

12.8. COATING INSPECTION AND TESTING

Tremendous financial losses may be incurred as a result of premature failure of paints and coatings. Costs of such failures often far outweigh the initial costs of painting because of the complexity of repairs and the liabilities associated with downtime to correct the problems. It is therefore important to choose the right coating system for an application and in order to do so coating operations of most any size should have some type of meaningful test program. Such programs are the only objective basis on which to make decisions relating to future work. These programs should evaluate materials, surface preparation, application, and inspection procedures.

It is also important to investigate coating failures when they do occur since this may provide critical clues on what should be corrected to avoid recurring problems. These investigations may be done in-house or contracted to the many consulting firms available to help those without the necessary personnel. A similar team of experts should also carry out condition surveys of a structure or a facility prior to beginning a protective coatings project by considering the following factors³:

- Determine the condition of the substrate
- Determine the condition of the existing protective coating system
- Identify the environment in which the protective coating systems will be required to protect the substrate
- Estimate the surface area to be protected with coating systems

A proper survey requires dividing the structure or facility into easily defined parts, zones, or sections before proceeding in a methodical fashion to establish exactly what has happened to the structures and the coating systems since its last painting program.

12.8.1. Condition of the Substrate

Determining the condition of the substrate is a critical part of any condition survey. Coatings can mask some rather severe corrosion for a period of time. Corrosion under insulation (CUI) is a particular example of the development of a very severe environment that may go unnoticed until a catastrophic leak occurs. Contaminants from process or environmental upsets can be difficult to find from a purely visual standpoint. The underlying substrate must be accessed in some way. If it is under insulation, strategically placed inspection windows may need to be cut into the insulation or its cladding so proper inspection or monitoring can be performed on the substrate to determine its true state.

If it is under an old protective coating system, strategically located sections of the coating system may need to be removed to provide access to the substrate for the same types of tests. Adhesion may need to be verified by following either ASTM D3359¹⁸ or ASTM D4541.¹⁹ If it is visually rusty, the extent of the rust and the depth of the pitting must be established. This can be accomplished using the SSPC-VIS 2 Guide²⁰ that provides comparative photographs in addition to the rust grades shown in [Table 12.14](#).

Table 12.14 Guide to SSPC-VIS 2: Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces

Rust grades	Description	Standard
10	No rusting or less than 0.01% of surface rusted	Unnecessary
9	Minute rusting, less than 0.03% of surface rusted	No. 9
8	Few isolated rust spots, less 0.1% of surface rusted	No. 8
7	Less than 0.3% of surface rusted	No. 7
6	Extensive spots, but less than 1% of surface rusted	No. 6
5	Rusting to the extent of 3% of surface rusted	No. 5
4	Rusting to the extent of 10% of surface rusted	No. 4
3	Approximately 1/6 of surface rusted	No. 3
2	Approximately 1/3 of surface rusted	No. 2
1	Approximately 1/2 of surface rusted	No. 1
0	Approximately 100% of surface rusted	Unnecessary

Blisters should be identified using the ASTM D714²¹ in which blisters are categorized by size, shape, location, and density. The standard has a set of photographs depicting blister sizes from No. 2, which is the largest size, to No. 8, which is the smallest. The photographs also depict the density of the blisters as few, medium, medium dense, and dense.

It is often critical to determine how much of the original wall thickness of the metal has been lost on visually rusty surfaces. This can be done with a number of instruments. A portable A-scan ultrasonic thickness gauge may be quite useful to determine and store in memory the remaining wall thickness at any given point of a structure. B-scan-type ultrasonic thickness gauges can measure and plot wall thickness on complete structures or sections of structures from which isolated corrosion pits, vessel corrosion rate, general wall thickness, and visual presentation of the section being measured can be produced.

If it is a tank or other vessel that has contained liquids, the type and temperature of the liquids must be identified. The substrate must then be analyzed for contaminants normally associated with those liquids. Coatings that have been otherwise properly applied over steel that appeared to be perfectly clean have failed due to the lack of identification and removal of such contaminants.

