Chapter 10.5
Maintenance Painting Programs

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Introduction

It is seldom that coating system components break down uniformly over a structure. By routinely evaluating the condition of coatings and designing and performing remedial actions in a planned fashion, it is often feasible to keep a coating system working to provide cost-effective corrosion protection and desired aesthetic features long after initial signs of degradation. This chapter describes the elements of a maintenance painting program—when to start and how to accomplish the steps. Other chapters of this book address maintenance painting issues specific to various industries.

Maintenance painting is defined in broad terms as all painting on industrial structures conducted for protection or aesthetics or as any coating work conducted subsequent to the coating work associated with construction to ensure continuous protection of coated surfaces.[1] Both of these definitions are used throughout this chapter.

According to the second definition, any coating work after the initial coating is maintenance coating; however, there are two distinctly different situations that may be encountered, each requiring different techniques:

- Existing coating system is considered to have served its useful life and should be removed to bare metal
- Existing coating system is performing its function to a significant degree, but requires either spot (localized) repair or spot repair and overcoating to extend its useful life. The situation where the existing coating is to be removed to bare metal is relatively simple to design in that the selection of surface preparation and coating system can be made without the constraints of having to respect the requirements of the existing coating system. Much is written on selecting surface preparation and coating systems for this situation, and it generally involves matching the coating system to the service conditions to be encountered, and then selecting the surface preparation to complement the coating system selection.

The remainder of this chapter will address the situation in which it is determined that spot repair or spot repair and overcoating may be economically feasible.

Why Maintenance Painting Might Be Valuable

The typical exterior protective coating system serves at least two primary functions: corrosion protection and aesthetics.

In the industry-standard zinc-rich epoxy, epoxy, aliphatic polyurethane coating system, the first two coats provide corrosion protection for the steel substrate, and since the epoxy is not resistant to UV radiation from sunlight, the aliphatic topcoat provides both protection of the underlying epoxy coats and aesthetic features (color and gloss).

There are many formulations of polyurethane and other UV resistant topcoat materials, and even though they are significantly more resistant to UV radiation than epoxies, all organic coating materials will eventually suffer from sunlight exposure and require replacement or "rejuvenation," which might consist of a simple overcoat. Likewise, many combinations of circumstances can adversely affect the corrosion protection coats, including damp or wet conditions, steel surface contaminants, daily and seasonal thermal cycling, and strain from structural loading/unloading.

In an ideal situation, the corrosion protection coats and the aesthetic/protective topcoats would all fail simultaneously, after a significant number of years of service. This situation does not occur very often, especially since most UV topcoat materials are not capable of providing suitable protection for the anticipated lifespan of the epoxy corrosion protection coats. Typical behavior will find that the topcoat may be replaced one to three times before the corrosion protection requires replacement. Even so, it is likely that some corrosion protection will fail prematurely in small areas and require treatment.

As most coatings have finite life-spans, it periodically becomes necessary to either rejuvenate the coating system or replace it. Rejuvenation can involve any combination of spot repair and overcoating to restore damaged areas to an acceptable condition and provide additional years of protection from any combination of sunlight, water, or chemical intrusion. Although coatings are sometimes replaced for aesthetic purposes only, and some are replaced on a fixed schedule, such actions are unlikely to be cost effective, due to the many variables involved in determining the useful life of a coating system. It is highly unlikely that the useful life of any coating system can be predicted with any accuracy, therefore, a methodology for identifying the specific needs of a coating system in service is required.

Because the cost of surface preparation for painting can easily exceed the cost of coating materials and coating application, any corrective action that does not require significant preparation to bare metal may be cost effective. To achieve the most timely and cost-effective actions, maintenance painting must be planned and accomplished systematically, using the latest available technologies. There are many examples of dramatic coating failures resulting from good intentions that were improperly planned or executed. The most notable failures are those caused by coating incompatibility related to:

- Differential coefficients of linear expansion between coats
- Attack of topcoat solvent on undercoat
- Limited adhesion between coats or to substrate

Early coating failures result in double payment, in that the service life extension that was recently executed is not realized, and the premature failure probably necessitates additional surface preparation and coating application to correct the failure. Such a failure is often addressed by complete removal because the owner does not want to risk further premature failure.

