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Chapter 18 - Coatings / Painting

Protective coatings are an integral part in the preservation systems for bridge structures. This chapter will address the maintenance of coating systems typically found on steel bridge superstructures. A maintained coating system will provide the optimal level of service by extending the time before a coating system requires replacement.

Preventive maintenance (PM) of coated steel may be needed on aged lead oil/alkyd paints as well as a number of more recently applied paint systems. Oil/alkyd paints were the most common kind of paint used on bridges up to about 1990 when health and safety became a large concern. This chapter will discuss corrosion basics, paint and corrosion evaluations, maintenance coating design options, and the most frequently used methods for surface preparation and application of maintenance painting materials. This chapter is not intended to review all the coating options for bridge superstructures undergoing 100 percent abrasive blasting to bare steel and coating system replacement. Instead, we will discuss work options related to spot or zone maintenance painting of typical bridge coating systems and materials and methods suitable for a maintenance organization.

18.1 Background on Bridge Coating Systems

Coatings generally have a dual purpose. They are typically applied to both prevent corrosion and improve aesthetics. Coatings may also be applied for safety marking of a structure.

The wide variety in coating surface preparation and coating material types is relatively new. Compared to the material choices of today, legacy systems were simpler and significantly less expensive to install. Over time, improvements in environmental and worker health and safety regulations have resulted in multiple systems and have increased the cost of painting.

Protective coatings should be an engineered system. That system is designed to protect a substrate from exposure. Substrate is a universal term used for whatever is being painted and can be old paint, corroded metal, shiny cleaned metal or any combination. Protective coatings may be in various forms, from the patina on weathering steel to 3-coat zinc-based paint systems applied to abrasive blasted steel to hot dip galvanizing. Given this variety in protective coating systems, selecting the most appropriate system can be challenging. To understand what types of coating systems work best in certain situations, a basic primer on steel corrosion is necessary.

18.1.1 Corrosion of Structural Steel

Corrosion of steel is an electrochemical process where the engineered structural steel is converted to a more stable oxide of iron. The cycle, whereby energy is used to create a finished steel product from iron oxide, is presented in Figure 18.1. Over time, however, steel will release the internal energy and convert back into an iron oxide. Applying a protective coating system to structural steel can significantly slow the corrosion process.

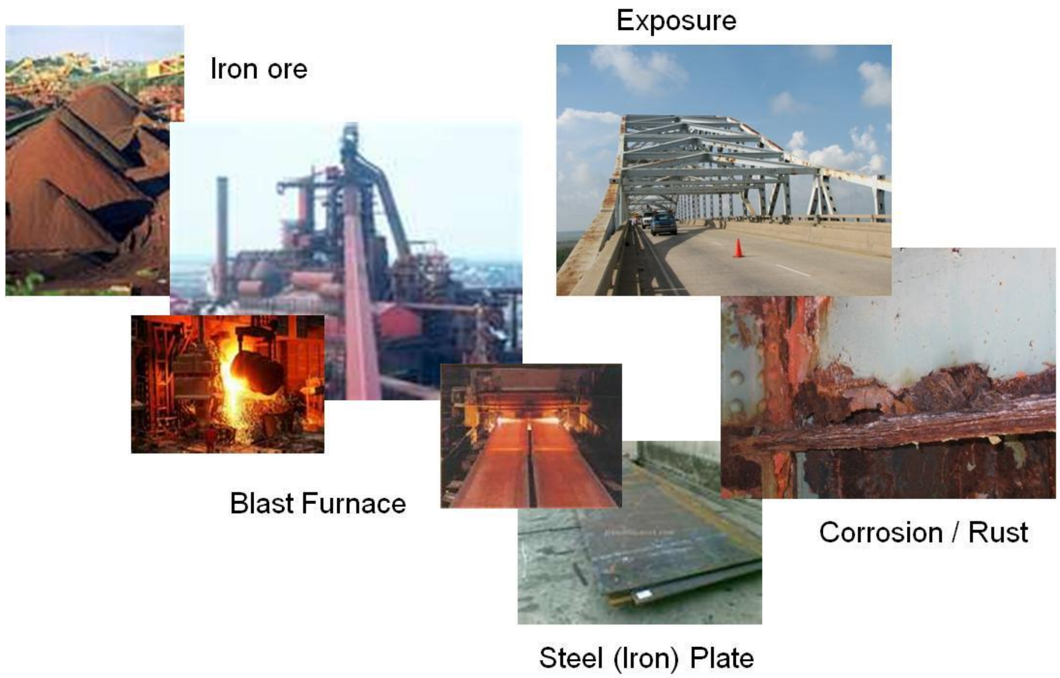

Figure 18.1 Various Stages of Steel Manufacture and Corrosion (from left to right)

It is necessary to understand a few fundamental concepts of the mechanism of steel corrosion or simply why steel rusts. Corrosion occurs when four required components are present. If any of the components is missing, the corrosion process will not proceed. The required elements of a “corrosion cell” are:

- Anode – Area on a steel surface that corrodes (rusts)
- Cathode – Area on a steel surface that does not corrode
- Metallic pathway – The steel substrate
- Electrolyte – Some type of surface contamination, the “environment”, capable of electrical and ionic transfer

The complete corrosion cell is the only possible way for steel to corrode. To prevent corrosion, we must disrupt the complete corrosion cell and this is done by trying to eliminate any one of the four required components of corrosion.

This is done by minimizing the reactions of the anodic sites (by isolating the surface from the electrolyte or environment) or by minimizing the relative amount of anodic sites. One a bridge a very corrosive electrolyte would be road cinders and debris wet with runoff water, a very mild corrosive electrolyte would be the humidity in the air. The more corrosive the electrolyte, the better its electrical conductivity, not to the extreme of an electrical wire, but more like in the earth or through a lake.

18.1.1.1 Factors Affecting Corrosion

The rate of bridge steel corrosion is primarily a function of environmental factors. From a corrosion cell perspective, the largest variable for bridge steel is the presence and effectiveness of the electrolyte. Environmental exposure conditions therefore play a key role in the rates of corrosion. The following list highlights some of these factors:

- Temperature – higher temperature coupled with environmental exposure means more aggressive corrosion. In general corrosion rates double with every 20 degree increase in temperature.
- Time of wetness – this is the relative time that an electrolyte is present on a surface. Note that a surface does not need to appear “wet” because thin films of moisture contamination are very effective electrolytes. Time of wetness is related to surface contamination and relative humidity. Water vapor coupled with atmospheric or surface contamination will provide an effective corrosion electrolyte.
    - Surfaces with salt contamination may “wet” at 55 percent to 60 percent relative humidity. This is due to the hydrophilic property of deicing salts or their strong affinity for water.
    - Surfaces without deicing salt contamination may rely on dust or other fine debris to aide formation of electrolyte. This typically happens at relative humidity above 85 percent.

The environment that bridge steel is exposed to is not only related to the location of the bridge (e.g., coastal, rural, urban) but is significantly related to the localized conditions on the bridge. Any surface that collects debris and then collects water will have a very effective corrosion electrolyte, as shown in the example in Figure 18.2.

Moisture-rich deicing salt is the prime example for bridges. When moisture evaporates and the previously wetted surfaces appear dry, salt is left on the surface. As discussed above, those surfaces with salt contamination are exposed to a very corrosive electrolyte at fairly “normal” levels of relative humidity.

Figure 18.2 Inside Truss Bracing - Debris Collection and Accelerated Areas of Corrosion

The surface characteristics of steel will also affect corrosion susceptibility. The flat surface of a steel plate corrodes uniformly, but steel with cuts, fasteners, previously corroded spots, or any other irregularity preferentially corrodes at these non-uniform locations. Figure 18.3 and Figure 18.4 show examples of weathered coatings with corrosion on the non-uniform surfaces. Notice that the flat areas show much less corrosion compared to the fasteners, welds, and edges.

Figure 18.3 Corrosion on Irregular Surfaces of a Steel Pier Column Base

Figure 18.4 Corrosion on Beam Edges

18.1.1.2 Barriers and Cathodic Coatings

Barrier Coatings

Isolating the steel surface from the environment with a barrier coating essentially minimizes the effect of the electrolyte and minimizes one of the four components required for corrosion. This is the fundamental protection method of many bridge coating materials. They are insulating and water resistant and so are able to keep the steel surface isolated from the environment. To be effective, these coatings must be uniform and not have holes, gaps, or missing spots (coating holidays). Any of these defects would be a likely place for corrosion to proceed.

Cathodic Coatings

Currently the most prevalent bridge coating systems applied to bare abrasive-blasted steel have a zinc pigmented primer. Zinc metal is fundamentally more anodic (chemically active) than steel. When the zinc is in contact with the steel (e.g., when it is in the primer or first layer of a coating system), the steel becomes cathodic (less chemically active) and exhibits significantly less corrosion. The zinc coating preferentially corrodes, thus protecting the underlying steel.

This method of protecting underlying steel with a zinc coating is also how the galvanizing process works. It is important to protect and maintain the zinc primer to maximize the life of a bridge coating system.

18.1.2 Coating System Design Basics

The coating system begins with a properly prepared substrate. Primers are selected based on their barrier or galvanic properties. Intermediate coats may be applied to provide or further enhance barrier properties. Finish coats are applied to withstand the environment, provide color, and prevent damage to underlying coats (i.e., to protect the primer).

The system does not always include three coats. For typical preventive maintenance painting there will be existing layers of coating on a bridge, so supplementing these existing coatings will not always require three separate coats. Many preventive maintenance systems include spot primers and a single full overcoat. Various preventive maintenance coating systems are reviewed later in this chapter.

Surface preparation is one of the most important steps for applying a coating system. Surface preparation addresses cleaning and roughening the surface to promote coating adhesion. The performance of a coating system depends on the surface preparation.

The most thorough surface preparation is abrasive blasting. The specified surface preparation for a particular project will consider factors such as complexity of the surface, allowable time, available budget, and expected service life. The specified surface preparation is not always the most thorough possible. Surface preparation is discussed in detail in Section 18.5.

