaces, including edges, corners, crevices, welds, and exposed fasteners receive a dry film thickness equivalent to that of flat surfaces.

2. Scheduling Painting: Apply first-coat material to surfaces that have been cleaned, pretreated or otherwise prepared for painting as soon as practicable after preparation and before subsequent surface deterioration.

a. Allow sufficient time between successive coatings to permit proper drying.

b. Do not recoat until paint has dried to a firm, undeformed, unsticky surface under moderate thumb pressure, and application of another

coat of paint does not cause lifting or loss of adhesion of the undercoat.

3. Minimum Coating Thickness: Apply materials at not less than manufacturer's recommended spreading rate, to establish a total dry film thickness as indicated or, if not indicated, as recommended by coating manufacturer.

4. Prime Coats:

a. Apply prime coat on material which is required to be painted or finished, and which has not already been prime coated.

b. Recoat primed and sealed surfaces where there is evidence of suction spots or unsealed areas in first coat, to assure a finish coat with no burn-through or other defects due to insufficient sealing.

5. Pigmented (Opaque) Finishes: Completely cover to provide an opaque, smooth surface of uniform finish, color, appearance and coverage. Cloudiness, spotting, holidays, laps, brush marks, runs, sags, ropiness or other surface imperfections will not be acceptable.

6. Completed Work: Match approved samples for color, texture and coverage. Remove, refinish or repaint work not in compliance with specified requirements.

3.04 ADJUSTING/CLEANING

A. Clean-Up:

1. During progress of work, remove from site discarded paint materials, rubbish, cans and rags at end of each work day.

2. Upon completion of painting work, clean window glass and other paint-spattered surfaces. Remove spattered paint by proper methods of washing and scraping, using care not to scratch or otherwise damage finished surfaces.

1.4 Bronze plaques and lettering

Cast bronze plaques and lettering are typically attached to a wall, stone, or other vertical surface. The cast bronze elements include text or an image in relief (or both) to commemorate one or more persons, an event, or a former use of the place.

1.4.1 Immediate concern for bronze

Time and weather conditions cause bronze plaques to become dull and eventually to form a green patina on the surface (e.g., Figure 12–Figure 15). A simple cleaning process can refurbish the plaque to restore its like-new finish.

Figure 12. Cast bronze plaque set within a concrete block shows signs of patina and staining due to the efflorescence coming from the concrete block (ERDC-CERL, 2015).

Figure 13. Cast bronze plaque with an image relief and text (ERDC-CERL, 2015).

Figure 14. Cast bronze plaque on the west side of O'Hara Hall (ERDC-CERL, 2015).

Figure 15. Cast bronze lettering at Vickery Gate (ERDC-CERL, 2015).

1.4.1 Guidelines, briefs, bulletins, and sources for bronze

In addition to the information contained in this manual, the authors have compiled the following federal resource publications (reproduced here for convenience, with links for online access given in References) to inform managers about standards, guidelines, and procedures for understanding architecture, and caring for, preserving, and rehabilitating historic buildings with emphasis on historic bronze material (see subsections 1.4.1.1–1.4.1.3).

1.4.1.1 Bronze: characteristics, uses and problems (GSA 2016f)

U.S. General Services Administration

Bronze: Characteristics, Uses And Problems

Procedure code:

501003G

Source:

Outdoor Sculpture Manual - Center For Public Buildings

Division:

Metals

Section:

Metal Materials

Last Modified:

08/05/2016

Introduction

The following guidelines provide general information on the characteristics and common uses of bronze and identify typical problems associated with the material. See also "Checklist for Inspecting Bronze Failures".

References

- Gayle, M., Look, D. and Waite, J. *Metals in America's Historic Buildings: Uses and Preservation Treatments*. Washington, DC: Department of the Interior, National Park Service, 1992.
- Preservation Science. "Preventing Galvanic Corrosion. By Choosing the Right Materials". Web. 2008.
- Weaver, M. *Conserving Buildings: Guide to Techniques and Materials* (1st Edition). New York: Wiley, 1997.
- Zahner, L. W. *Architectural Metal Surfaces*. New York: Wiley, 2004.

Introduction

Bronze is an alloy of copper which can vary widely in its composition. It is often used where a material harder than copper is required, where strength and corrosion resistance is required and for ornamental purposes. The variations in bronze (both in proportion and elemental composition) can significantly affect its weathering characteristics. "True" bronze is a combination of approximately 90% copper (Cu) and 10% tin (Sn), however there are three major classes or types of "bronzes" used in sculpture and construction. They are:

1. Statuary Bronze - approximately 97% copper (Cu), 2% tin (Sn) and 1% zinc (Zn); this composition is the closest to "true" bronze.
2. Architectural Bronze - actually more of a "leaded brass", this composition is commonly composed of approximately 57%

copper (Cu), 40% zinc (Zn) and 3% lead (Pb).

3. Commercial Bronze - composed of approximately 90% copper (Cu) and 10% zinc (Zn).

Traditionally, a copper alloy which contains zinc is a "brass"; a copper alloy which contains tin (not exceeding 11%) is a "bronze". Bronze composition may vary significantly however, and contemporary bronzes are typically copper alloys which may contain silicon (Si), manganese (Mn), aluminum (Al), zinc (Zn) and other elements, with or without tin (Sn).

In its "raw" state, bronze is a semi-pink or salmon-colored metal; however it is rarely seen in its pure state. Bronze usually exhibits some patination or corrosion so that its color normally ranges from lime green to dark brown. Exposed bronze undergoes continuous change and progresses through several predictable "stages" of oxidation and corrosion. The stages of bronze corrosion vary in duration and time of onset, based on many factors, including:

1. Composition of the bronze
2. Patination or other protective treatments applied at the foundry
3. Weather
4. Location and exposure to rain, sun, and other climatic conditions
5. Atmospheric pollutants
6. Scheduled maintenance/cleaning
7. Adjacent materials including residual core materials

Typical Uses

Statuary bronze is typically used in outdoor sculpture. Its forms are almost limitless since it may be cast in any shape for which a mold can be devised. The most common types of forms include the human figure, landscapes, battle scenes, animals, weapons, decorative elements such as stars, rosettes, etc., and plaques.

Architectural bronze is typically used for:

1. Door and window frames
2. Door and window hardware
3. Mail boxes and chutes
4. Trim or rails
5. Furniture hardware

As a general rule, architectural applications seek to preserve the natural, highly polished "pinkish" finish of raw bronze, in contrast to the patination of outdoor sculpture/ornament. This is achieved by the frequent polishing and oiling of bronze/brass decorative and structural elements, or the application of clear lacquers which must be renewed on a periodic basis.