When viewed from a risk-management perspective, any maintenance effort other than complete removal and replacement seems to carry some additional risks over those of normal coating preparation and application. The risk of incompatibility of repair and existing coating is an added factor. Even though some believe that this risk is not manageable, proper knowledge of coatings may reduce these risks to manageable levels. This allows for cost-effective maintenance painting with relatively low risks but does require an understanding of the properties and the condition of the existing coating system.

Personnel concerned with the protection of structures and equipment by coatings often ask the following questions:

- How can I best develop a program for maintaining coating protection for different plant structures or facilities?
- How can I define the point of failure of the existing coating system?
- How can I determine whether localized repair of damaged substrate and coating or substrate repair and total coating replacement is the better choice?
- What coatings systems should be used in each case?
- When is the best time to take the necessary actions?

SSPC PA Guide 5, currently under revision, provides a methodology for planning and executing a maintenance painting program for steel structures, and discussion in this chapter is based on the general outline of the revised document.[2] While SSPC PA Guide 5 is specifically limited to steel substrates, the processes outlined in it are applicable to many other substrates, including concrete. The significant differences in the maintenance practices are in surface preparation and coating selection.

Maintenance painting programs can be developed for a plant, a government facility, a group of structures, or a single structure. There is efficiency inherent in managing a large facility or group of facilities over managing a small facility, as inspections are more cost effective for larger facilities, and contracting is more efficient for larger projects.

The methodology outlined in SSPC PA Guide 5 is:

- Perform a condition assessment survey
- Determine necessary corrective action
- Evaluate economics of available options
- Establish procedures for corrective action
- Execute corrective action and follow-up activities

Condition Assessment Surveys

Specific information required for developing a painting program for existing structures is generally acquired by a survey that is sufficiently detailed to provide for the appropriate decisions. Surveys range from simple walk-through inspections, intended to establish general painting needs, to detailed itemizations of painted components with an assessment of the type and condition of coatings present on each. The varying levels of surveys, when used in an iterative process of identifying defects and prescribing priorities, provide an efficient and effective methodology for developing a maintenance painting plan.

While the costs of implementing a condition assessment survey program can be significant, there may be viable options that make use of existing inspection assets, particularly for initial screening, as described in the general overview survey here. Reference 6 describes the use of federally mandated bridge safety inspections to collect data on coating condition. Bridge safety inspectors are given visual guides for identifying specific coating and corrosion-related problems, and are provided minimal training in identifying and reporting those problems for further evaluation. The incremental cost of collecting this data is very low compared to a specific inspection for that purpose, making full use of the mobilization and demobilization costs of the safety inspections.

In other cases where operators are routinely working in or inspecting large portions of a facility or plant, simply making operators aware of the signs of both sound and stressed coatings, and how to report appropriate deficiencies, has proven effective in providing initial screening for coating maintenance needs.

This discussion specifically addresses a plant survey, yet the principles are equally applicable to individual components of a structure, complete structures, and multiple structures. The three levels of surveys are general overview survey, detailed visual survey, and physical inspection survey.

General Overview Survey

A general overview survey consists of a visual assessment of the overall conditions of substrates and coatings on plant structures. It is a relatively fast and inexpensive method to prepare general information on the overall conditions and establish times when maintenance actions can be anticipated. A simple numerical rating system (e.g., priority ratings of 1 through 5 as shown in **Table 1**) can establish work priorities if limited funds do not permit all of the desired work to be done. This method may also provide data for establishing a logical approach to subdividing the facilities into smaller units for a systematic collection of data in more detail.