18.1.2.1 Primer

The primer is the first coat applied over a prepared surface. Its primary function is to adhere to the surface. For bridge coating systems, the primer may also include corrosion inhibitors or passive cathodic protection as a means for corrosion protection. Common primers for bridge preventive maintenance painting include organic/inorganic zinc, epoxy, alkyd, acrylic, or urethane materials. All of these products protect the steel by isolating the substrate from the environment and the zinc coating also provides cathodic protection. A more detailed description of coating materials is in Section 18.3.

18.1.2.2 Other Coats

A bridge coating system may consist of one to five coats, with each layer providing a designed performance function. An example of a five coat system is a “re-paint” coating with up to two additional stripe coats. In general, second coats provide barrier protection and may be used as a tie coat to isolate the primer from the intermediate or topcoat. The top coat or finish coat selection is usually based on its ability to weather in the service environment. For bridges this would include being resistant to chalking and fading in sunlight, having a smooth uniform appearance, and maintaining a proper color. A more detailed description of coating materials is in Section 18.3.

18.1.3 Types of Coating System Degradation

Bridge coatings may degrade in a number of ways. The degradation is typically seen as either peeling of a coating (loss of adhesion) or corrosion of the steel substrate. Peeling can happen between layers of coating or between the coatings and the substrate. A common occurrence of coating peeling is with aged systems applied over hot rolled steel (mill scale). The surface of mill scale is smooth and is not ideal for long term coating adhesion. Most modern high durability coating systems are applied to steel that has been blast cleaned to remove the mill scale. Figure 18.5 shows an alkyd system peeled from mill scale.

Figure 18.5 Aged Coating Exhibiting Peeling

Peeling also occurs between coats, as shown by the examples in Figure 18.6, and possibly when coatings are applied over previous coats that are contaminated or incompatible. The examples in Figure 18.6 show the topcoat peeling from a primer on the downward sides of a truss member (left) and white paint peeling to reveal grey undercoat and general corrosion (right).

Figure 18.6 Paint Peeling Examples

Corrosion will occur any time the barrier properties of the coating system are not sufficient and environmental exposure includes a corrosive electrolyte. The thickness of the barrier is referred to as the dry film thickness (DFT). Figure 18.7 shows a bridge beam with the DFT marked (in mils). Notice how the 4.0 mils of coating on the flange is showing corrosion and the 7 to 8 mils of coating on the web does not show corrosion.

Figure 18.7 Corrosion Due to Low Dry Film Thickness (DFT)

Rust undercutting may occur in many bridge coating systems and is the loss of coating adhesion due to expanding spots of corrosion. On bridges with exposure to an aggressive environment (such as splash or wet areas where roadway runoff may contact the bridge or areas under leaking deck expansion joints the corrosion may undercut the coating. Over time the percentage of the surface area with corrosion will increase as more coating is forced off of the substrate. Figure 18.8 and Figure 18.9 show this common bridge corrosion mechanism.

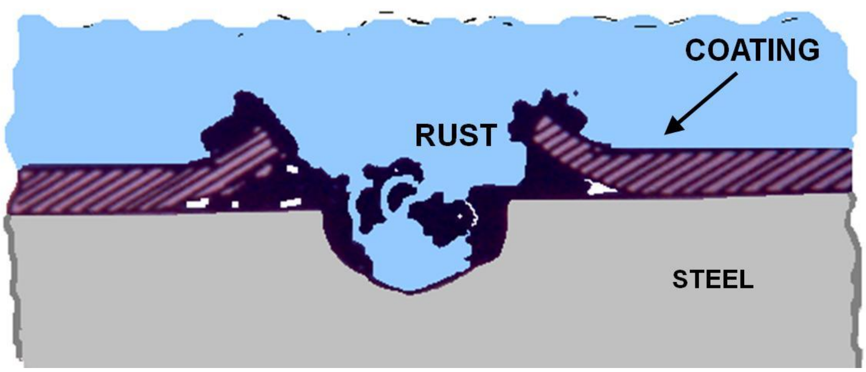

Figure 18.8 Schematic of Rust Undercutting and Progressive Loss of Coating

Figure 18.9 Coating Undercutting and Peeling

Combinations of these coating failure mechanisms can be seen on most steel bridges. Often the failure of coatings is due primarily to installation difficulties. Some surfaces are more difficult and time consuming to clean and paint. It is in these situations that additional effort, time, or alternate cleaning and painting methods should be used or premature degradation is likely. Figure 18.10 and Figure 18.11 show some common examples of more difficult to paint surfaces on bridges. The back-to-back angle can be painted with a narrow dauber and the blind sides of fasteners require a mirror or alternate access angle to ensure workers apply complete coats. Figure 18.11 shows the obstructed side of a rivet pattern that will need to be cleaned and painted from more than one direction.

Figure 18.10 Back-to-Back Angles May Require Alternate Methods to Apply Coatings

Figure 18.11 Obstructed Side of Rivet Pattern is Difficult to Paint

18.2 Evaluating Bridges for Preventive Maintenance Painting

Preventive Maintenance tasks for bridge coatings can be routine, such as washing / cleaning, or can be condition based. Maintenance painting is a condition based. Evaluating the structure to determine the most appropriate painting actions is important.

Evaluating a bridge for corrosion damage and the likely effects of future corrosion is best done by identifying "zones" of a bridge with similar corrosion tendencies. The general severity of coating damage in a given zone leads to the selection of preventive maintenance painting method selection. This could range from deferring preventive maintenance painting, to spot repairs, to full coating replacement in the zone, to spot priming with a full overcoat.

18.2.1 Understanding NACE and SSPC Standards

The National Association of Corrosion Engineers (NACE or NACE international) and the Society for Protective Coatings (SSPC) are industry associations that have published consensus cleaning and painting related specifications. They have also published technical guides, paint specifications, guide specifications and technical updates. For the purpose of preventive maintenance painting on bridges these standards can be classified as those used to evaluate structures or those used to help procure equipment, perform surface preparation, or measure applied coatings for specification compliance. Standards for condition evaluation are discussed in this subchapter. Standards related to surface preparation and coating application are discussed in Sections 18.5 and 18.6.

18.2.2 Bridge Zones

Evaluations on bridges are best done by grouping like areas of the superstructure together and estimating a rating for that entire area. For example a routine girder overpass structure may have deck expansion joints at each pier. Coating systems applied uniformly over the entire bridge will tend to show degradation near the expansion joints first. The amount of degradation will increase in severity and expand into other areas of the structure with time. These specific, repetitive areas that tend to show coating degradation first are the heart of the zone concept used to develop a typical preventive maintenance painting scope.

The typical zones used to delineate bridge preventive maintenance activities are logical and generally follow the conditions observed on the structure. Keep in mind that conditions primarily determine the zones, so the main task is to group areas of a structure into zones of similar coating and corrosion condition. Additionally the access to the structure for certain preventive maintenance painting methods may be difficult or restricted. In these cases getting access to the structure may supersede painting zones. Examples of common bridge zones are included below.

The bridge in Figure 18.12 is a common 4 span, non-continuous-girder, overpass for a 2 lane road crossing over a divided highway. Painting zones typical to this configuration include:

- Fascia beams – areas visible to the traveling public (sometimes includes the bottom of the lower flanges of the girders located over traffic) (see Figure 18.12).
- Beam ends and bearings – area below the deck joints at each abutment and pier. This includes the ends of the girders, bearings, and any diaphragm or cross bracing in the immediate vicinity (see Figure 18.13).

- Underside – majority of the girder surface area located under the deck and away from the expansion joints. (see Figure 18.14).
- Roadway splash zone – any place traffic may cause mist or roadway splash to contact the bridge. Includes members such as railing guide posts and rail, may include the bottom of the lower flanges over high speed traffic and may include the sides of girders facing traffic over high speed traffic (see Figure 18.15).

Figure 18.12 Example of an Overpass Bridge

Figure 18.13 Example Beam End and Bearing Zone

Figure 18.14 Underside of the Bridge

The black coating in Figure 18.14 is the bridge interior zone. The fascia is painted green. The lower flanges of the girders show the most corrosion and would be considered a separate zone for preventive maintenance paint planning.

Figure 18.15 Railing on the Top Deck. Roadway Splash Zone.

Each of the example zones from Figure 18.12 may be areas for preventive maintenance washing and/or painting. There is no mandatory rule for determining bridge zones, as it will vary depending upon the configuration, age, location, and exposure conditions for the bridge. Figure 18.16 shows a creek crossing that was preventive maintenance zone painted at the beam ends and bearings (shown by the white arrow).

Figure 18.16 Beam End and Bearing Zone Painting

Other bridge configurations will show typical areas of coating deterioration. Figure 18.17 shows the underside of a deck relief joint on a girder, floor beam, stringer-type bridge. The subfloor beams and the main girder directly under this joint could be considered a preventive maintenance painting zone.

Figure 18.17 Deck Relief Joint is a Potential Painting Zone

Figure 18.18 shows the underside of the edge of a bridge deck. This was an area of runoff leakage and has resulted in a pattern of corrosion along the underside of the structure.

Figure 18.18 Corrosion Accelerated by Water Leaking at the Edges of a Roadway Deck

Figure 18.19 shows the upper chord of a truss bridge that is exposed to splash from traffic. The drainage path and splash zone areas of this bridge could be separated for preventive maintenance painting.

Figure 18.19 Truss Near Roadway Level in the Splash Zone

Figure 18.20 shows the underside of a deck truss bridge away from any expansion joints. This relatively large surface area is protected from debris and runoff by the deck.

Figure 18.20 Bridge Underside Zone on a Deck Truss

Bridge fasciae are highly visible to the traffic under the bridge. As such they may be an area of emphasis for good visual condition and treated as a separate preventive maintenance painting zone.