Problems and Deterioration

Bronze has good resistance to:

1. Industrial, rural and marine atmospheres
2. Weak acids if suitably shielded with appropriate protective coatings.

Bronze has poor resistance to:

1. Ammonia
2. Ferric and ammonia compounds
3. Cyanides
4. Urban pollution
5. Acid rains
6. Bird droppings

Problems may be classified into two broad categories: 1) Natural or inherent problems based on the characteristics of the material and the conditions of the exposure, and 2) Vandalism and human-induced problems.

Although there is some overlap between the two categories, the inherent material deterioration problems generally occur gradually over long periods of time, at predictable rates and require appropriate routine or preventive maintenance to control. Conversely, many human induced problems, (especially vandalism), are random in occurrence; can produce catastrophic results; are difficult to prevent, and require emergency action to mitigate. Some human induced problems, however, are predictable and occur routinely.

Natural or Inherent Problems

Bronze, like cast iron, is a manufactured product. Copper is extracted from natural ores and alloyed with tin to create a metal which does not exist in nature. Many of the inherent problems relate to the normal physical process of the bronze "returning to nature", i.e. to the most stable states of its components.

Additionally, most outdoor bronze is erected with a foundry applied patina of some type. The actual surface patina could be one of dozens of different composites as a result of the foundry applied finishes. Each of these finishes may react differently with the environment and result in different corrosion types and rates.

Regardless of which finish exists, the bronze will begin the deterioration process described below, where the surface will be subjected to the alteration of the patina through oxidation and sulfuration. Patinated and protected surfaces will resist the effects of exposure more than bare metal; therefore, such pieces will maintain their original appearance longer and exhibit changes more slowly.

Corrosion

Corrosion of one form or another is the chief cause of the deterioration of metals, including statuary and architectural bronze. The degree of corrosion which occurs, and the corrosion by-products which result, are affected by several factors including bronze composition or formulation, environmental conditions and adjacent materials.

While the composition of bronze does affect the rate of corrosion, it has been generally recognized that composition is one of the least significant factors in bronze deterioration. The existence of chemicals in the atmosphere, such as chlorine, sulfur, and nitrogen oxides, in the presence of moisture, is the most significant cause of bronze deterioration.

There are numerous causes and symptoms of corrosion, including:

1. Uniform Oxidation or Corrosion: Corrosion attacks the metal surface evenly.
2. Pitting: Attacks the metal surface in localized areas.

3. Selective Attack: When a metal is not homogenous throughout, certain areas may be attacked in preference to others.
4. Erosion: When a corrosion-resistant oxide layer is removed and the bare metal beneath corrodes.
5. Oxygen Cell Corrosion (or Atmospheric Corrosion): The most common form of corrosion; Moisture containing environmental gases (carbon dioxide, oxygen, sulfur compounds, soot, fly ash, etc.) produces chemical corrosion on the metal.
6. Galvanic Corrosion: The increased corrosion of a metal due to its contact with another metal, or in some cases, the same metal.
 - a. Galvanic corrosion causes extensive deterioration to the attacked metal(s), and in turn the corrosion products stain and streak the adjacent surfaces.
 - b. It is an electrolytic reaction. For this to occur, there must be an anode (negatively charged area), a cathode (positively charged area), and an electrolyte (conducting medium). The electrolyte can be rainwater, condensation, acid, alkali, or a salt. The formation of an anode and a cathode may occur due to the presence of impurities, difference in work hardening, or local differences of oxygen concentration on the surface.
7. Stress Corrosion Cracking: Attacks areas in a metal which were stressed during metal working.
8. Humidity, temperature and condensation: Affect the rate of corrosion; in a marine environment, aerosols can deposit chloride and other salts which will accelerate the rate of atmospheric corrosion.

The bronze corrosion process goes through five predictable stages. The specific results of each stage can differ due to combinations of atmospheric elements, bronze composition, patination, and other protective treatments such as waxing, oiling or lacquering. The five stages are:

1. Induction is when normal oxidation takes place, normally producing the dark brown copper oxide film which can be a protective barrier against future pollutants. The actual film composition is dependent upon the type and concentration of pollutants in the atmosphere, upon the duration of exposure, and upon the relative degree and duration of wetness on the surface. High concentrations of sulfides in the atmosphere can dramatically alter the result of stage 1, producing less protective, even potentially damaging films. The rate of oxidation can also have an effect on long term durability of the surface finish; oxides formed over longer time periods seem much more resistant to deterioration.
2. The conversion of the topmost metallic surface to copper sulfate normally begins to occur on surfaces with the most severe exposure, such as horizontal surfaces. Oxygen deprivation and deposition of particulates and moisture create a catalytic situation where electrolytic reactions occur. (This is the same principle as a battery, where the charged ions move from a positive to a negative pole.) The visual symptom of this phase is the formation of thin, light green patches on the more exposed areas.
3. Run-off streaking and scab formation occurs at a slower rate than the two previous stages but the consequences are significant. Copper sulfates and sulfides may have been formed during the earlier stages, yet the degree of solubility of these compounds may vary widely. It is during Stage 3 that the familiar streaking and uneven discoloration may occur due to differential weathering of the corrosion by-products. This erosion can continue until uneven blackish areas or island-like scabs are present on the surface.
4. Pitting may spread around the black scab formation; the pitting can also continue to spread below what appears to be a stable surface. Pitting is generally caused and accelerated by microscopic particles of chlorides deposited from the air, and if chlorides are present below a crust or a barrier coating, the corrosion can continue unchecked and invisible to casual observation.

5. Complete conversion of all exposed surfaces to the bright blue-green copper sulfate is the final stage of corrosion. The result is the familiar solid green bronze with the lime- green color and a matte texture. This condition is sometimes misperceived as the desirable end condition, but it is actually a phase of active corrosion.

Oxidation

Unprotected areas of raw bronze will oxidize, or combine with oxygen present in the air, resulting in a thin film of copper oxide along the surface of the exposed bronze. The resulting appearance is a flat, dark brown surface. The most common example to which most users can relate is the process of oxidation of a copper penny. The specular (shiny) finish of a new penny is familiar, as is the shift to the dark, red-brown finish as the surfaces oxidize over time.

This normal process of oxidation is a form of corrosion. The resultant oxide film is less reactive than raw bronze and forms a stable, protective barrier with a greatly reduced rate of oxidation.

Sulfurization

Bronze also reacts with many atmospheric pollutants, especially sulfur compounds, which are normally found in the atmosphere as sulfur dioxide and hydrogen sulfide. Both are produced in industrial manufacturing processes. Concentrations of these gasses are generally greater in or near urban and industrial areas; therefore higher rates of corrosion can normally be expected in such areas. The initial symptom of sulfurization is the appearance of patches of light green primarily on exposed surfaces. This usually begins on horizontal surfaces which receive the greatest exposure to rains and water run-off.