12.8.2. Condition of the Existing Coating System

Historical records of a coating system when it was first applied, as well as during periodic annual surveys, can provide a good indication of the relative life left in the coating system, particularly when compared with the life expectancy charts published by the Society for Protective Coatings (SSPC). These life expectancy charts are categorized both by the generic type of coating and the environment to which it is exposed. For example, epoxy resins are known to be fragile to sunlight UV rays that can degrade them to a powdery film easily removed by wind and rain, eventually exposing underlying coats or the substrate. By checking the historical records, the remaining life of a coating system can be estimated fairly well.

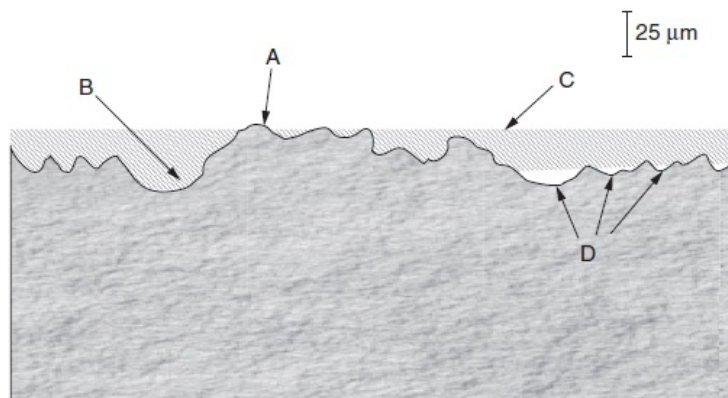
Simple visual scans do provide a broad indication of the areas of a structure that are deteriorating at a faster rate. The appearance of red iron oxide pigmented primers through the remaining colored topcoats is a very convincing indication of the need for immediate corrective action at the lowest maintenance cost of any maintenance practice. Unless corrosion is visually seen, a simple water jet washing with fresh water, and a new topcoat of the same generic coating previously used, or of one that is compatible with the previous coating system, can extend the life of the current system by a few years.

If only small isolated areas of the structure show corrosion while the majority of the structure appears sound, it can prompt the maintenance engineer to schedule a spot blast or power tool white metal cleaning of the rusty spots, a spot prime with an inhibitive primer, and a new refresher coat of the topcoat of the system. Again, the economy comes in avoiding a total breakdown of the protective coating system, which would require total removal and replacement of the entire system. That is the most costly of all maintenance programs.

12.8.3. Coating Inspection

Characteristics of a properly prepared surface may include specification of a surface profile in terms of mils depth, as well as other criteria. This is important in some instances, especially when a thin film coating is to be applied. If the surface profile is such that an inadequate thickness of coating is deposited on the peaks, or the coating bridges the valley (Fig. 12.16), a coating failure may follow, or, at best, a greater volume of coating will be required for adequate coverage of the peaks than would be the case if the profile was of proper depth and spacing.

Figure 12.16 Diagram showing cross section through a base which has been centrifugally blasted with G-50 grit (fine) and then coated. Note that peak A extends above coating surface, B indicates a valley, and C indicates coating surface. Coating fails first at peak A, while D indicates “bridging” of valleys where coating failure may start.



Gauges and equipment are available for checking surface profiles (Figs. 12.17–12.22). In the hands of an experienced person, a good statistical estimate can be made in a short time of a properly prepared surface. Profilometers (useful laboratory instruments) give exact information on the profile, but it is difficult and usually impossible to use them in the field.

Figure 12.17 Keane-Tator surface profile comparator disc. (Courtesy of KTA-Tator, Inc.)