No matter what bridge zones are identified, access to the area for painting work must be considered during the maintenance planning process. For a highway overpass with a wide median and shoulder, access may be via a lift truck or small scaffold. As long as the identified zone is accessible, preventive maintenance painting is a very cost effective approach to coating system maintenance. Conversely on heavily traveled roadways the bridges above may only be accessible at night or during off-peak hours. This may encourage contracting of painting work because of the more complicated access. On bridges with extreme height or long spans access may only be via custom rigging and scaffolding. Again this would be a situation where the cost of access is more significant than the cost of the painting method. Patterns of coating deterioration, worker access, and the required cleaning and painting methods all are items a project designer will consider when planning a painting project.

18.2.3 Coating and Corrosion Evaluation

There are four main criteria needed to assess a coating system and determine if it is a candidate for maintenance painting. Each of these criteria relates to either the feasibility or the potential reliability of preventive maintenance painting.

- Extent and severity of coating damage (peeling, blisters, etc.)
- Adhesion of the existing coating
- Thickness of the existing coating
- Extent and severity of corrosion

The following table lists some common test methods and standards used for condition evaluation of bridge coatings. The use of these standards requires careful review of the standard and may require experience with the method to produce an objective assessment.

Table 18.1 Test Methods and Their Uses

Test Method	Significance and Use
ASTM D610, Standard Test Methods for Evaluating Degree of Rusting on Painted Steel Surfaces	Method for quantifying visual corrosion of painted steel. Use to determine if corrosion extent and severity falls within ranges recommended for preventive maintenance painting.
SSPC-VIS 2, Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces	Pictorial guide based on ASTM D610. Pocket sized guide with color reference photographs.
SSPC TU3, Society of Protective Coatings Technology Update 3	Used to assess whether the risk of overcoating an existing coating is warranted. Risk is assessed on adhesion and existing coating thickness. These parameters are usually quantified during an on-site condition assessment per ASTM standards.
ASTM D6677 Standard test method for evaluating adhesion by knife	Knife cut and probe adhesion test. Does not require tape and can identify poor adhesion quickly. Good for thick or irregular coatings.
ASTM D3359 Standard test methods for measuring adhesion by tape test	Knife cut test to evaluate coating adhesion. Requires uniform coating and a specific type of adhesion tape.
ASTM F1130 Standard practice for inspecting the coating system of a ship	Contains an alternate/more detailed method for assessing visual coating damage by identifying affected area percentages and then assigning a representative visual pattern to the area.
ASTM D7091 Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Nonferrous Metals	General guidance for use of dry film thickness gauges.
ASTM D714, Standard test method for evaluating degree of blistering of paints	May be used to quantify coating blisters.

The approach to a coating and corrosion evaluation should start with the use of visual comparison standards to assess the extent of corrosion in each zone. ASTM D610 “Standard Test Methods for Evaluating Degree of Rusting on Painted Steel Surfaces” is the most applicable evaluation standard. The standard provides pictorial guidance on the amount of surface area covered with visible rusting. There are three “typical rust distributions” for spot, general, and pinpoint corrosion. Ratings are assigned by matching the observed surface to a series of graphics in the standard.

SSPC developed VIS 2 "*Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces*" as a pocket guide based on ASTM D610. The procedure, rating scale and graphics in ASTM D610 and SSPC-VIS 2 are the same. The cover page, example reference photographs, and reference scales from SSPC-VIS 2 are presented in Figure 18.21, Figure 18.22, and Table 18.2.

Figure 18.21 SSPC-VIS 2 Cover

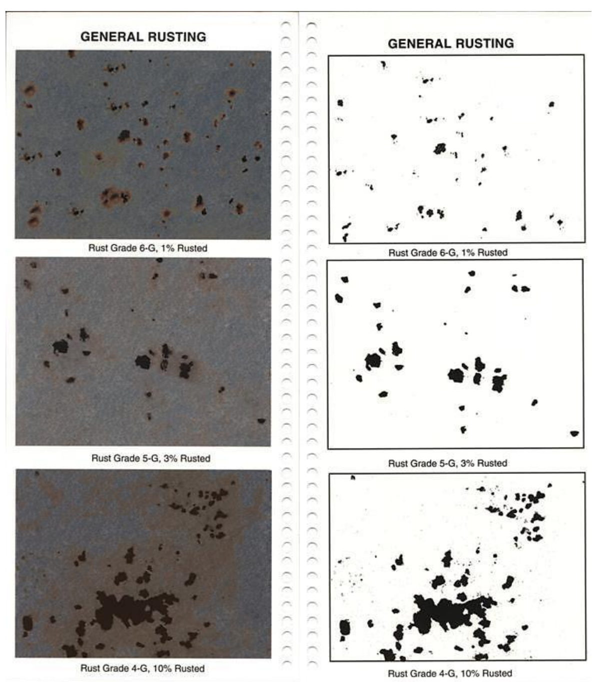

Figure 18.22 Example Reference Photographs for Evaluating Degree of Rusting

Table 18.2 Scale of Rust Percentages from SSPC-VIS 2

Rust Grade	Percent of Surface Rusted	Spot	General	Pinpoint
10	Less than or equal to 0.01 percent		NONE	
9	Greater than 0.01 percent to 0.03 percent	9-S	9-G	9-P
8	Greater than 0.03 percent to 0.1 percent	8-S	8-G	8-P
7	Greater to 0.1 percent to 0.3 percent	7-S	7-G	7-P
6	Greater than 0.3 percent to 1 percent	6-S	6-G	6-P
5	Greater than 1 percent to 3 percent	5-S	5-G	5-P
4	Greater than 3 percent to 10 percent	4-S	4-G	4-P
3	Greater than 10 percent to 16 percent	3-S	3-G	3-P
2	Greater than 16 percent to 33 percent	2-S	2-G	2-P
1	Greater than 33 percent to 50 percent	1-S	1-G	1-P
0	Greater than 50 percent		NONE	

Using these visual standards, adhesion and thickness testing, and some judgment on worker access and feasible work staging, the project designer can outline a scope of work for a preventive maintenance painting project. A project designer is the person who wrote the specifications, usually a maintenance planner or an engineer for larger projects. The basic steps in evaluation of bridge coatings to determine if they are candidates for preventive maintenance painting are presented in the following procedure.

Suggested Procedure

Bridge Coating Evalution Procedure

1. Make a visual "overview" assessment of the entire structure. Take visual stock of coating conditions to establish zones. Observe the consistency of coating conditions between different locations within a zone (e.g., are the beam ends at pier 3 more corroded than the beam ends at pier 6).
2. Label zones using references to BIRM nomenclature for pier numbers, superstructure components etc.
3. List types of coating deterioration observed. Peeling and corrosion are the most important.
4. Rate each zone using VIS 2 or ASTM D610 visual rating criteria.
5. Spot assess coating adhesion and thickness for each zone.
6. Quantify the size (painted surface area) of each zone for estimating purposes.
7. Assess the existing finish paint for compatibility with anticipated preventive maintenance painting materials.
8. Assess risk of overcoating.

As the above steps are performed the project designer should be thinking ahead to the anticipated work. Will there be a way to access the work area that is a reasonable cost? Will significant containment be required? How long will the work take compared to full coating removal and replacement? The key to the assessment is to gather objective data to support maintenance painting. If the data does not support maintenance work then other options should be pursued.

Various researchers and state agencies have developed criteria to help decide what painting actions are best for a bridge. However, decisions made with this information do not always follow a set hierarchy and policies unrelated to painting conditions may supersede. The following guidance has been used.

- Percentage rusting – Very minor corrosion may not trigger preventive maintenance painting. Moderate corrosion has been found to be best addressed by maintenance painting with percent corrosion ranging from 1 percent to 15 percent. Corrosion over 20 percent of an area typically means coating systems replacement is the least cost action.
- Adhesion of existing coating – If coating adhesion is poor, any spots of maintenance coating applied over existing coating may be at risk for peeling. For the specific case of aged lead paints over mill scale this is something to be wary of.
- Thickness of existing coating – In general the thicker an existing coating is the more likely the over coated or new composite paint system will show adhesion failure. Note that there can be significant uncertainty with the adhesion of over coated bridge paints. That uncertainty should be compared to the cost and risks associated with other painting options.
- Severity of corrosion – if corrosion is located in difficult to access spots and not practically removed with pressure washing, hand or power tool cleaning, then

maintenance painting may be viewed as a short term solution for corrosion protection. More thorough cleaning and painting (such as abrasive blasting) or structure alterations may be required to adequately arrest corrosion.

18.3 Review of Preventive Maintenance for Coating Systems

Preventative Maintenance, by definition, is intended to prevent deterioration of the coating system. In the following subsections we will review the most feasible tasks for preserving bridge paint systems and extending the time they prevent steel corrosion.

18.3.1 Scope of Preventive Maintenance Painting Work

The preventive maintenance painting system is an as-needed product. It is intended to preserve the coating system on the bridge by addressing defects in the coating and preventing those defects from increasing in severity. Therefore, the exact scope of where to paint is condition based.

A consensus on best methods for maintaining atmospherically exposed protective coatings was summarized based on detailed interviews of painting professionals (*Expected Service Life And Cost Considerations For Maintenance And New Construction Protective Coating Work*, Helsel et al., NACE 2008). Most structure owners viewed the following painting “life cycle” as the most cost effective for protective coatings:

1. Apply an initial protective coating system
2. Perform spot touch-up and repair painting when needed
3. Perform maintenance painting when needed (spot prime and full overcoat)
4. Re-apply the protective coating system (total coating removal and replacement)

If we look at this model of the ideal life cycle for a bridge coating system, preventive maintenance painting would be addressed with the spot touch up and maintenance painting portions of the cycle (steps 2 and 3).

The coating conditions, combined with the feasible bridge painting zones outlined earlier, are typically the driving factors in defining the scope of preventive maintenance painting work. Because the zones are typical for the majority of overpass type structures, the zone concept works well in conjunction with preventive maintenance actions. The preventive maintenance painting actions typically include bridge washing, spot painting, zone painting, and full overcoating. Each of these terms is discussed below.