Table 1. Priority Rating System for Maintenance Painting.

Rating	Condition Evaluation
1	Slight or no damage to coating or substrate, requiring no maintenance in near future.
2	Slight localized damage to coating or substrate, requiring localized maintenance within one year.
3	Moderate localized damage to coating or substrate, requiring localized maintenance within one year.
4	Thin coating from erosion or application, requiring additional thickness for corrosion protection, often with slight or moderate localized coating or substrate damage, requiring overcoating within one year. This may also identify aesthetic requirements.
5	Extensive coating or substrate damage, requiring total coating replacement, often with substrate repair.

Detailed Visual Survey

In a detailed visual survey, facilities are subdivided into smaller units in order to obtain more information about individual components. Alternatively, these components can be subdivisions related to function (e.g., architectural, electrical, mechanical, etc.). This survey level provides more detailed data.

The types and extents of substrate and coating deterioration are made in accordance with industry standards. Definitions for defects are found in Reference 1 and depicted pictorially in References 3, 4, and 5. The latter three references can be used very effectively to identify types of defects. Additional assistance can be found in the chapter of this book that discusses coating failures and failure analysis.

The extent (percent) of defects in localized areas can be determined using SSPC VIS 2.[7] A series of pictures visually depicts different levels of deterioration for more precise estimation. The general distribution of defects in large areas can be determined using Reference 8, which presents a series of pictures of known distributions levels of deterioration.

It should be noted that natural deterioration occurs more rapidly at edges and other irregular areas where cleaning and coating is more difficult or in localized areas where the environmental forces are more severe. Exterior water traps (where rain water collects) present an especially severe environment.

Physical Inspection Survey

In a physical inspection survey, the individual components are further subdivided, and actual physical tests are conducted on the coatings, notably dry film thickness and adhesion. These values are critical in establishing whether the existing coating has adequate properties for localized repair rather than total replacement.

Deterioration including film erosion, blistering, rusting, chalking, checking, cracking, peeling, flaking, and dirt and mildew accumulation should be identified and quantified using ASTM rating standards. In some cases, it may be necessary to inspect the surface for contaminants including grease, oil, and soluble salts. The inspection should determine the types, quantities, and locations of contaminants.

If appearance is important, the extent of color fading, discoloration, loss of gloss, etc., should be measured using standard ASTM procedures. Should the generic type of the existing coating be unknown, it may be necessary to submit a sample for analysis to find a compatible repair material.[9] When the composition of the existing coating is not known, it may be necessary to submit a sample for analysis to determine if any constituents (e.g., lead, chromium, cadmium, PCB, etc.) will require actions for health, safety, or environmental compliance.

When pitting corrosion is present, measuring pit depth may be very important. Ultrasonic measurements of substrate thickness are sometimes performed on steel that is subject to severe general or localized corrosion and subsequent loss of cross section. These inspections are performed because severe localized or general corrosion may affect structural integrity or the intended function of the structure, such as containing a fluid. Pit shape and aspect ratio also have a bearing on the type of surface preparation that will be required.

A physical inspection survey provides the necessary data that defines the work requirements for a specification. The additional expense for a detailed survey is well justified by minimizing risks associated with maintenance painting.

Performing a Hazardous Content Assessment

If the composition of the coating system is unknown, then samples should be submitted for laboratory evaluation for hazardous materials such as lead, chromium, cadmium, polychlorinated biphenyls (PCBs), and other materials controlled by federal, state, or local laws or regulations. The existence of hazardous materials may be a major factor in determining both short and long-term strategies for management.

Determine Corrective Action Required

Analysis of Survey Data

The condition of the existing coating system, which may vary from area to area, and component to component, will dictate the approach that is required to restore functionality. The survey data should be collected systematically using a standard printed form in a complete and quantitative manner to obtain sufficient data for reliable decisions. There are seldom too much data available.