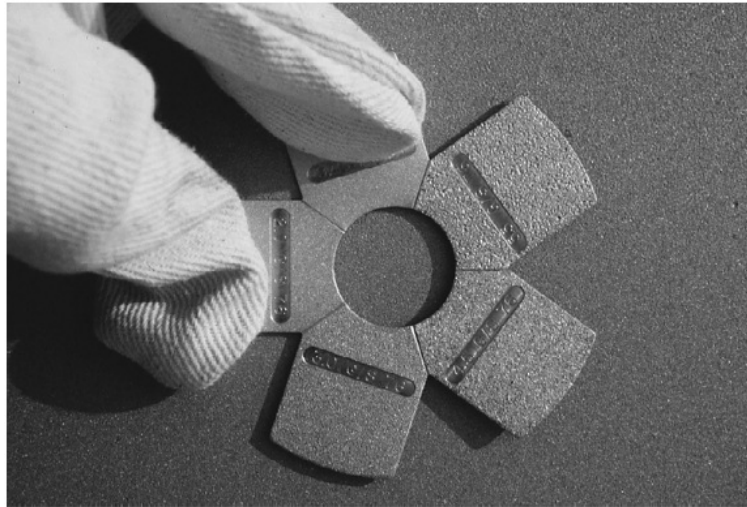


Figure 12.18 Use of Keane-Tator surface profile comparator method for measurement of surface profile depth. (Courtesy of KTA-Tator, Inc.)



Figure 12.19 Measuring surface profile depth using depth micrometer. (Courtesy of KTA-Tator, Inc.)



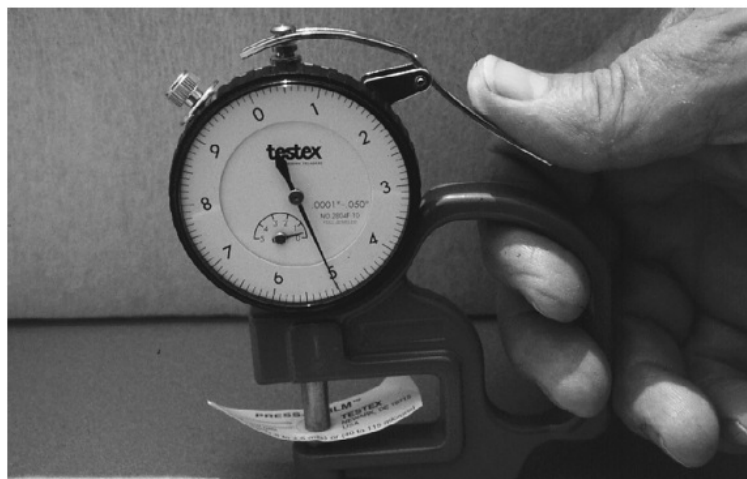
Figure 12.20 Testex Press-O-Film replica tape surface profile measurement equipment. (Courtesy of KTA-Tator, Inc.)



Figure 12.21 Burnishing Testex Press-O-Film replica tape. (Courtesy of KTA-Tator, Inc.)



Figure 12.22 Measuring surface profile depth using Testex micrometer. (Courtesy of KTA-Tator, Inc.)



Wet film gauging: Thickness of a wet film can be determined by any of several gauges which consist of a series of calibrated indentations along the edge of a handheld ruler (Fig. 12.23). Probable thickness of the dried film can be calculated if solids content by volume is known.

Figure 12.23 Notch-type wet film thickness gauges (top: stainless steel; bottom: aluminum).
(Courtesy of KTA-Tator, Inc.)



Dry film gauging: Electrical and magnetic nondestructive and visual destructive equipment for determining thickness are described in several places (Figs. 12.24 and 12.25).

Figure 12.24 Magnetic pull-off dry film thickness measurement gauge. (Courtesy of KTA-Tator, Inc.)



Figure 12.25 Electronic dry film thickness measurement gauge. (Courtesy of KTA-Tator, Inc.)



Coverage completeness: Coverage completeness can be checked by using different colors of multiple coats or conductive and nonconductive coats.

Visual inspection: Visual inspection can be conducted with or without magnification. The Tooke gauge, which makes a diagonal cut through a coatings system to the substrate, permits measurement and identification of the coating layers under magnification (Figs. 12.26 and 12.27). These gauges are less commonly used because they are slower to operate, and create a cut through the film.