A general layer of surface corrosion can eventually spread over the entire metallic surface, resulting in an overall bright green surface. The uniform green surface is often accepted by the general public, and others, as protective and the normal state of bronze. This is a misconception, and one which has probably resulted in the public acceptance of appearances which are actually symptoms of corrosion and deterioration. The sulfides and sulfates will continue to form in the presence of moisture and atmospheric sulfur compounds. The presence of green corrosion products on the bronze is always an indication of active corrosion. The pattern and result of this process will vary based upon several environmental factors such as wind, rain, pollutants, patina, and the nature of previous corrosion.

Differential weathering due to winds, rain and surface orientation can result in uneven corrosion with patterns of green streaking on a dark blackish surface.

The process of sulfurization is complicated by two factors, both of which result in aesthetically unacceptable appearances; appearances which are generally perceived as neglect and deterioration. Uneven black and green streaking of bronzes is one of the most disfiguring problems which can occur with bronze. Random dark (black) and light (green) streaks follow the contours downward, resulting in distracting visual patterns with no relationship to the form or texture of the surface of the work. The artistic details which give form and definition to the bronze become extremely obscured by streaking which results from two phenomena:

1. Differential solubility of the corrosion products, and
2. Electrochemical processes between the dark (black) and light (green) areas.

The streaking of bronze indicates a differential corrosion of the bronze which will be permanently disfiguring. Two different surface corrosion products are dissolving at significantly different rates. The geological analogy is the formation of canyons by the erosion of the land surface. Where such corrosion has already occurred, conservation techniques are likely to be required. Early indications of streaking should be given serious attention in the inspection process, and called to the attention of the Regional Historic Preservation Officer (RHPO) at the earliest possible time.

Bronze Disease

Bronze disease is the result of exposure to chlorine compounds which can come from any saline source, such as contact with saline soils, atmospheric pollutants or airborne salt spray near bodies of salt water. The chlorine reacts with the copper in bronze to form copper chloride. The primary symptom is pitting, and the process can proceed unchecked below apparently sound patinas, or protective coatings.

The copper chloride is relatively unstable and the only way to arrest the continuing corrosion is the complete removal of the chlorides using electrochemical methods. All such methods of chloride removal are advanced conservation techniques requiring the employment of a skilled professional.

Core Migration

Bronze is cast in a foundry process which consists of the pouring of molten bronze into a mould containing a central core. Frequently this core material is gypsum or plaster of Paris, and occasionally portions of the core are left inside the casting. It is possible for the core material to migrate through the casting wall over time and appear on the exterior surface of the bronze.

The removal and repair of core migration problems is not a maintenance procedure and will require an "existing conditions analysis" supporting a proposed conservation treatment. The RHPO should be notified of the problem following its identification. The most common symptom is the appearance of whitish spots, which gradually enlarge, in the bronze surface.

Pitting

Corrosion of bronze, unlike that of natural stones, is in part an electro-chemical phenomenon. Points of negative electrical potential called cathodes and points of positive potential called anodes form on the bronze. In the presence of moisture, the corrosion process is driven by an electrical differential between the two points. This process can occur at a highly accelerated rate.

An electric potential can develop between both large and small areas. Atmospheric pollutants, especially chlorides, can be deposited on the surface of bronze. Tiny "islands" of corrosion can form, rapidly eroding/converting away the bronze metal and resulting in tiny voids or pits in the surface of the bronze. Pits may begin small and increase in size due to the continued electrochemical action and deposition within the pits. This may continue as long as moisture is present.

Pitting may be pinpoint or broad, as in patterns of deep etching created by differential erosion. (Also see: Bronze Disease)

Bird Droppings

Bird, or other animal, droppings may collect on the surface of bronze and (because of the acidic nature) may accelerate localized corrosion and deterioration. Droppings can also build up in sheltered areas, providing concentrations of damaging chemical agents of deterioration.

Galvanic Corrosion

Galvanic corrosion, also known as dissimilar metal corrosion, occurs when two dissimilar metals are brought into contact with one another. One of the metals will corrode, and the other will remain intact. As an example, if bronze is brought into contact with iron, the iron will frequently begin to corrode. Galvanic corrosion is caused by an electric potential between two dissimilar metals in the presence of water or moisture, where the water's electrolytes allow the flow of metallic ions from the more active metal, or the anode, to the more noble metal, or the cathode. The movement of these metallic ions represents a physical loss of metal from the metal being corroded. It can continue until the source metal is completely gone.

Below, thirteen construction metals are ranked according to their susceptibility to corrosion, from most to least susceptible, or from active to noble. This type of ordered list is called a Galvanic Series chart.

The rate of the transfer of iron from the passive to the active metal is determined by the difference in electrode potential between the two metals. Therefore, the farther apart two metals are in the list below, the more likely the active metal (higher on the list) is to corrode.

1. Zinc
2. Aluminum
3. Galvanized steel
4. Cast iron, mild steel
5. Lead
6. Tin
7. Brass, bronze
8. Copper
9. Silver solder
10. Stainless steel
11. Silver
12. Graphite
13. Gold

Galvanic corrosion typically occurs where dissimilar metals are used as connectors or parts of a building's armature. It can be stopped by replacing the more active metal with a more noble metal such as stainless steel. When two dissimilar metals must be in contact with one another, the risk of corrosion can be substantially reduced by applying a coating to both of the materials but especially to the noble metal, or applying a sacrificial metallic coating that is more active than both of the metals.

The relative mass or sizes of the two metals in contact will also determine the rate at which galvanic corrosion occurs. As an example, in a bronze plaque with iron bolts, the bolts would corrode rapidly, but an iron plaque with bronze or copper bolts would exhibit a much lower, almost negligible, amount of galvanic corrosion as a result of its contact with the bolts. Therefore, bolts and other fasteners should be made of more noble metals where possible.

Erosion

Erosion or "wearing away" of metal from the surface may be due to natural or environmental factors, or due to man-induced factors such as excessive handling or rubbing. Erosion due to human contact is by far the most serious problem, but erosion can occur due to the abrasive action of wind-driven pollutants.

Natural erosion will be a slow process and one which is, therefore, difficult to detect. It will be most obvious on outdoor bronze or in exposed locations. Industrial settings and areas where there are higher concentrations of airborne particulates, which can act as abrasives, also offer the possibility for higher rates of erosion. Natural, wind-driven abrasion will be generally so slow that it will be most apparent when comparing different exposures/orientations of bronze which has been in service for long periods. The differential loss of detail between protected and exposed surfaces will begin to be apparent over many years. Examination for this differential weathering should be part of any inspection.