While it would seem appropriate to establish deterioration levels at which maintenance work should be undertaken (e.g., 10% substrate or coating deterioration), there are many other factors that affect decision making. Those related to the coating survey are discussed here.

Type and Extent of Substrate Damage and Coating Deterioration. The nature of any corrosion (e.g., uniform, pitting, filiform, etc.) is very important in determining the best corrective actions. Thus, pitting corrosion may be critical to a storage tank, if penetration of a steel wall or floor is threatened.

Concrete deterioration should be described separately. Conditions such as efflorescence, laitance, cracking, and spalling, and appropriate corrective actions for each, are described in Reference 10.

The nature of the coating deterioration is important in order to determine the causes and thus appropriate corrective actions. Reference 1 describes causes and corrective actions for coating deterioration.

Judging the extent of damage to substrates and coating is critical in determining whether spot repair of substrate and coating or more extensive substrate repair and a total replacement of coating is more appropriate. To determine the total extent of coating deterioration, it may be necessary to scrape with a dull putty knife to expose all of the damaged areas. Visually sound coating may have poor adhesion to its substrate.

Distribution of Substrate and Coating Deterioration. The distribution of substrate and coating damage can determine whether only localized damage repair will be necessary. For example, at a coastal airfield at a tropical location, all of the metal corrosion and coating deterioration on a group of hangars was limited to the exposure facing the ocean.

Loss of Coating Function. Some coatings have functions other than substrate protection. These include non-slip, reflective, or electrical-conductive properties. If these properties have been significantly reduced, it may be necessary to restore them by total repainting.

Rate of Increase of Deterioration. An important part of a deterioration control program is the periodic survey of the component structures. (Navy shore facilities receive annual condition inspections.) By establishing the current rate of deterioration, the likelihood of further significant deterioration with deferred maintenance can be deduced.

Type of Coating. The type of coating is important in determining compatibility with the system selected for localized repair as well as the type of surface preparation necessary prior to overcoating. All localized-repair coatings must not only cover the damaged areas but also overlap onto the sound existing coating.

If compatibility cannot be established from historical records, a test patch of the proposed system may be applied to the existing coating to establish this. Additionally, a laboratory technique, Fourier Transform Infrared Spectroscopy (FTIR), is frequently used to determine the generic coating type. This requires only a tiny sample paint chip to identify the coating type, and is available at a nominal price.

Adhesion. Coatings with limited adhesion, either to their substrates or between coats, are likely to have their adhesion further reduced. Thus, topcoating may actually accelerate total coating deterioration. This situation is frequently seen on newly overcoated structures, where the coating comes off in sheets.

ASTM test methods provide for both qualitative and quantitative methods of testing adhesion. Adhesion generally becomes more of an issue as the thickness of the coating system increases, although intercoat delamination due to application deficiencies can occur at any thickness. *SSPC TU 3: Overcoating* discusses the significance of adhesion testing in maintenance overcoating.

Film Thickness. It is important to determine if the existing coating system is sufficiently thick to provide the required barrier protection. Unusual thinness could be a result of improper application, or from chalking erosion or some other mechanism that has significantly reduced the film thicknesses of the existing coatings. This may, in turn, significantly reduce the barrier protection of the substrate. It is also important to know if there is excess coating thickness, as this can cause premature failure if the thickness overstresses the adhesion to the substrate, or between coats. SSPC TU 3, *Overcoating* discusses the significance of high film thickness in maintenance overcoating. SSPC PA 2 describes a standard process of determining the coating thickness on a structure.[11]

Appearance. Coating appearance may be an important factor in selecting the types of corrective actions. This is especially true for structures in public view and where worker morale is important. Localized repair may produce an unsightly patchy appearance. A complete finish coat may be applied to remove this.