18.3.2 Bridge Washing

Washing is performed in accordance with “Waterjet Cleaning of Metals SSPC-SP WJ-4/NACE WJ-4 – Light Cleaning.” This standard describes the cleaning criteria applicable to using a common commercial duty pressure washer. The SSPC WJ-4 standard includes a definition for low pressure water cleaning (LP WC) that is defined as nozzle pressures of 5,000 psi or less. Anything above 5,000 psi is considered high pressure. The cleaning criteria require the removal of all visible oil, grease, dirt, dust, loose mill scale, loose rust and other corrosion products, and loose coating.

Washing makes sense from a corrosion control point of view, as the main sources for a corrosive electrolyte are significantly reduced. Unfortunately, few if any factual studies have been conducted on the tangible benefits of bridge washing. A recent survey found only anecdotal assumptions as the reasoning for bridge washing. However these assumptions pose a very strong case for the benefits of washing. For bridges located in areas that experience frozen precipitation and deicing chemical use, the benefits of routine washing are significant. Timing the washing in the spring would be ideal, to both remove debris and remove deicing chemical runoff from the bridge structure before temperatures increase. Some other comments on bridge washing include:

- Washing may already be a planned activity on some bridges for cleaning of decks and drainage systems, so piggy backing the targeted washing of deck joint areas could be easily justified.
- Bridge washing will create dirty runoff water. Be aware of any local rules for collecting debris or monitoring how dirty the water may be. If these constraints exist bridge washing may be less feasible.

18.3.3 Coating Types and Properties

As discussed earlier, the functional properties of a potentially good performing bridge coating system include both barrier protection and galvanic protection. Because of these attributes, the majority of newer bridge painting systems include a zinc based primer, barrier intermediate coat, and a weather able finish coat. Unfortunately the general population of painted steel bridges is diverse, with the majority of structures having either aged lead alkyd paints, newer 3-coat systems, other newer zinc based systems, or other variations of aged coatings. This means preventive maintenance painting systems must be flexible enough to address the corrosion concerns of a diverse inventory of bridge paint systems. The ideal situation would be replacing all older poorly adhered and poor performing paint systems, but that is unrealistically cost prohibitive.

Selecting the most appropriate preventive maintenance painting materials is aided by a review of coating material types and properties. Table 18.3 provides a basic summary on preventive maintenance painting material characteristics and commentary of their applicability to preventive maintenance bridge painting. The table includes a description of the coating type, comments on advantages and disadvantages as they relate to preventive maintenance bridge painting, and a relative service life for the coating. Note that service life for preventive maintenance painting is highly variable. Studies have shown that the “spots” that were previously corroded, prepared, and then painted with the preventive maintenance coatings are the most likely spots to re-corrode. The relative service life is a gauge of the material’s ability to prevent this re-corrosion and it is highly depended on the level of cleanliness achieved before the preventive maintenance coating was applied. Also note that specific coating formulations are proprietary and will vary. It is recommended that agencies use case history and testing information to assemble a Qualified Product List (QPL).

Table 18.3 Preventative Maintenance Paint Material Characteristics

Coating Type	Description	Advantages	Disadvantages	Relative Service Life
Alkyd / oil based	Single component synthetic oil and oil based coatings. Long use history.	Easy to apply. Can be formulated with corrosion inhibitive pigments. Less expensive.	Volatile Organic Compounds (VOC) rules may soon phase out. Sensitive to thickness variations.	Medium
Epoxy	2 component materials with good barrier properties and adhesion. May be formulated as zinc primer.	Numerous variations and supplier options. Can include corrosion inhibitive pigments. Can apply higher thickness with less coats. Can be less expensive	Requires field mixing. Poor resistance to sunlight.	Medium - high
High Ratio Calcium Sulfonate	Single component corrosion inhibiting coating.	Designed for application to corrosion and poorly adhered coatings.	Remains wet and/or soft for extended period. Requires planning for best application. May be overcoated only with self.	Medium - high
Moisture Cured Urethane (MCU)	Single component materials with good barrier properties. May be applied in very high moisture environments. May be formulated as zinc primer.	Wide range of formulation variables. Tolerance for wide range of environmental conditions during application.	May bubble or crack at higher Dry Film Thickness DFT. More expensive.	Medium high
Waterborne Acrylic	Single component materials with good finish quality and aesthetic properties	Low VOC may be formulated with corrosion inhibitors. Excellent sunlight service.	High build required for corrosion performance requires multiple coats. Limited range of environmental conditions during application.	Medium
Organic Zinc Rich Primer	Typically epoxy or Moisture Cured Urethane (MCU) material with high zinc pigment load. Used as a primer or spot primer over unpainted areas.	Have some cathodic protection properties. More sensitive to thickness variation that non-zinc primers.	May require field mixing. More expensive. Limited use history over corroded substrates.	High
Low viscosity sealers	Typically 2 component epoxy materials with little to no pigmentation. Used to pre-treat spots of adhered corrosion.	Designed to penetrate and enhance adhesion of additional preventive maintenance painting materials.	May require field mixing. May require extended cure times.	Medium - High
Corrosion Preventing Compounds (CPC)[i]	Single component corrosion "treatments" such as oils, water displacing chemicals and other proprietary technologies. Used in equipment industry as part of routine maintenance. Many are not film forming. Not designed to "coat" the substrate.	Penetrate crevices and effectively slow active corrosion. assist in life extension programs through a simple annual preventative maintenance plan. Inexpensive simple application.	Not tested over significant amounts of corrosion that may be common on bridges. Would require routine and repeated application. Not designed to cover or fully stop visible corrosion. Easily wear or are washed away.	Highly dependent on application frequency.

Vinyl coatings were not included above because of their high solvent content and inability to meet VOC regulations. They have a good history but have been phased out.

Also note that corrosion resistant additives and pigments may be in many types of material. Pigments such as leafing aluminum and Micaceous Iron Oxide (MIO) are proven performance enhancers.

18.3.4 Spot, Zone, Overcoats

Spot coats are applied only to the immediate locations that are missing coating or are corroded In a preventive maintenance coating system there may be one or more spot coats applied. Spot painting alone is commonly used for touch-up or repair of a newly applied coating. Spot painting is also necessary when re-coating heat straightened steel or for steel repairs using new steel. Multiple spot coats may be used to add thickness to a preventive maintenance coating system and are recommended over previously corroded areas. Spot coats may contrast slightly with the surrounding coating making areas with multiple spot coats have a patchwork appearance.

Zone painting is applying the coating system to the entire extent of the zones described in Section 18.2.2. This provides a uniform appearance in the entire bridge zone. Since a potentially large area of existing coating will be painted over (overcoated) the existing coating should be adequately characterized for overcoating. Zone painting is most feasible if the zones are easily accessible for containment and workers. An example of zone painting is shown Figure 18.23.

Figure 18.23 Zone Painted Below / Near a Roadway Expansion Joint

An overcoat is the term used for applying coating over existing paint. All areas must be characterized for overcoat compatibility, as many areas not "requiring" preventive maintenance painting will receive additional layers of coating. SSPC TU-3 is an evaluation procedure that may be used to assess the risk of overcoating.

18.3.5 Example Preventive Maintenance Painting Systems

Feasible surface preparation combined with the choice of coating materials shown in Table 18.3 may be used to build a good performing preventive maintenance painting system. This system would be applied to spots and zones as appropriate on a bridge. Because the coating and corrosion condition of the bridge will dictate the scope of work it is difficult to show all possible scenarios, but the following are common:

- For an overpass bridge with a 20 year old, zinc based coating system. Corrosion at the beam ends and bearings is ASTM D 610 of 3 to 5 (16 percent to 3 percent). No other significant corrosion. Existing coating adhesion is very good.
    - Alternative 1 – Pressure wash entire beam end zone. Thoroughly prepare entire zone with power tools to SSPC-SP 11. Spot apply an organic zinc rich primer if the preparation exposes bare metal OR a low viscosity sealer if substantial corrosion remains. Note that use of a sealer precludes use of a zinc rich primer. Apply an epoxy or Moisture Cured Urethane (MCU) barrier coat. Zone overcoat with alkyd or waterborne acrylic finish coat to match existing colors. A Polyurethane overcoat could also be selected for additional durability.
    - Alternative 2 - Pressure wash entire beam end zone. Spot prepare with power tools. Spot apply high ratio calcium sulfonate products (1 or 2 coats) to corroded areas. Zone overcoat with high ratio calcium sulfonate to match existing bridge color. Note that calcium sulfonate may only be over coated with additional calcium sulfonate in the future.
- For an overpass bridge with a 30 year old, lead alkyd coating system applied to mill scale. Corrosion at the beam ends and bearings is ASTM D 610 of 3 to 5 (16 percent to 3 percent). No other significant corrosion. Existing coating adhesion is marginal.
    - Alternatives 1 or 2 as above
    - Alternative 3 - Pressure wash entire beam end zone. Spot prepare with power tools. Spot apply alkyd primer. Apply 2 zone overcoats with alkyd finish coat to match existing colors.

Maintenance painting durability is related to the maintenance coating ability to prevent the originally corroded spots from “re-corroding”. The better performing spot maintenance coatings are generally as thick as feasible to provide good “barrier” protection in these spot locations. Note that thickness can be added with multiple coats, never by application over a manufacturers recommended thickness. Any coating that is applied over existing paints is adhered only as well as the existing coating, and the risk of that existing coating combined with a new coating losing adhesion should always be considered.

18.4 Containment and Worker Protection

Laws related to environmental and worker protection will have significant impact on bridge painting activities. The high occurrence of existing/aged coatings containing potentially hazardous material means that any cleaning debris must be collected with containment. Workers performing cleaning methods must be monitored and protected from exposure to hazardous materials. This subsection will review basic strategies for containing debris generated during bridge preventive maintenance construction and rules for worker safety related to hazardous materials.