Vandalism or Human-Induced Problems

Mechanical Deterioration (Purely Physical Processes)

1. Abrasion: Causes removal of the protective metal surface. Some metals such as zinc are relatively soft and therefore vulnerable to abrasion damage, especially in areas similar to roof valleys where the metal can be worn paper-thin.
2. Fatigue: Failure of metal that has been repeatedly stressed beyond its elastic limit, due to failure to provide necessary allowances for thermal expansion and contraction caused by temperature differences.
3. Creep: The permanent distortion of a soft metal which has been stretched due to its own weight. Thin areas of the metal will be among the first to fail. Can be found in lead sculptures which have inadequate or corroded internal armature.
4. Heat: Usually in the form of fire, will cause many metals to become plastic, distort, and fail.
5. Distortion: Permanent deformation or failure may occur when a metal is overloaded beyond its yield point because of increased live or dead loads, thermal stresses, or structural modifications altering a stress regime.

Connection Failure

1. Chemical and mechanical processes can cause the breakdown or reduced effectiveness of structural metal fixings such as bolts, rivets, and pins. Stress failure is often a contributor to breakdown situations. Iron connections which are water traps are particularly susceptible.
2. Most bronze corrosion can be characterized as "general" or "uniform" and "pitting", with occasional signs of selective attack. Galvanic corrosion appears mostly in connection with pins, bolts, and replacement parts in different metal. Erosion is apparent most often in bronzes in fountains. Stress corrosion is less apparent in bronze than in brass, but could be a factor in some cases in bronze sculptures.

1.4.1.2 Cleaning and polishing bronze (GSA 2017)

U.S. General Services Administration

Cleaning And Polishing Bronze

Procedure code:

501001S

Source:

Developed For Hspg (Nps - Sero)

Division:

Metals

Section:

Metal Materials

Last Modified:

01/27/2017

ALL CLEANING REMOVES SOME SURFACE METAL AND PATINA. THEREFORE, USE CAUTION, AS EXCESSIVE CLEANING CAN REMOVE THE TEXTURE AND FINISH OF THE METAL.

THE CLEANING OR STRIPPING OF METALS MAY INVOLVE THE USE OF ABRASIVES, LIQUIDS OR SOLVENTS WHICH MAY SPLASH OR RUN OFF ONTO ADJACENT MATERIALS. TAKE SPECIAL CARE TO PROTECT ALL ADJACENT MATERIALS, AND DO NOT USE THIS PROCEDURE ON METALS OTHER THAN THOSE SPECIFIED IN THE SUMMARY.

PART 1---GENERAL

1.01 SUMMARY

A. This procedure includes guidance on the general cleaning of dirt and oil on bronze.

B. For general information on the characteristics, uses and problems associated with bronze, see 05010-03-S.

PART 2---PRODUCTS

2.01 MANUFACTURERS

A. The Procter & Gamble Co.

P.O. Box 599

Cincinnati, OH 45202

513/983-1100

B. Leo Silfen, Inc.,
Industrial Chemical Division
525 Fourth Avenue
Mt. Vernon, New York
914/699-4800

2.02 MATERIALS

NOTE: When the common name of a chemical is used on the label, it is usually a sign that the substance is not as pure as the same chemical sold under its chemical name. However, the grade of purity of the common-name substance is almost certain to be adequate for stain removal work, and because it is likely to be less expensive, the common-name product should be purchased when available. Common names are indicated by an asterisk (*).

A. Mineral spirits:

1. Other chemical or common names include Benzine* (not Benzene); Naphtha*; Petroleum spirits*; Solvent naphtha*.
2. Potential Hazards: TOXIC AND FLAMMABLE.
3. Safety Precautions:
 - AVOID REPEATED OR PROLONGED SKIN CONTACT.
 - ALWAYS wear rubber gloves when handling mineral spirits.
 - If any chemical is splashed onto the skin, wash immediately with soap and water.
4. Available from construction specialties distributor, hardware store, paint store, or printer's supply distributor.

B. Neutral detergent such as "Orvis" (Procter & Gamble), or approved equal.

C. Marine Type Metal Polish Formula 90 (Leo Silfen, Inc., Industrial Chemical Division), or approved equal.

D. Clean, potable water

E. Lint-free wiping cloths

2.03 EQUIPMENT

A. Soft natural bristle brushes (non-metallic)

B. Wooden scrapers

C. Fine bronze wool -or- Silicon carbide abrasive pads such as "Scotch-Brite" (3M Company), or standard commercially available pumice stone or stainless steel wool. DO NOT USE STEEL WOOL, AS IT MAY PROMOTE DISCOLORATION OF THE BRONZE.

D. Rubber gloves

PART 3---EXECUTION

3.01 ERECTION, INSTALLATION, APPLICATION

NOTE: WHEN CLEANING, TRY TO RETAIN THE BRASS PATINA, AS THIS PROTECTS THE BRASS FROM FURTHER CORROSION.

A. Remove loosely adhered soiling, such as bird droppings, with wood scrapers before washing.

B. Remove more tenacious deposits with fine bronze wool.

C. Mix warm water (ONLY) with neutral detergent, or use proprietary metal cleaner.

NOTE: AVOID CLEANING BRONZE WITH ALKALINE SOAPS THAT DO NOT CONTAIN SODIUM HYDROXIDE, DETERGENTS CONTAINING PYROPHOSPHATES SUCH AS "TIDE" OR AMMONIA SOLUTIONS (ESPECIALLY ON LACQUERED SURFACES). THESE WILL DETERIORATE THE COATING ON BRONZE.

D. Brush solution on bronze with soft natural bristle brush (no metallic bristles) or a lint-free cloth. Rub along the grain of the metal.

E. If dirt is greasy, dilute cleaning solution 1:1 with mineral spirits.

F. Rinse thoroughly and dry with another lint free cloth.

G. Wash bronze periodically (twice a year) with a non-ionic detergent such as "Orvis" (Procter & Gamble). Rinse with distilled water and wipe dry with a clean soft cloth, to prevent water spots and streaks.

H. For guidance on removing corrosion, removing lacquer and reapplying a protective coating, see 05010-31-R and 05010-12-P.

1.4.1.3 Caring for outdoor bronze: cleaning and waxing (NPS 2005)

Conserve O Gram

September 2005

Number 10/5

Caring for Outdoor Bronze Plaques, Part II: Cleaning and Waxing

Preparation for Cleaning and Waxing

Before you start to clean and wax your plaque, refer to Conserve O Gram 10/4, "Caring for Outdoor Bronze Plaques, Part I: Documentation and Inspection." Only after you have carried out all the documentation and inspection procedures that are outlined here can you commence with cleaning and waxing.