Hazardous Materials in Paint. There are numerous issues involved in evaluating coatings containing hazardous materials, most of which are detailed in References 12 and 13. While deciding how to treat coatings containing hazardous materials, it may be advantageous to consider that the hazardous materials may be an integral part of the corrosion protection mechanism (e.g., inhibiting effects of lead pigments). Depending on the condition of the coating system, it may be possible to achieve additional use from that corrosion protection mechanism through timely and appropriate maintenance.

Other Factors Affecting Decisions

Unfortunately, there are some factors unrelated to survey data that affect the choice of maintenance actions. Some of these factors are described here.

Limited Funding. Maintenance funds may not be available in sufficient quantity to cover all of the needed work. In these cases, work should be prioritized to maximize the overall economic benefit. To avoid funding shortfalls, take surveys periodically, so that future funding requirements can be determined and requested to meet anticipated maintenance requirements in future years.

Risk of Deferred Maintenance. If needed repairs are deferred, then it is possible that future coating repairs will need to be more extensive.[14] In extreme cases, deferred maintenance may lead to severe substrate damage and subsequent loss of structural functionality. This may result in significantly increased life-cycle maintenance costs and other unintended economic losses from things like environmental contamination, service outages, and various emergency repairs.

Effects of Maintenance Actions on Plant Operations. Maintenance work of any kind is likely to affect continuing operations. It may be necessary to conduct the maintenance work at night, on weekends, or at a time of total operational shut down. Obviously, interference with plant operations must be minimized.

At times of total operational shut down, other maintenance work is often undertaken as well. In such cases, schedules must be established to minimize interference between trades.

In some instances, the indirect cost of an outage far exceeds the cost of the maintenance painting itself. This is especially true of systems that produce large revenue streams, such as processing, manufacturing, transportation, and power production equipment. Here coating repairs are sometimes scheduled to coincide with other repairs.

Sometimes the scheduled outage is short lived and coating repairs must be rapid, sacrificing thoroughness for speed. This may be an economical approach where periodic maintenance outages are fairly frequent, such as in paper plants. In other situations it is more economical to ensure that coating repair life is as long as possible to minimize the frequency of repair outages. This is often true for power generating hydro turbines and chemical process tanks.

Contamination of Products. If substrate and/or coating deterioration is causing contamination of products, immediate corrective action is usually necessary. This is particularly true for such industries as food processing, pharmaceuticals, chemical production, electronics manufacturing, and sophisticated electronic instrumentation.

Maintenance Painting Strategies

There are four approaches to maintaining a structure in satisfactory condition, generally in the order of increasing cost:

- **Cleaning—**Pressure washing or steam cleaning may satisfactorily restore structure to an acceptable condition.
- **Spot repair—**Repairing areas with localized damage but otherwise sound paint should be done before the damage becomes more extensive.
- **Localized spot repair—**Combine localized spot repair with complete topcoat refinishing only when localized repair would produce an unacceptable aesthetic finish or where localized repairs plus added film build are needed to repair eroded coating.
- **Complete removal—**Remove all existing paint and then totally repaint only when the damage is so extensive that spot repair or overcoating are not economical.

These strategies may be used individually or in combination, based on the requirements of the specific structures. The objective is to provide complete corrosion protection and suitable aesthetics with the least amount of paint, and the least number of painting/repair/repainting evolutions. This requires that each situation be considered on its merits.

Economics of Maintenance Painting Options

Regardless of the needs of the coating system, economics generally is the most important variable, and it frequently dictates the characteristics of the chosen action. Periodic structural condition assessments should be performed in advance of the budgeting process; however, even that does not guarantee that necessary funds will be available when needed.

The fact that properly executed maintenance painting plans will provide a basis for evaluating all viable alternatives is advantageous to the owner, and should not be overlooked as a valuable tool for both protective coating maintenance in both routine and “lean” times.

Establishing Procedures for Corrective Action

As a result of surveys and analysis, deficiencies should be identified and the need for corrective action should be apparent. The next step is to match potential solutions to the deficiencies in a manner that is both achievable by the prospective workforce and addresses the deficiencies appropriately.