18.4.1 Containment Requirements

A containment system, or enclosure, may be made up of combinations of cover panels, scaffolds, supports, screens, and tarps. Its purpose is to prevent both lead and other debris generated during surface preparation activities from entering the environment. The system also helps to collect and properly dispose of debris. Containment may be constructed and temporarily left in place (e.g., installed for the time a cleaning action is performed).

The cost and feasibility of the containment system are driving factors in selecting cleaning and painting methods. Regardless of the materials used to construct containment, the effectiveness of the containment system must meet design requirements outlined in a project specification. An example of a containment system is shown in Figure 18.24.

Figure 18.24 Class 1A Containment for Zone Painting

18.4.1.1 Applicable Regulations

Many regulations apply to waste collection / control and worker safety practices for bridge preventive maintenance painting. The list below provides a description of the current Federal regulations:

- EPA Clean Water Act - Regulates discharge of materials into waterways
- EPA Clean Air Act Amendments - In part, regulates discharge of dust into air from bridge painting
- EPA Resource Conservation and Recovery Act (RCRA) - Regulates the handling, storage, and disposal of lead (and other heavy metals) containing waste
- EPA Comprehensive Environmental Response Compensation and Liability Act (CERCLA or Superfund) - Assigns ownership of and responsibility for hazardous waste to the generator "into perpetuity"
- OSHA CFR 29 1926.62, Lead in Construction - In part, establishes guidelines for protection and monitoring of workers removing lead paint from bridges

The bridge assessment (during project design) should include sampling of the existing coating to test for the presence of lead or other hazardous materials. Some agencies have reported asbestos in existing bridge coatings. While this testing does not conclusively determine a waste type, it provides guidance on the potential regulatory impacts for the preventive maintenance painting work. The actual impacts must be determined during the work. For example, waste is determined to be hazardous or nonhazardous only after it is generated, sampled and tested. Similarly, if there exists any potential for worker exposure to hazardous material, the worker is protected according to OSHA guidance until worker exposure monitoring demonstrates the needed worker protection.

Hazardous waste includes debris, dust, and other waste that is sampled, analyzed, and classified as hazardous based on toxicity results. The most common hazardous waste for steel bridge superstructures is lead paint residue and dust, generated when mechanical surface preparation and power washing occurs to remove existing paint from steel bridges. This waste is subject to project site storage rules including:

- Waste must be properly labeled
- Waste must be properly containerized
- Waste must be in a secure location
- Waste may be site stored for no more than 90 days

Any preventive maintenance painting that removes paint waste will require manifesting of the waste to legally transport the waste between the project storage location and a disposal facility. A manifest is a written document that creates a record of the waste's removal from the temporary storage area to a disposition site. Specific rules should be verified as there may be some exemptions for small quantities of waste.

FHWA Publication No. FHWA-RD-94-100, Lead-Containing Paint Removal, Containment, and Disposal, provides information on regulations affecting the removal of lead-containing paints from steel bridges and includes a guide for waste reduction, control, and disposal of the hazardous material.

18.4.1.2 Types of Containment

Bridge painting containment is designed according to the criteria in SSPC Technology Guide No. 6 "Guide for Containing Surface Preparation Debris Generated During Paint Removal Operations". The guide contains definitions of containment Types (what cleaning method will it be used for), containment Class (construction methods that relate to the effectiveness of the containment) and levels of emissions (amount of material that is permitted to escape the containment). The following reviews these design parameters for containment:

- Type A containments are for dry abrasive blasting
- Type W containments are for water cleaning methods
- Type P containments are for power tool cleaning methods
- Type C containments are for chemical cleaning methods

For bridge preventive maintenance and surface preparation we are most concerned with Type W and Type P containment.

The Classes of containment range from 1 to 4, with a Class 1 containment providing for the highest degree of emissions control and Class 4 the lowest degree of emissions control. Emissions are any dust, spills or debris that escapes the containment or work area. Guide 6 outlines seven methods for monitoring containment emissions:

- Method A: Visible Emissions

- Method B: Ambient Air Monitoring for PM-10
- Method C: Occupational Monitoring of Area Emissions of Lead
- Method D: Ambient Air Monitoring for Toxic Metals (TSP Lead)
- Method E: Soil Analysis for Toxic Metals
- Method F: Water and Sediment Analysis for Toxic Metals
- Method G: Visual Assessment of Site Cleanliness

The visual methods for assessing emissions are most applicable to preventive maintenance painting work on bridges. These include Method A – Visible emissions and Method G – Visual assessment of site cleanliness. This means preventive maintenance painting construction must be monitored for the visual escape of debris from the worksite, and the worksite must be cleaned of visual debris on a daily basis.

The project specification should include limits on visible emissions. The most applicable method for assessing these emissions is with General Surveillance. The levels of emissions may be restricted according the following:

- Level 0- No emissions
- Level 1- Random emissions, cumulative duration of no more than 1 percent of the work day
- Level 2- Random emissions, cumulative duration of no more than 5 percent of the work day
- Level 3- Random emissions, cumulative duration of no more than 10 percent of the work day
- Level 4- Unrestricted emissions

The work methods for most preventive maintenance of bridge coatings will include pressure washing and power tool cleaning. The washing is most often contained with Class 3W or 4W containment. Class 4W would be for areas where wash water is allowed to escape and Class 3W would be for areas where wash water must be collected and disposed. Power tool cleaning is most often contained with Class 3P containment. When the power tool cleaning is on lead or hazardous containing paints the use of vacuum shrouds on the power tools may also be required.

18.4.2 Worker Protection

The Occupational Safety and Health Administration (OSHA) regulates worker safety in the United States and requires employers to provide a safe workplace by setting and enforcing standards. Specific OSHA standards regulate various types of work environments and activities, including construction industries.

Lead containing paints were the primary coatings technology for the corrosion protection of atmospherically exposed steel for many years. In 1978, lead containing paints were banned for use on residences or other buildings where consumers could be exposed and shortly thereafter industrial use of lead containing coatings was phased out.

There are a significant percentage of steel bridges in the United States with heavy metal pigments (e.g., lead, chromate) in the coatings. These paint systems are aging and in need of maintenance. Maintenance operations may range from small component replacement jobs to major maintenance activities including total removal of existing paint and repainting. These metals can be hazardous to human health if inhaled or ingested in relatively small quantities in the form of dusts or fumes. It is important to take appropriate measures to protect workers and inspectors potentially exposed to these hazards. Protection measures are straight forward, and when followed, can protect personnel while allowing for safe and productive work.

Lead is hazardous to human health when it enters the bloodstream. In the bloodstream, lead will replace other useful elements (e.g., calcium, iron) and adversely affect the effectiveness of the blood in carrying oxygen to various organs including the liver, kidneys, reproductive system, and brain. In this manner, lead is particularly dangerous to small children, but can also poison adults. Once in the bloodstream, lead can concentrate in the organs or in the bones and produce long-term effects as it leaches back into the bloodstream over time.

Lead can enter the bloodstream by being breathed and absorbed through the lungs, or by being ingested and absorbed through the digestive system. Lead cannot be absorbed through the skin, but a common form of lead intake is via "hand-to-mouth" ingestion when eating or smoking with lead dust on the hands. Only a very small amount of lead is needed in the bloodstream to exceed the current OSHA limit of 50 µg/dL (micrograms per deciliter of blood, OSHA standard unit of measurement for blood contamination).

Required measures for worker protection during occupational exposure to lead are covered in the OSHA Lead-in-Construction Standard, 29 CFR 1926.62. This standard addresses the following issues in detail:

- Requirements for dedicated work clothes
- Controlled lead work areas and warning signs
- Requirements for periodic blood lead level checks for workers
- Requirements for clean break and eating areas
- Hand washing station and showers
- Documented respirator use and maintenance program
- Proper fit testing, use and storage of respirators
- Designation of a "competent person" to deal with hazards on the jobsite

The identification of a lead hazard (as well as hazards of cadmium, chromium, inorganic arsenic, or asbestos) is accomplished with breathing zone air monitoring, or an initial exposure assessment to ascertain expected exposures during a work operation. Exposures are quantified according to the weight per unit volume of breathing air applied over an 8-hour time weighted average. The OSHA action level (AL) for lead-in-air is an 8-hour average of 30 $\mu g/m^3$, where $\mu g/m^3$ is microgram per cubic meter (OSHA standard unit of measurement for air contamination). This action level will be exceeded by almost all abrasive blasting activities, and many power tool-cleaning and torch cutting or demolition activities on lead containing bridge paints. Once the AL is exceeded, the employer must follow all of the guidance of the standard to maintain worker exposure below the permissible exposure limit (PEL) of 50 $\mu g/m^3$. This includes engineering controls, administrative controls, personal protective equipment and medical monitoring.

Medical monitoring quantifies the level of lead in a workers blood. Blood levels above 50 µg/dL require removal of the worker from the hazard (where µg/dL is micrograms per deciliter).

Engineering controls are any piece of equipment or modified maintenance procedure which reduces the hazardous dust exposure to workers. Examples are: ventilation equipment (dust collectors) attached to blasting containments; shrouds and vacuum attachments for power tools; and alternative low-dusting surface preparation methods (e.g., wet abrasive blasting, high pressure water blasting, chemical stripping).

Administrative controls are typically enacted by mixing "high-exposure" activities with "low-exposure" activities. This may reduce a particular worker's or inspector's overall exposure over the workday.

Respirators are personal protective equipment and different types of respirators have different assigned protection factors. For example, a half-face mask with proper filters and properly fitted reduces the ambient hazard by a factor of 10 times. A typical continuous-flow, supplied-air abrasive blasting helmet reduces the hazard by 25 times, with certain models designed to provide 1000 times protection. Although exposure levels vary from job to job, for abrasive blasting inside of containment, a 1000X rated respirator is generally required. For workers outside of a dry abrasive blasting containment and for inspection personnel, a half-face, negative pressure respirator with HEPA (high efficiency particulate air) filters (magenta color) may be sufficient. Since exposure levels for workers vary greatly depending on worker job description, containment design and operation, and other site-specific conditions, respirator selection and use should consider these factors.