This Conserve O Gram provides instructions for cleaning and waxing bronze plaques, protective measures that can be carried out without a conservator. It does not address the following: missing bolt heads, peeling or flaking coatings, or graffiti. If your plaque has any of these problems, or other problems not addressed here, call a conservator.

Introduction to Cleaning and Waxing

Periodic cleaning and waxing can retard the rate of corrosion on bronze plaques. Wax serves as a protective barrier against moisture; it also serves as a removable interface should graffiti or some other material be applied or deposited. Note that the plaque may look different after cleaning and waxing. It may appear darker and less green in color, but it will not look new. You cannot restore the original appearance of a plaque with wax; restoration work should be carried out by a conservator.

You should inspect your plaque and apply a

protective coating of wax on an annual basis. In marine environments or in areas subject to high rainfall or humidity, bi-annual work may be required. Conversely, in arid environments, work may be carried out on a two-to-three-year schedule. If the plaque is subject to frequent winds that blast the surface with air-borne abrasives or dusts, waxing may be necessary on a more frequent basis. Your inspections will help determine maintenance frequency.

The procedures for cleaning and waxing outlined here are for "cold" waxing ("hot" waxing involves heating the plaque with a propane torch and should only be carried out by a conservator as part of a full conservation treatment). Procedures are carefully detailed and should be followed as written. Cleaning and waxing should be carried out on a bright, dry, warm day (hot days with full sun are ideal). Water from cleaning and solvents in wax will evaporate quickly in this weather.

Preparation

1. Wear an apron or old clothes.
2. Wear proper protective gloves and a respirator fitted with fresh organic vapor filters when waxing.
3. Spread out a drop cloth beneath the plaque and lay out all your supplies in the order in which you will be using them.

4. Wrap the metal ferrules of all your brushes with duct tape to avoid scratching the bronze with the ferrule. Those brushes that will be used for waxing or buffing should be labeled "wax" for re-use.

Cleaning

1. Begin cleaning with dry, clean, soft bristle brushes. Small stencil brushes and bamboo skewers may be useful in dislodging dirt and debris from interstices of letters and other sculpted areas. Brush away all loose dirt and debris.
2. Flood the substrate surface (usually masonry, but also may be wood or metal) beneath the plaque with clean water to prevent absorption of cleaning agent. Keep the area flooded during the entire cleaning operation.
3. Scrub the plaque with water and a small amount of a non-ionic detergent. Use natural or plastic bristle brushes. Scrubbing will remove dirt packed in interstices and loosely adhered corrosion products.
4. Rinse the surface after washing and make sure no cleaning agent remains. Water can either be poured over the plaque or it can be sprayed on with a hose or garden pump sprayer.
5. You may want to repeat the cleaning operation if the plaque is especially dirty.
6. Allow the plaque to dry thoroughly before waxing. If there is a lot of water left on the surface, use a clean sponge or rag to blot—not wipe—the water off. A hair dryer can accelerate drying if necessary.

De-ionized or distilled water (the latter is commonly sold in grocery stores) is more aggressive for cleaning than tap water and is recommended for use on bronze plaques. However, de-ionized or distilled water should not be used for cleaning plaques mounted on highly polished stone, marble, limestone, or concrete as the water can cause slight surface etching.

Don Burciaga cleaning plaque, King Kamehameha I statue, Hilo, Hawai'i. (Glen Wharton & Associates, Inc.)

Detergents increase the wetting action of water, thereby increasing its ability to remove soiling materials. Non-ionic detergents are low in toxicity and can be easily rinsed from surfaces. They are sold in concentrated form and only a small amount is added to water to create good sudsing action.

Waxing

1. Tuck strips of aluminum foil (double thickness works well) in between the plaque and the substrate, surrounding the plaque as best as possible, to protect the substrate from wax.
2. Using a paint stirring stick, scoop about a half a cup of wax out of its container and place in a plastic container (with lid). Pour a petroleum solvent (in about the same amount as the wax) through a funnel into the container, and mix thoroughly with the stirring stick to get rid of all the lumps; this will take at least 5 minutes. The resulting slurry should be the consistency of heavy cream. Label the container "wax" with a permanent marker.
3. If the substrate surface below the plaque has dried, flood it again with clean water and keep it flooded for the duration of the waxing process to avoid stains from wax drops.
4. When the plaque is completely dry from cleaning, apply the wax slurry with a large round natural-bristle brush. Apply a thin layer to the entire plaque, making sure to get the wax into all interstices and on all edges. Do not apply too much wax; only a small amount is needed. "The less the better" is the general rule.
5. Take care not to get wax on surrounding surfaces.
6. Wait for the solvent to evaporate. It will have evaporated sufficiently when the plaque appears dry and when the solvent odor has weakened.
7. Remove all excess wax with paper towels or a clean rag and spend time removing accumulated wax from interstices; this step is critical since accumulated wax will turn white and flake off the surface over time.
8. Buff the surface of the plaque with a clean cotton rag and use plenty of pressure. Buffing compresses the wax, making it more durable and providing a soft sheen. Use a toothbrush to buff interstices of letters and other sculpted areas.
9. Apply a second layer of wax and buff, following the same procedure outlined above.
10. Carry out a final buffing with a horsehair shoe-polishing brush, making sure to brush over the entire surface.

Waxing a plaque, Saint Paul's Church NHS, Mt. Vernon, NY. (Judith M. Jacob, NPS)

Wax is a solid or semi-solid material that is slightly greasy to the touch and not soluble in water. Conservators use commercial paste waxes that are composed of natural and synthetic waxes in petroleum solvents for coating bronze plaques.

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Note: The solvents used for diluting wax and cleaning off old wax are hazardous materials. Be sure to wear your respirator, fitted with fresh organic-vapor cartridges and appropriate gloves when working with these solvents.

Petroleum solvents are materials used to dissolve wax. They are derived from petroleum, a thick flammable mixture of gaseous, liquid, and solid hydrocarbons found beneath the earth's surface. Petroleum solvents can be purchased in hardware stores.

Clean-up

1. Rinse out cleaning brushes. Keep them together for future use.
2. Rinse out wax brushes in the solvent. Since the brushes will be used only for waxing, they do not have to be perfectly free of wax. Store brushes in zipper-lock bags to keep them clean and together.
3. You can keep the strips of aluminum foil for reuse.
4. You may have diluted wax left over. This can be saved for the future, at which time it may be necessary to replenish the solvent. (You can also pour the excess solvent from cleaning brushes into the wax container.) Close the wax and mixing containers and make sure lids are tight fitting. Place the containers in a plastic bag, seal, and then place in a second plastic bag and seal.
5. Make sure solvent evaporates from rags and containers before storing them (with waxing supplies) or disposing of them.