Figure 12.26 Tooke gauge. (Courtesy of KTA-Tator, Inc.)



Figure 12.27 Use of Tooke gage for measurement of paint layers. (Courtesy of KTA-Tator, Inc.)



12.8.4. Laboratory Testing

Whenever possible, standard test procedures and means of evaluation provided by organizations such as ASTM, NACE, or SSPC should be consulted and followed. Only in this manner can correlation with the results of other workers be established. SSPC and NACE certified coating/corrosion professionals are trained to investigate paint failures and know which analytical technique or investigation method may provide the most useful information.

For example, gas chromatography is excellent at detecting solvents, but would be of little use in determining why an alkyd resin failed. Another example is that only electrochemical impedance spectroscopy (EIS) and actual exposure tests can provide a distinction between storage-related problems and paint application/formulation problems when white rust is formed on painted galvanized steels. Traditional approaches cannot make such distinction. These insights could save unnecessary effort and expense, simply by selecting the right test.

The number and types of tests that can be conducted in the laboratory is almost limitless. [Table 12.15](#) lists some of the ASTM tests relevant to protective coatings. Because field testing of coatings is so costly in time, labor, and facilities, it has been the persistent aim of formulators, raw materials producers, and users of coatings to establish meaningful accelerated tests. These may involve a wide variety of comparatively simple, as well as highly sophisticated procedures.

Table 12.15 Coatings Tests and Methods Pertinent to Corrosion Protection

ASTM standard	Title
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B 117	Test Method of Salt Spray (Fog) Testing
B 368	Method for Copper Accelerated Acetic Acid-Salt Spray (Fog) Testing (CASS Test)
B 457	Test Method for Measurement of Impedance of Anodic Coatings on Aluminum
C 536	Test Method for Continuity of Coatings in Glassed Steel Equipment by Electrical Testing
C 743	Test Method for Continuity of Porcelain Enamel Coatings
D 522	Test Methods for Mandrel Bend Test of Attached Organic Coatings
D 523	Test Method for Specular Gloss
D 610	Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces
D 662	Test Method for Evaluating Degree of Erosion of Exterior Paints
D 714	Test Method for Evaluating Degree of Blistering of Paints
D 822	Practice for Conducting Tests on Paint and Related Coatings and Materials Using Filtered Open-Flame Carbon-Arc Light and Water Exposure Apparatus
D 823	Practices for Producing Films of Uniform Thickness of Paint, Varnish, Lacquer, and Related Products on Test Panels
D 870	Practice for Testing Water Resistance of Coatings Using Water Immersion
D 968	Test Methods for Abrasion Resistance of Organic Coatings by Falling Abrasive
D 1014	Test Method for Conducting Exterior Exposure Tests of Paints on Steel
D 1186	Test Method for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base
D 1400	Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base
D 1567	Test Method for Testing Detergent Cleaners for Evaluation of Corrosive Effects on Certain Porcelain Enamels
D 1653	Test Method for Water Vapor Transmission of Organic Coating Films
D 1654	Test Method for Evaluation of Painted or Coated Specimens Subject to Corrosive Environments
D 1735	Practice for Testing Water Resistance of Organic Coatings Using Water Fog Apparatus
D 2197	Test Methods for Adhesion of Coatings by Scrape Adhesion
D 2247	Practice for Testing Water Resistance of Coatings in 100% Relative Humidity
D 2248	Practice for Detergent Resistance of Organic Finishes
D 3258	Test Method for Porosity of Paint Films
D 3273	Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber
D 3276	Guide for Paint Inspectors (Metal Substrates)