Hygiene practices are required and are intended is to minimize inhalation and ingestion of the hazard by the worker while on the jobsite and to keep the worker from taking the lead hazard off the jobsite to expose others in their personal vehicles or homes. This is best accomplished by using dedicated work clothes which remain on the jobsite and are either disposable or laundered separately; and by supplying reasonable washing facilities for workers to use before they eat, smoke, or leave the jobsite.

Workers, by law, have a right to know when they may be exposed to working conditions that are known to be harmful to them. Safety Data Sheets (SDS) (previously referred to as "Material Safety Data Sheets") list hazards and required precautionary measures. These SDS give detailed information about the nature of a chemical, such as physical and chemical properties, health, safety, fire, and environmental hazards of a chemical product.

At minimum, supervisors should have an up-to-date book of Safety Data Sheets (SDS) available at all times for new materials purchased for the project. These same SDS should also be available for materials that are part of the existing structure.

18.5 Surface Preparation

The purpose of preventive maintenance painting surface preparation is to clean and roughen the surface so that preventive maintenance painting materials have maximum service life. Surface preparation is one of the more critical aspects of applying a coating system. In the case of bridge re-painting, surface preparation is typically the step that takes the longest amount of time, and uses the highest volume of materials and the largest amount of equipment.

Water washing and power tool cleaning are the most feasible preventive maintenance bridge painting surface preparation methods. These methods remove contaminants, loose rust and paint, as well as paint that no longer have protective qualities.

18.5.1 Industry Standards for Surface Preparation

Surface preparation is specified as a performance requirement. As such it may be one of the more judgment-filled aspects of a project. A significant number of consensus standards have been created to aide in achieving desired levels of surface cleanliness prior to painting. These standards describe the amounts of material (e.g., rust, coatings, and mill scale) that is allowed to remain on a surface after cleaning with a certain method.

Table 18.4 lists surface preparation standards that help standardize the quality and conformity of surface preparation. The SSPC and joint SSPC/NACE standards to be described are those most applicable to preventive maintenance bridge painting.

Table 18.4 Surface Preparation Standards for Preventive Maintenance Bridge Painting

Surface Preparation Standard	Summary of Key Criteria	Bridge PM Painting Significance and use
SSPC –SP1 Solvent Cleaning	Removes visible grease, oil, and dirt contamination	Indirect preliminary requirement of all other SSPC surface preparation standards.
SSPC-SP2 Hand Tool Cleaning	Removes loosely adhering materials*	Good for fast removal of loose corrosion or materials with the least containment possible.
SSPC-SP WJ-4/NACE WJ-4 – Light Cleaning	Water cleaning method to remove loosely adhering materials*	Typically pressure washing up to 5,000 psi. Very common PM Bridge painting preparation method.
SSPC-SP WJ-4/NACE WJ-4 – Thorough Cleaning	Waterjet cleaning method that significantly removes material. Allows 33 percent tightly adherent randomly dispersed material.	Typically requires higher pressure equipment than WJ-4 (up to 20,000 psi). Typically requires containment of water and debris.
SSPC-SP3 Power Tool Cleaning	Removes loosely adhering materials*	More thorough removal than SP2. Preferred method for spot preparation prior to maintenance painting.
SSPC-SP15 Commercial Grade Power Tool Cleaning	All mill scale, rust, and paint must be removed. Up to 33 percent staining may remain. Slight residues may remain in the bottom of corrosion pits.	Very thorough power tool cleaning. Time consuming, yet may be desired for small areas.
SSPC-SP11 Power Tool Cleaning to Bare Metal	All mill scale, rust, and paint must be removed. Slight residues may remain in the bottom of corrosion pits.	Most thorough power tool cleaning. Time consuming, yet may be desired for small areas.
SSPC-SP7 Brush-off Blast Cleaning	Removes loosely adhering materials*	Abrasive blasting requires containment and significant equipment.
SSPC-SP14 Industrial Blast Cleaning	All loosely adhering materials must be removed. Up to 10 percent adhered material may remain. Unlimited staining may remain	More thorough blast cleaning compared to SP7. Abrasive blasting requires containment and significant equipment.
SSPC-SP10 Near-White Blast Cleaning	All mill scale, rust, and paint must be removed. Stains of material are allowed up to 5 percent	Common cleaning for bridge repainting. Abrasive blasting requires containment and significant equipment.

*Material (dirt, dust, loose mill scale, loose rust and other corrosion products, and loose coating) is considered adherent if it cannot be removed with a dull putty knife.

Visual guides have been developed to aide in the determination of surface preparation cleanliness. These guides include color photographs of example conditions that match the descriptions in the surface preparation standards. The most applicable guide to preventive maintenance bridge painting is SSPC-VIS 3 "Guide and Reference Photographs for Steel Surfaces Prepared by Power and Hand Tool Cleaning". The front page of the SSPC-VIS 3 is shown in Figure 18.25. This manual is available for purchase from the SSPC at http://www.sspc.org/sspc-vis-3.html.

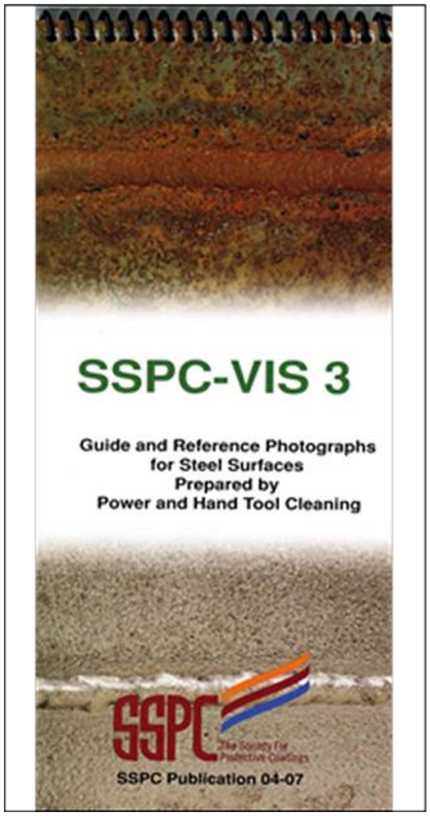

Figure 18.25 SSPC-VIS 3 Guide Reference

The guide steps through photos of initial conditions (condition of the steel prior to any cleaning of a surface) that represent some common weathered paints on steel. The conditions labeled G are the most applicable to weathered paints on bridges. An example "G" condition is shown in Figure 18.26.

Figure 18.26 Initial Condition G

The guide shows various levels of cleaning applied to the initial conditions. (All photos taken from the SSPC-VIS 3 Guide Reference). Figure 18.27 shows examples of different levels of power tool cleaning over condition G. In this series of photographs the sample increases in cleanliness from (a) to (d), starting with SP2 at the upper left. Specifically shown are: (a) Condition G cleaned using hand tools, (b) Condition G cleaned to SP3 using power wire brush, (c) Condition G cleaned to SP15 using power tools, and (d) Condition G cleaned to SP11 using power tools.

(a) Condition G cleaned using hand tools

(b) Condition G cleaned to SP3 using power wire brush

(c) Condition G cleaned to SP15 using power tools

(d) Condition G cleaned to SP11 using power tools

Figure 18.27 Example Cleanliness Levels (Courtesy of SSPC)

Suggested Procedure

SSPC VIS Guide

1. Determine an initial condition based on the description of the surface and comparison to an example photograph.
2. Project designer identifies the level of cleanliness required for the project and note the description of the material or staining that may remain.
3. Find the picture illustrating the selected initial condition cleaned to the project required cleanliness.
4. Compare illustration with the actual cleaned surface.

Obtaining the guide from SSPC is highly recommended, as the photos in this chapter show only a small sample of the various conditions and cleanliness levels illustrated in VIS 3. Anyone using a VIS guide needs to read it thoroughly first, as it is not intuitive. Also note that other VIS guides exist for abrasive blast cleaned surfaces and for water jet cleaned surfaces.

The following subsections highlight details of water cleaning, tool cleaning, and abrasive blasting methods of surface preparation. Each method has distinct advantages and disadvantages when applied to a particular project. Overall, for bridge preventive maintenance painting, the areas requiring surface preparation are relatively small. This makes preparation methods with relatively small equipment and less cleanup more cost effective. As such, low pressure water cleaning and power tool cleaning are the methods most popular for preventive maintenance bridge painting.

18.5.2 Water Cleaning Methods

The water cleaning methods use pressurized water to remove material from the substrate (see example in Figure 18.28). The SSPC "WJ" Standards define cleaning terminology based on the pressure capability of the equipment. The water may be heated and detergent may be added to aid in the cleaning. Low pressure water cleaning (LP WC) involves pressures less than 5,000 psi. LP WC, often called power washing, is effective in removing dirt, loose coatings, and visible mildew on coated metals and is generally safe on adjacent wood and concrete/masonry.

Figure 18.28 HP Water Cleaning on a Bridge (10,000 psi)

High-pressure water cleaning (HP WC) uses pressures from 5,000 to 10,000 psi. High-pressure water jetting (HP WJ) is defined as cleaning from 10,000 to 30,000 psi. For pressures over 30,000 psi, the cleaning is defined as UltraHigh-Pressure Water Jetting (UHP WJ).

Some advantages of water cleaning include:

- Compared to dry cleaning methods, soluble salts are more thoroughly removed. The addition of a soluble salt remover should be considered. This is a significant benefit for preventive maintenance bridge painting in zones under leaking deck joints as these areas are commonly contaminated with salts from roadway runoff.
- The low pressure equipment is common and relatively inexpensive.
- The low pressure equipment will effectively remove loose corrosion, dirt, poultice, and loose/poorly adhered existing coatings.

- The low pressure equipment does not pulverize or remove marginally adhered existing coatings.
- The high pressure equipment is capable of removing nearly all corrosion and existing coatings.