6. Store all waxing materials together so they are easily accessible for the next application. Store wax and solvents in a flammables storage cabinet.

Note: Solvents, solvent rags, and containers of solvent for disposal are considered hazardous waste. Consult with your park HAZMAT Coordinator to arrange for proper disposal.

Documentation

Make a record of the cleaning and waxing and add to the plaque's file. Include the date, specific materials used, and any noted change in condition since the last waxing.

Reducing Wax Build-up Prior to Re-waxing

1. Over time, wax will build up in interstices of the plaque. When this occurs, excess wax should be reduced using petroleum solvents and clean cotton rags.
2. Dip the rag in the solvent and rub it over the surface. The solvent will dissolve the wax and the rag will absorb it.
3. Keep using a clean area of the rag to dip into the solvent.
4. Bamboo skewers and toothbrushes can be used to dislodge wax in the interstices of letters and sculpted areas.
5. This process may take a while, but you should be able to notice the difference once wax build-up has been reduced.
6. New wax can be applied in the same manner as that outlined above.

Supplies

- Drop cloth
- Buckets
- Garden pump sprayer
- Sponges
- Hair dryer
- Non-ionic detergent (one of the following)
 - Igepal® CA-630
 - Triton® XL-80N
 - Chemique® Ion-417
- Wax (one of the following)
 - Butchers® White Diamond Bowling Alley Wax (clear)
 - Trewax® Paste Wax (clear)
 - Johnsons® Paste Wax (clear)
- Cleaning brushes (tape all metal ferrules with duct tape)
 - Scrub brushes (plastic or natural bristle)
 - Toothbrushes (used are fine)
 - Large round natural-bristle brushes
 - Large stencil brushes
- Waxing brushes (tape all metal ferrules with duct tape and write “wax” on the shafts)
 - Large round natural-bristle brushes
- Buffing brushes (write “wax” on handles)
 - Toothbrushes (used are fine)
 - Horsehair shoe polishing brush
- Bamboo skewers
- Aluminum foil
- Empty containers for mixing wax and for rinsing out wax brushes (old plastic take-out or packaged-food containers are fine)
- Funnel
- Paint stirring sticks, write “wax” on one end
- Petroleum solvent (one of the following)
 - VM&P Naphtha
 - Mineral spirits
 - Stoddard’s Solvent
- Clean cotton rags
 - Old t-shirts and cotton diapers work well
 - When laundering, do not use fabric softener; it reduces the cotton’s ability to attract dust and to absorb liquids
- Paper towels, as highly absorbent as possible
- Container for storing supplies and zipper-lock bags

Materials used for cleaning and waxing: scrub brushes, bamboo skewers, waxing brush, toothbrushes for buffing, and horsehair shoe polishing brush. (Judith M. Jacob, NPS)

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- Solvent-proof gloves (nitrile works well)
- Respirator with fresh organic-vapor cartridges

Note: This Conserve O Gram recommends the use of specific commercial products. Should any of these products be removed from the market, a similar product can be used. One can find similar products by consulting with conservators and asking questions of product manufacturers and conservation supply store employees.

Sources of Supplies

1. Hardware stores
2. Art supply stores
3. Conservation supply stores or websites, such as:
 - Conservator's Emporium
<http://www.consemp.com>
 - Conservation Resources International
<http://www.conservationresources.com>
 - Conservation Support Systems
<http://www.silicon.com/~css>
 - Talas
<http://talasonline.com>

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1.5 Preservation and rehabilitation guidelines for metal

According to *The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings*, the proper procedure for preservation and rehabilitation is to respect the significance of the original materials and features, repair and retain them wherever possible, and replace them only when absolutely necessary (Grimmer 2017) .

The following recommendations for care of historic metal elements are to be thoroughly read and understood before a treatment is specified. Table 1 and Table 2 contain information excerpted from Grimmer (2017). Any related NPS or GSA guidelines should also be consulted to determine the appropriateness of any treatment.

Table 1. Preservation treatment for metals (Grimmer 2017, 41–43).

Preservation Treatment for Metal Elements	
RECOMMENDED	NOT RECOMMENDED
<i>Identifying, retaining, and preserving</i> metal features that are important in defining the overall historic character of the building (such as columns, capitals, pilasters, spandrel panels, or stairways) and their paint, finishes, and colors. The type of metal should be identified prior to work because each metal has its own properties and may require a different treatment.	<p>Altering metal features which are important in defining the overall historic character of the building so that, as a result, the character is diminished.</p> <p>Replacing historic metal features instead of repairing or replacing only the deteriorated metal.</p> <p>Changing the type of finish, coating, or historic color of metal features.</p>
<i>Stabilizing</i> deteriorated or damaged metal as a preliminary measure, when necessary, prior to undertaking preservation work.	Failing to stabilize deteriorated or damaged metals until additional work is undertaken, thereby allowing further damage to occur to the historic building.
<i>Protecting and maintaining</i> metals from corrosion by providing proper drainage so that water does not stand on flat, horizontal surfaces or accumulate in curved decorative features.	<p>Failing to identify and treat the causes of corrosion, such as moisture from leaking roofs or gutters.</p> <p>Placing incompatible metals together without providing an appropriate separation material. Such incompatibility can result in galvanic corrosion of the less noble metal (e.g., copper will corrode cast iron, steel, tin, and aluminum).</p>
Cleaning metals, when necessary, to remove corrosion prior to repainting or applying other appropriate protective coatings.	<p>Failing to reapply coating systems after cleaning metals that require protection from corrosion.</p> <p>Removing the patina from historic metals. The patina may be a protective layer on some metals (such as bronze or copper) as well as a distinctive finish.</p>
Identifying the particular type of metal prior to any cleaning procedure and then testing to ensure that the gentlest cleaning method possible is selected; or, alternatively, determining that cleaning is inappropriate for the particular metal.	Using cleaning methods which alter or damage the historic color, texture, and finish of the metal, or cleaning when it is inappropriate for the particular metal.
Using non-corrosive chemical methods to clean soft metals (such as lead, tinplate,terneplate, copper, and zinc) whose finishes can be easily damaged by abrasive methods.	Cleaning soft metals (such as lead, tinplate,terneplate, copper, and zinc) with abrasive methods (including sandblasting, other media blasting, or high-pressure water) which will damage the surface of the metal.
Using the least abrasive cleaning method for hard metals (such as cast iron, wrought iron, and steel) to remove paint buildup and corrosion. If hand scraping and wire brushing have proven ineffective, low-pressure abrasive methods may be used as long as they do not damage the surface.	Using high-pressure abrasive techniques (including sandblasting, other media blasting, or high-pressure water) without first trying gentler cleaning methods prior to cleaning cast iron, wrought iron, or steel.
Applying appropriate paint or other coating systems to historically-coated metals after cleaning to protect them from corrosion.	Applying paint or other coatings to metals (such as copper, bronze or stainless steel) if they were not coated historically.
Repainting historically-painted metal features with colors that are appropriate to the building and district.	Using paint colors on historically-painted metal features that are not appropriate to the building or district.
Applying an appropriate protective coating (such as lacquer or wax) to a metal feature that was historically unpainted, such as a bronze door, which is subject to heavy use.	
Protecting adjacent materials when working on metal features.	Failing to protect adjacent materials when working on metal features.
Evaluating the overall condition of metals to determine whether more than protection and maintenance, such as repairs to metal features, will be necessary.	Failing to undertake adequate measures to ensure the protection of metal features.
<i>Repairing</i> , stabilizing, and reinforcing metal by using recognized preservation methods	Removing metals that could be stabilized, repaired, and conserved, or using improper repair techniques, or untrained personnel, potentially causing further damage to historic materials.
<i>The following work is highlighted to indicate that it represents the greatest degree of intervention generally recommended within the treatment Preservation, and should only be considered after protection, stabilization, and repair concerns have been addressed.</i>	
Limited Replacement in Kind	
<i>Replacing</i> in kind extensively deteriorated or missing components of metal features when there are surviving prototypes, such as porch balusters, column capitals or bases, or porch cresting, or when the replacement can be based on documentary or physical evidence. The new work should match the old in material, design, scale, color, and finish.	<p>Replacing an entire metal feature, such as a column or balustrade, when limited replacement of deteriorated or missing components is appropriate.</p> <p>Using replacement material that does not match the historic metal feature.</p>