Coating Selection

Numerous factors may require attention, such as compatibility with any existing coatings, exposure environment, surface preparation and application conditions, surface preparation limitations, and health, safety, or environmental requirements.

Surface Preparation Method and Coating Materials for Complete Recoat Strategy

This is generally the easiest maintenance strategy in terms of selecting surface preparation methods and coatings, since compatibility with existing coatings is not involved, and the surface preparation requirements can be properly matched to those of the chosen coating system. Much guidance exists on selecting these items for specific structures and service and work conditions, including numerous chapters of this book.

Surface Preparation Method(s) and Coating Materials for Spot Repair or Spot Repair and Overcoat Strategy

This is a matter of matching the needs of the existing coating system with compatible and suitable coatings that can be applied under the specific field conditions using appropriate and achievable surface preparation. The process can become a multi-dimensional equation and it is frequent that sacrifices must be made to accommodate certain limitations.

Surface preparation requirements may also vary from area to area, or component to component, and should be chosen to provide the required surface conditions and a useful repair but not be so onerous as to be impossible or impractical to achieve.

Although abrasive blasting is a recognized surface preparation method for bare steel surfaces, the use of abrasive blasting for spot repairs may not be suitable in all cases, due to controls on dust and grit, or the potential for damage to surrounding coatings, equipment, or other sensitive parts or surfaces. Spot repairs, particularly where there is a paint build-up, will generally require feathering the old paint to provide for a transition to the new paint.

Select Method of Work Accomplishment

There are numerous methods of accomplishing coating work, and owners generally have one or more methods that suit their needs. The first decision is whether to perform the work in-house or by contract, and if by contract, which form of contract, and so on. This is typically a decision that the owner makes after evaluating the needs of the coating work with respect to in-house capabilities, if any.

Prepare Specifications and Execute Work

Reference 15 provides guidance for preparing protective coating specifications for atmospheric service. An extremely important part of any coating project is competent inspection. There are multiple sources of such inspection, including those certified by the National Association of Corrosion Engineers International (NACE) under the Coating Inspection Program (CIP), and from inspection companies certified by SSPC to the requirements of SSPC QP 5.[16] It is most important to try to maintain inspector independence from the contractor operations to avoid undue influence on the inspection results.

If an extended warranty is desired, the precise details of that warranty should be delineated, such as term, identification of warrantor (contractor, manufacturer, other), definition of failure, and allowance for manufacturer/contractor to inspect at regular intervals and make appropriate repairs.

It is quite typical for an owner to rely heavily, even to the point of eliminating the owner's inspection, on a warranty that is subsequently found to be unenforceable due to the manner is which it was written. This situation significantly increases the life-cycle cost of coating maintenance.

Follow-up Actions

Regular inspections are an important part of any maintenance program. All inspections should be documented for warranty and latent-defect purposes. An inspection should be made prior to the end of the warranty, if only a one-year general warranty was required, or at appropriate intervals if an extended warranty was required. The American Waterworks Association, for instance, recommends that water storage facilities be inspected at an interval not exceeding 3 years, for safety, sanitation, and cost-effective maintenance.[17] Guidance is provided for inspecting the coating system.

Life-cycle costs may be significantly reduced by identifying and implementing preventive measures to reduce stresses on coatings, such as timely removal of chemical spills, deicing salts, etc.

Summary

Generally speaking, it is easier to design for maintenance coating by requiring complete removal of all coating material to bare steel rather than evaluating the existing coating system for repair and/or overcoating. However, this is often the most expensive option. Other options that might be much more cost-effective will require competent evaluation.

Yet such evaluations are frequently overshadowed by the savings when considered in a life-cycle cost analysis. By implementing a complete coating maintenance program that includes routine inspections and appropriate evaluations, an owner may be able to significantly reduce the life-cycle costs of corrosion protection and functional aesthetics in addressing the specific needs of coating systems as they occur.

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