Some disadvantages of water cleaning include:

- Water applied to adhered corrosion may require extended time to dry. All surfaces to be painted should be thoroughly dry.
- Some localities may require capture of low pressure water cleaning wastewater and debris.
- Water and debris from high pressure water jetting will require capture with containment structures.
- Any bare spots of steel will likely generate flash rust, although the use of corrosion inhibitors will prevent flash rusting
- Water cleaning and water jetting do not produce a profile, but they may expose a previous profile.

18.5.3 Hand and Power Tool Cleaning

Hand tool cleaning is typically performed with wire brushes, scrapers, and other tools that do not depend on electric or pneumatic power to operate (see Figure 18.29). These hand tools are only intended to remove loosely adhering corrosion products, old paint, and flaking mill scale, and are not intended to produce a profile in the steel. This method of surface preparation is slow and labor-intensive if large amounts of material must be removed, but may be the most expedient method of preparation if isolated small spots are all that require preparation. Hand tools are frequently used to prepare surfaces for spot touch-up during maintenance painting activities. Because of the relatively small amounts of debris and dust generation, hand tool cleaning is typically performed with minimal containment.

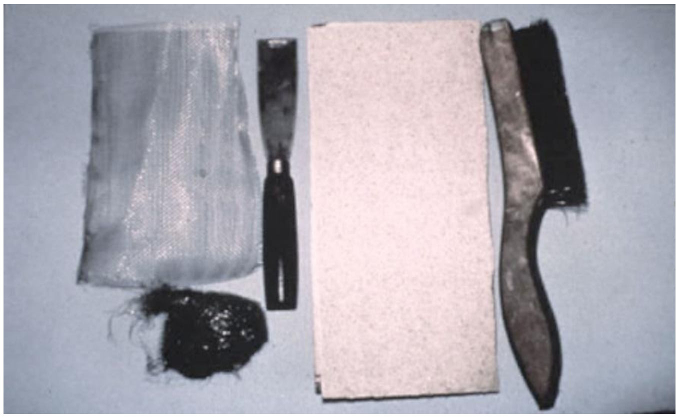

Figure 18.29 Various Hand Tools for Surface Preparation (SSPC)

Power tool cleaning is typically performed with grinders, pneumatic chisels, needle scalers, and rotopeen tools that require an electric or pneumatic power source to operate. Examples of these tools are shown in Figure 18.30 through Figure 18.32. Most of these tools can remove both loosely and tightly adhering corrosion products, paint, and mill scale from the steel surfaces. Loose material is removed relatively quickly, while adhered material may take significant time and effort to fully remove. Stratified rust, pack rust and rust scale are also removed using these types of tools. In Figure 18.31, the lower needle gun has a vacuum shroud that may reduce dust emissions.

Figure 18.30 Common Power Tools for Surface Preparation (Courtesy of SSPC)

Figure 18.31 Needle Guns (Courtesy of SSPC)

Figure 18.32 Needle Gun Cleaning for Spot Repairs to a Bridge Coating

Some of these tools can also roughen the substrate to promote coating adhesion. Tools such as abrasive impregnated woven disks and needle scales may impart roughness, where tools like power wire brushes may polish a surface.

Many tools may be purchased with vacuum ports and hoses for attachment to High Efficiency Particulate Air (HEPA) filtered vacuums so that the fine, airborne particles that are generated during surface preparation activities are collected at the point of generation. The combination of a vacuum shroud and minimal containment make power tool surface preparation popular for preventive maintenance bridge painting because the deteriorated coating is typically in discrete zones or spots.

18.5.4 Abrasive Blasting

The dual purpose of surface preparation (clean and roughen) is most often efficiently achieved with abrasive blast cleaning. This method of surface preparation uses pressurized air or a centrifugal wheel to propel an abrasive media at the surface. The media impacts and abrades the surface and has the ability to impart the surface profile or roughness that is desirable for long term coating performance.

The basic components of a compressed air abrasive blasting set up are shown in Figure 18.33.

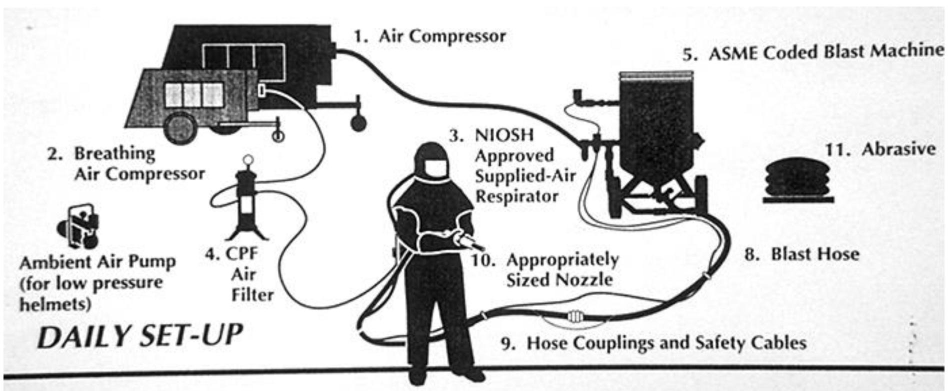

Figure 18.33 Basic Daily Set-Up for Dry Air Abrasive Blasting (Courtesy of SSPC)

The advantages of abrasive blast cleaning include:

- Produces a very high quality surface because it can completely remove all rust, scale, dirt, and old coating.
- Roughens the surface to produce a profile that promotes coating adhesion and durability.
- Many types of media may be used. These have varying density and hardness and will clean different surfaces effectively. Some abrasives can be collected, cleaned and re-used. The use of recycled abrasives can significantly reduce the volume of disposal waste. Typical abrasives include:
  - Natural materials such as sand, garnet, nut shells
  - Synthetic materials such as slags, glass, plastic
  - Metals such as steel and iron shot, steel grit (popular for bridge repainting)

Some disadvantages of abrasive blast cleaning include:

- Does not remove grease or oil, which must be removed by solvent cleaning before blasting
- Is extremely noisy - both the nozzles and equipment produce significant noise.

- Requires relatively large and expensive equipment
- Produce a very large amount of waste (for disposable abrasives)
- Requires the use of an effective containment structure. For abrasive blasting on bridges an SSPC Guide 6 Class 1 or 2 containment is typically used. This requires dust collection equipment

The advantages of abrasive blasting coupled with the waste minimization aspects of recyclable steel grit blasting have made it the most popular surface preparation method for steel bridge re-painting. These projects are large, expensive, and require full containment of the structures. The objective of a bridge re-painting project is to install the most durable coating system possible for the least cost, and abrasive blasting fits that goal well. An example of an abrasive blast machine commonly used for bridge re-painting surface preparation is shown Figure 18.34.

Figure 18.34 Recyclable Steel Grit Machine Used for Abrasive Blasting

The use of abrasive blasting for preventive maintenance bridge painting is limited. Such a large amount of set-up and equipment is not feasible, although severe corrosion is best arrested with complete removal. Since the objective of preventive maintenance painting is life extension for the existing paint system with minimal cost impact, surface preparation methods that require less equipment are typically selected. Examples of abrasive blasting are presented in Figure 18.35 and Figure 18.36. In Figure 18.36, notice that significant dust is created. Lighting shown in the figure is typical practice for the workers.

Figure 18.35 Abrasive Blasting on a Bridge (Courtesy of SSPC)

Figure 18.36 Abrasive Blasting with Disposable Abrasive

When to Call the Engineer

Abrasive blasting will remove corrosion product and expose loss of steel section resulting from corrosion. If there is more than expected section loss, the Engineer should be contacted to determine if steel repairs will also be necessary.

18.5.5 Sponge Blasting

Blasting with sponge media is a specific subset of abrasive blasting. Sponge media is an open-celled, polyurethane material that is impregnated with abrasives. The pliant nature of sponge media allows its particles to compress/flatten on impact which exposes the abrasive. After leaving the surface, the media expands to locally capture a percentage of what would normally have become airborne contaminants.

These proprietary systems consist of the Sponge-Jet Media Feed Units and the Sponge-Jet Media Classifiers. The feed unit, an example of which is shown in Figure 18.37, has specially designed components for use with sponge media. An example of sponge media with embedded abrasive is shown in Figure 18.38. The Classifier allows collection and re-use of the sponge media. Typically, between 60 percent and 90 percent of Sponge Media is reusable after each blast cycle, although the effectiveness of the media reduces with re-use.

The Sponge Media is produced with a variety of abrasive sizes and types offering different characteristics and blasting capabilities. Some are designed for use on soft substrates, but for bridge preventive maintenance painting surface preparation, aggressive media would be used.

Key advantages of sponge media blasting over traditional abrasive systems include:

- Less containment – sponge media is low dusting
- Less large equipment – the sponge jet equipment is manufactured as separate individual systems allowing portability and flexibility in project set-up
- Effective cleaning and roughening – cleaning capability is similar to traditional blasting and more thorough than power tool cleaning

Some disadvantages may include:

- Proprietary system – sponge media blasting is single sourced
- Lower production compared to traditional blasting

Figure 18.37 Sponge Jet Feed Unit (Courtesy of Sponge Jet)

For preventive maintenance bridge painting, where the spots or zones to be cleaned are relatively small, sponge media blasting may be a viable alternative to dry abrasive blasting. The ideal scenario would be spots or zones on a bridge that require cleaning more thorough than could reasonably be achieved with power tools.

Figure 18.38 Sponge Media with Embedded Abrasive (Courtesy of SSPC)

18.6 Applying Coatings

Preventive maintenance coating materials are applied to bridges with the purpose of protecting the substrate. The selection of application method should take into consideration the coatings characteristics, the size of the area to be painted, and the available time for painting. Quality and correctness in applying the coatings is critical to the longevity of the coating system.