Table 2. Rehabilitation for metals (Grimmer 2017, 93–97).

Rehabilitation Treatment for Metal Elements	
RECOMMENDED	NOT RECOMMENDED
Identifying, retaining, and preserving metal features that are important in defining the overall historic character of the building (such as columns, capitals, pilasters, spandrel panels, or stairways) and their paints, finishes, and colors. The type of metal should be identified prior to work because each metal has its own properties and may require a different treatment.	Removing or substantially changing metal features which are important in defining the overall historic character of the building so that, as a result, the character is diminished. Removing a major portion of the historic metal from a façade instead of repairing or replacing only the deteriorated metal, then reconstructing the façade with new material to achieve a uniform or “improved” appearance.
Protecting and maintaining metals from corrosion by providing proper drainage so that water does not stand on flat, horizontal surfaces or accumulate in curved decorative features.	Failing to identify and treat the causes of corrosion, such as moisture from leaking roofs or gutters. Placing incompatible metals together without providing an appropriate separation material. Such incompatibility can result in galvanic corrosion of the less noble metal (e.g., copper will corrode cast iron, steel, tin, and aluminum).
Cleaning metals when necessary to remove corrosion prior to repainting or applying appropriate protective coatings.	Leaving metals that must be protected from corrosion uncoated after cleaning.
Identifying the particular type of metal prior to any cleaning procedure and then testing to ensure that the gentlest cleaning method possible is selected; or, alternatively, determining that cleaning is inappropriate for the particular metal.	Using cleaning methods which alter or damage the color, texture, or finish of the metal, or cleaning when it is inappropriate for the particular metal. Removing the patina from historic metals. The patina may be a protective layer on some metals (such as bronze or copper) as well as a distinctive finish.
Using non-corrosive chemical methods to clean soft metals (such as lead, tinplate,terneplate, copper, and zinc) whose finishes can be easily damaged by abrasive methods.	Cleaning soft metals (such as lead, tinplate,terneplate, copper, and zinc) with abrasive methods (including sandblasting, other abrasive media, or high-pressure water) which will damage the surface of the metal.
Using the least abrasive cleaning method for hard metals (such as cast iron, wrought iron, and steel) to remove paint buildup and corrosion. If hand scraping and wire brushing have proven ineffective, low-pressure abrasive methods may be used as long as they do not abrade or damage the surface.	Using high-pressure abrasive techniques (including sandblasting, other media blasting, or high-pressure water) without first trying gentler cleaning methods prior to cleaning cast iron, wrought iron, or steel.
Applying appropriate paint or other coatings to historically-coated metals after cleaning to protect them from corrosion.	Applying paint or other coatings to metals (such as copper, bronze or stainless steel) if they were not coated historically, unless a coating is necessary for maintenance.
Repainting historically-painted metal features with colors that are appropriate to the building and district.	Using paint colors on historically-painted metal features that are not appropriate to the building or district.
Applying an appropriate protective coating (such as lacquer or wax) to a metal feature that was historically unpainted, such as a bronze door, which is subject to heavy use.	
Protecting adjacent materials when cleaning or removing paint from metal features.	Failing to protect adjacent materials when working on metal features.
Evaluating the overall condition of metals to determine whether more than protection and maintenance, such as repairs to metal features, will be necessary.	Failing to undertake adequate measures to ensure the protection of metal features.

(Table continues on next page.)

RECOMMENDED	NOT RECOMMENDED
Repairing metal by reinforcing the metal using recognized preservation methods. Repair may include the limited replacement in kind or with a compatible substitute material of those extensively deteriorated or missing components of features when there are surviving prototypes, such as column capitals or bases, store-fronts, railings and steps, or window hoods.	Removing metals that could be stabilized, repaired, and conserved, or using improper repair techniques, or unskilled personnel, potentially causing further damage to historic materials.
Replacing in kind an entire metal feature that is too deteriorated to repair (if the overall form and detailing are still evident) using the physical evidence as a model to reproduce the feature or when the replacement can be based on historic documentation. Examples of such a feature could include cast-iron porch steps or steel-sash windows. If using the same kind of material is not feasible, then a compatible substitute material may be considered.	Replacing an entire metal feature, such as a column or balustrade, when repair of the metal and limited replacement of deteriorated or missing components are feasible. Removing a metal feature that is unrepairable and not replacing it, or replacing it with a new metal feature that does not match. Using a substitute material for the replacement that does not convey the same appearance of the surviving components of the metal feature or that is physically or chemically incompatible.
<i>The following work is highlighted to indicate that it is specific to Rehabilitation projects and should only be considered after the preservation concerns have been addressed.</i>	
Designing the Replacement for Missing Historic Features	
Designing and installing a replacement metal feature, such as a metal cornice or cast-iron column, when the historic feature is completely missing. It may be an accurate restoration based on documentary and physical evidence, but only when the historic feature to be replaced coexisted with the features currently on the building. Or, it may be a new design that is compatible with the size, scale, material, and color of the historic building.	Creating an inaccurate appearance because the replacement for the missing metal feature is based upon insufficient physical or historic documentation, is not a compatible design, or because the feature to be replaced did not coexist with the features currently on the building. Introducing a new metal feature that is incompatible in size, scale, material, or color.

1.6 Maintenance / management for metal elements

All building materials deteriorate with age and exposure to the weather. Through routine inspection and cyclical maintenance, the useful life span of a building and its historic fabric will be greatly increased. Preventive maintenance involves regular inspection of those parts of the building that are most likely to develop problems. Having a checklist for each USMMA building is advised to help the USMMA CRM and maintenance department identify and keep an accurate record or inventory of the building's problems, to facilitate systematic repair and maintenance. Begin early in project planning to ensure that design scopes, qualifications, and budgets address preservation compliance requirements.

Repair, renovation, and replacement of character-defining features to the contributing features to the USMMA historic district **MUST** be coordinated with the NY SHPO. If a character-defining feature has been previously removed or replaced on the contributing building, prior to this report and as future renovation occurs, these features need to be replaced with elements that replicate the original character-defining features of that building. Historic photographs found in *Character-Defining Features of*

Contributing Buildings and Structures in the United States Merchant Marine Academy Historic District report (Smith, Enscoe, and Adams 2014) will help guide this process in coordination with the NY SHPO.

Metal – general

The following steps should be taken to manage preservation of historic Cast or wrought iron features should be painted to protect them from corrosion. The existing paint should be tested for lead before stripping cast and wrought iron elements. Old paint may be stripped by hand-sanding or by using an appropriate chemical stripper. If the metal component is detachable without harming it or adjacent materials, the component may be removed and dipped in an appropriate chemical bath. After cleaning, cast and wrought iron should immediately be primed and painted. Historically, cast and wrought iron were painted black.

If the historic ironwork has structural problems, the first step is to check all connections. Cast or wrought iron elements will be bolted together, and they may simply need to be tightened. If bolts are missing or are rusted, or the bolt holes are rusted, more work will be necessary to ensure tight connections.

Joints between elements of cast iron should be closed to ensure a water-tight seal. This seal prevents water from entering the composition, which can either cause rust from the inside out or freeze and crack the cast iron. Caulk and fillers are used for this purpose. Fillers should have iron particles in them to ensure that they thermally expand and contract in a manner similar to the ironwork.

Breaks in cast or wrought iron must be welded—a process usually best left to a professional. Similarly, repairs to broken pieces of cast or wrought iron are best done by a professional as the pieces can easily be damaged.

The following points also should be observed when inspecting older metal:

- Minor oxidation of ironwork can be removed on site, although a significant amount of rust is often most easily removed off site by dipping the pieces in a diluted phosphoric or sulfuric acid.

- Remove loose paint and oxidation on-site, use a fine wire brush and hand scrapers. Heavy wire brushes or very aggressive scraping can gouge and damage details, so this must be done with extreme care.
- Missing hardware should be replaced with iron or stainless steel bolts of the same size and style.
- Rusted hardware can be drilled out using a bit smaller than the bolt's diameter.

Metal railings

Iron fencing and railings are significant components of historic landscapes and buildings. Building owners should periodically inspect and complete minor repairs to keep these features in good condition. However, if major repairs are needed, it is highly recommended to consult with a historic ironwork specialist. Many of the advanced techniques for restoring ironwork are damaging—either to the ironwork or to a person's health—if not conducted properly.

Metal windows

A preliminary step in the routine maintenance of metal windows is to remove surface dirt and grease in order to determine the degree of deterioration, if any. If it is determined that the metal window is in basically sound condition, the following steps can be taken; removal of light rust, flaking and excessive paint; priming of exposed metal with a rust-inhibiting primer; replacement of cracked or broken glass and glazing compound; replacement of missing screws or fasteners; cleaning and lubrication of hinges; repainting of all metal sections with two coats of finish paint compatible with the primer, and caulking the surrounds with a high quality elastomeric caulk (Park 1984).

Preserve historic metal windows. Properly maintained and sealed historic metal windows are efficient and sustainable. When glass is broken, the color and clarity of replacement glass should match the original historic glass.

Metal doors

The deterioration of metal doors is primarily caused by corrosion. Minor corrosion can be cleaned by gentle sanding or brushing, while more extensive corrosion may require cleaning with chemical solvents. If the area was painted, the cleaned area should be primed and repainted immediately.

Before any action is taken, the type of metal should be determined—particularly if chemical cleaning is considered. Some types of metal react adversely to certain cleaning chemicals; using the wrong one may accelerate deterioration rather than remove corrosion.

Damage that is more extensive than minor corrosion may require patching the door with the same metal or with a compatible substitute material. Patches and replacements should be designed and detailed to match the existing historic door.

Bronze plaques and letters

A simple cleaning process can refurbish the bronze plaque and restore its like-new finish. Begin by wiping dust and dirt off the plaque with soft cotton cloths. (It's best to avoid touching the bronze because the oil from human skin can increase the level of discoloration from oxidation.) Then, create a paste by mixing together equal parts of flour and salt in a small container, and adding a few drops of vinegar until the mixture has a consistency that is similar to toothpaste. Rub the mixture on the bronze plaque with a small cotton cloth and continuing rubbing as needed to restore the original shine. Dry with a clean cotton cloth. Once dry, apply a thin, even layer of paste wax to the bronze plaque. Let the wax dry, then buff it with a clean dry cloth. Continue buffing until the plaque shines.

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14. ABSTRACT The U.S. Merchant Marine Academy is located in Kings Point, New York. The Academy is listed on the National Register of Historic Places (#14000538). The historic district contains contributing mansions constructed during the Gold Coast Era and the Academy buildings constructed in 1942 to 1969. All buildings require regular planned maintenance and repair. The most notable cause of historic building element failure and/or decay is not because the historic building is old, but rather it is caused by an incorrect or inappropriate repair and/or basic neglect of the historic building fabric. This document is a maintenance manual compiled with as-is conditions of building materials at the Academy. The <i>Secretary of the Interior's Standards for the Treatment of Historic Properties on Preservation, Rehabilitation, and Repair</i> are discussed per material. This 8-volume report includes an overview volume plus volumes on each of the following elements: concrete, wood, brick, metal, roofing, stucco, and mechanical systems. All mentioned repair procedures are from the U.S. General Services Administration (GSA): Historic Preservation Technical Procedures and/or the National Park Service's series of Preservation Briefs. This report satisfies Section 110 of the National Historic Preservation Act (NHPA) of 1966, as amended.					
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