18.6.1 Quality Control Criteria

The process of applying a coating is subject to many quality criteria. Most of these are specifically stated in a project specification, but a Product Data Sheet (PDS) from a coating manufacturer will contain much of this information. A list of some of these factors is highlighted below:

- Ambient conditions – the air temperature, dew point, relative humidity, and surface temperature are all part of the ambient conditions. Solvent evaporation and other coating curing mechanisms are highly sensitive to these conditions. The specific conditions for a coating are included on a PDS, however, most coatings should follow these general rules during the application and cure stages of work:
    - Protect from rain, condensation, contamination, snow, and freezing until sufficiently cured for exterior exposure.
    - Relative humidity should be no more than 85 percent.
    - The temperature of the surface being painted should be 5 degrees F or greater than the temperature of the dew point.
    - Air and surface temperature should generally be between 50 and 100 degrees F.
- Mixing and thinning – the PDS will include mixing instructions. These may be mandated by a project specification and should be followed exactly as directed by the manufacturer. Typical requirements include a high-shear mixing device and no partial proportioning of paint kits. Thinners shall be as indicated by the manufacturer.
- Coating Thickness – Coating Dry Film Thickness (DFT) is a critical design factor for adequate coverage and good performance. The project specification typically contains a minimum and maximum DFT range. The Wet Film Thickness (WFT) can be estimated with a notch gauge and is the only means for assessing thickness of Calcium Sulfonate Alkyd (CSA) materials (due to softness of the material). Note that WFT and DFT may be determined using the percent volume solids provided on Product Data Sheets (PDS).

- Coverage – Any skips, missed spots, or small holes are all areas where the coating system will be ineffective. The best tool for a coverage check is a detailed visual inspection using sufficient light and an inspection mirror. Coating specifications typically require contrasting coating colors to aid inspection for complete coverage.
- Recoat times – The coating material will require a minimum amount of time (that varies with ambient conditions) before any additional coating may be applied. The coating may also have a maximum time that should not be exceeded before additional coating is applied. This is called the re-coat window and is critical to the adhesion of various coats and performance of the system.

The entire cleaning and painting process is cumulative in nature. The quality control checks, and often required quality assurance audits by the bridge owner, are necessary for detecting errors and ensuring the performance of the coating system. Minor errors that are not corrected early in the painting process can result in more significant re-work at a later time. Some oversights are catastrophic and show little signs when they are made. An example of this is applying coatings under adverse ambient conditions where the entire day's work would be affected. Good guidance on the criteria and practices for applying coatings can be found in SSPC-PA 1 "*Shop, Field, and Maintenance Painting of Steel*."

18.6.2 Substrate Conditions

The substrate should be prepared according to the project requirements. SSPC surface preparation standards address the visual criteria for cleanliness. Other criteria typically include:

- Roughness – Also called surface profile. This is a measure of the texture in a thoroughly cleaned surface (such as SP 10 abrasive blasting).
- Clean, dry and dust free are typical requirements for all levels of surface cleanliness. Coatings will adhere to sound substrates only, so removal of dust and debris is a critical step. Compressed air "blow down" is a common practice and should be completed with clean, oil and moisture free, compressed air.
- Feathering of edges – this is the practice of tapering the fractured edges of adhered remaining coatings. These conditions are common in preventive maintenance bridge painting. Edge preparation is only possible with hand/power tools or abrasive blasting. Water cleaning typically removes loose material but does not feather remaining coatings.

18.6.3 Application Method

The three principal methods of coating application are brush, roller, and spray. Selection of the best method for a particular project depends upon the specific material properties, how much area needs to be painted, the specific location of the areas to be painted and how fast the work can progress. Descriptions of the major application methods include:

- Brushes – Are natural or synthetic bristle and come in a variety of shapes and sizes. Are typically used for spot painting, touch-up, coating at obstructed spots or less accessible areas, and stripe coating. Production is slow, but paint waste is the least of all methods. Control of WFT depends on applicator skill.

- Rollers – Come in various materials and nap sizes. Faster than brushing for large, flat surfaces. Paint waste is minimal with roller application. Using a combination of brush and roller application is common practice. Control of WFT may be difficult with a roller.
- Spray – The most common method used on bridges to apply coating to large areas. Highest production rates possible. Paint waste may typically be 10 percent to 15 percent due to overspray and clean-up. Requires cleaning and maintenance of spray equipment. Spray painting is a line of sight process, so obstructed spots require spot brushing during spray painting (a recommended and common practice).

18.6.4 Coating Handling and Mixing

Liquid coatings are supplied in single component and multi-component kits for use. The most common multi-component kits contain a base portion and an activator (or catalyst) component. Each component will require mixing and the combined parts in a multi-component material will also require mixing as they are combined.

Most of the supplied containers are a combination of solid powders and liquid base ingredients, so mixing to obtain a uniform composition is especially critical. For multiple component coatings, each component shall be thoroughly mixed before combining and further mixing. An example of a coatings mixing area is shown in Figure 18.39, where paint kits, mixing containers, waste containers, and an airless paint spray pump are seen.

Figure 18.39 Mixing Area for Coatings (Courtesy of SSPC)

The coating manufacturer's written instructions for mixing shall always be followed. General guidance includes:

- Rotary power mixers with a high shear design are common (i.e., jiffy mixers)
- Do not shake industrial coatings
- Do not use spiral mud mixers
- Avoid whipping air bubbles into the material
- Mix according to the times/durations on a PDS
- Follow PDS instructions for induction or "sweat in" time (if applicable) for multi-component materials
- Follow PDS instructions for allowable pot life of multi-component materials

- Always check for complete uniformity of mixed materials (no solids at bottom of container)
- Zinc pigmented coatings typically require straining and constant agitation during mixing and application
- Solvent containing materials should be mixed with flammable material precautions

18.6.5 Brush and Roller Application

Brush and roller application are recommended for smaller areas and for thorough application to more textured surfaces. For PM bridge painting the combination of brush and roller are quite common. They effectively transfer the coating well to the bridge and "work" the material into the roughness of existing adhered corrosion or old coatings.

A common use of brush application is for "stripe painting" or applying an additional layer of coating to any non-flat surfaces, an example of which is shown in Figure 18.40. The stripe coat is only applied to edges, crevices, previously corroded spots, adhered corrosion, fasteners, or any other areas that are not smooth and uniform. This enhances the barrier protective ability of the coating without adding un-needed coating over large areas.

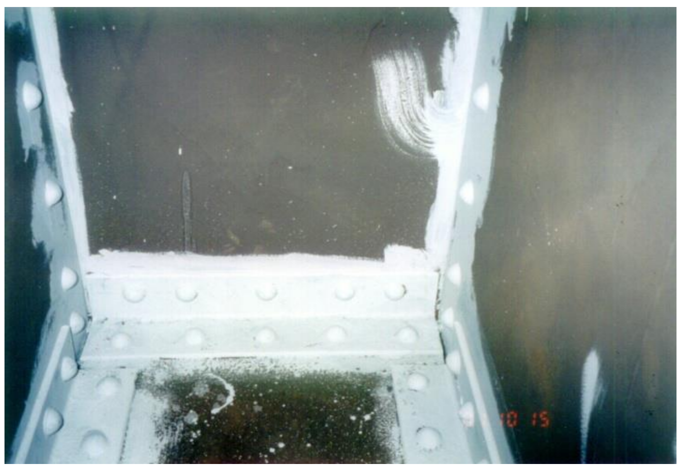

Figure 18.40 Stripe Coat Inside a Chord Member

There are some characteristics of brush and roller application that may be undesirable. These include the potential for brush marks (more common with higher solids materials) or for roller nap residue to remain in the film.

18.6.6 Spray Painting

Spray application is the process of atomizing the coating in the air and projecting it to the surface. There are many methods of spray application including:

- Conventional (air) spray – uses compressed air to atomize and propel the coating. It has very good film control, poor transfer efficiency, and is the slowest of the spray methods.
- Airless spray – uses very high hydraulic pressure to force the coating through an orifice that creates a spray pattern. This is the highest production method of paint application. Control is reduced because the spray is either on or off. A wide range of pressure capacities and tip (orifice) sizes are available. This is the method most often used for industrial and bridge spray painting (see Figure 18.41 and Figure 18.42).

- Air-assisted airless spray – is a variation of airless spray with enhanced application control. Not common for bridge painting.
- High-Volume, Low-Pressure (HVLP) spray – is a variation of conventional air spray that uses lower air pressure and reduces bounce back. Transfer efficiency is improved over conventional spray. Not common for bridge painting.
- Plural component spray – is specialized equipment for the application of very fast reacting 2-component coatings. Traditional mixing and application with an airless sprayer would result in curing of the material in the equipment. The equipment proportions and pumps the coating components separately, then mixes them very near the spray gun or in the spray pattern. This is not common equipment for bridge painting.

Figure 18.41 Airless Spray Application

Figure 18.42 Airless Spray Application on a Bridge Project

The major advantages of spray painting are speed and uniformity of application. The best looking coatings are spray applied.

The major drawbacks are less efficient transfer of coating to the surface, applicator training is required, and spray painting must be supplemented with a brush for any surfaces out of the line of sight of the spray gun. Cleaning and maintenance of spray equipment is also required.

18.6.7 Coating Touch-up and Repair

The painting process includes many steps. Before final acceptance a thorough inspection should be completed by the workers, supervisors, and inspectors. Typically there are visual spots of missing paint or spots that do not fully conform to project specifications. Typical repair areas include any spot where rigging was attached to the bridge, tie-in locations between contained areas, spots that are difficult for workers to see, or other spots identified through inspections.

The methods used for preventive maintenance bridge spot painting are ideal for touch-up and repair of recently applied coatings systems. This incorporates spot preparation with power tools (feathers the repair spot well with surrounding coating) and brush application of the required number of coats.

Figure 18.43 exemplifies the importance of these procedures. This bridge was pressure washed and spray painted with 2 coats of urethane coating. The spot shown in Figure 18.43 has rough edges of adhered existing coating that were spray painted without attention to application from an upward direction. The result is corrosion at the edges of the existing paint because of incomplete coverage.

Figure 18.43 Close-Up Area on Bridge Showing Degradation from Poor Painting Practice

Good practices, workmanship, and attention to detail in preventive maintenance bridge painting will ensure the coating systems perform as expected.

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