D 3359	Test Methods for Measuring Adhesion by Tape Test
D 3361	Practice for Operating Light- and Water-Exposure Apparatus (Unfiltered Carbon-Arc Type) for Testing Paint, Varnish, Lacquer, and Related Products Using the Dew Cycle
D 3363	Test Method for Film Hardness by Pencil Test
D 4145	Test Method for Coating Flexibility of Prepainted Sheet
D 4585	Practice for Testing Water Resistance of Coatings Using Controlled Condensation
D 4587	Practice for Conducting Tests on Paint and Related Coatings and Materials Using a Fluorescent UV-Condensation Light- and Water-Exposure Apparatus
E 376	Practice for Measuring Coating Thickness by Magnetic-field or Eddy-Current (Electromagnetic) Test Methods
G 8	Test Method for Cathodic Disbonding of Pipeline Coatings
G 12	Test Method for Nondestructive Measurement of Film Thickness of Pipeline Coatings on Steel
G 42	Test Methods for Cathodic Disbonding of Pipeline Coatings Subjected to Elevated Temperatures
G 53	Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials
G 60	Method for Conducting Cyclic Humidity Tests
G 80	Test Method for Specific Cathodic Disbonding of Pipeline Coatings
G 84	Practice for Measurement of Time-of-Wetness on Surfaces Exposed to Wetting Conditions as in Atmospheric Testing
G 85	Practice for Modified Salt Spray (Fog) Testing
G 87	Practice for Conducting Moist SO ₂ Tests
G 90	Practice for Performing Accelerated Outdoor Weathering of Nonmetallic Materials Using Concentrated Natural Sunlight
G 92	Practice for Characterization of Atmospheric Test Sites

These tests can define certain characteristics of a coating system. This discrimination usually is specific to the type of accelerated test, and frequently does not indicate in advance how a given coating will perform in service. However, the tests are invaluable when developing coatings or appraising new concepts in coatings application or use.

General immersion tests: General immersion tests can be as simple as the standard saltwater immersion test for coatings to be used in the atmosphere, or as complicated as “cold wall” effect immersion tests for heavy coatings to be used constantly in immersion service. It is essential to reproduce the anticipated conditions of the field exposure as closely as possible when evaluating coatings for immersion service.

Salt spray testing: The salt spray test, which was originally designed to test coatings on metals, has been widely used to evaluate the resistance of metals to corrosion in marine service or on exposed shore locations.^{22,23} However, extensive experience has shown that, although salt spray tests yield results somewhat similar to those exposed in marine environments, they do not reproduce all the factors causing corrosion in marine service. Salt spray tests should thus be considered to be arbitrary performance tests and their validity dependent on the extent to which a correlation has been established between the results of the test and the behavior under expected conditions or service. Despite the current

widespread use of continuous salt-spray methods, their unrealistic simulation of outdoor environments is a serious shortcoming.

Cathodic protection exposures: One accelerated test involves subjecting the material to which the coating has been applied to various voltages of impressed current, often in excess of that normally required to achieve cathodic protection, with the aim of demonstrating the ability of the coatings to resist the disbonding effect of the cathodic current or to resist electroendosmosis (Fig. 12.28).

Figure 12.28 Laboratory setup to test for disbonding during the application of cathodic protection.
(Courtesy of Corrpro.)



Condensation apparatus: Relying on the known susceptibility of coatings to permeation by condensed water, a screening test is available in a laboratory-type cabinet which results in condensation of water on the painted surface. Disbonding of poorer coatings occurs.

Environmental test rooms: Environmental test rooms which permit various combinations of temperature, fogging, humidity levels, and shower effects to simulate rain can reproduce in an accelerated mode many of the factors present in an actual exposure. For the most part, these tests use small cut or machined specimens, but assemblies of simulated components and complete systems can also be tested as shown in Chap. 2 Fig. 2.24a and b.

12.8.5. Holiday Detection

Holidays are pinholes and voids in normally nonconductive organic coatings that allow current to pass through the protective coating to the metal base material. These discontinuities are usually not detectable with normal or even enhanced visual inspection techniques. A holiday detector will help to find coating defects by impressing an electrical voltage across the coating (Fig. 12.29). An electrode passes over the entire coating surface and as it crosses a defect, it gives off an electrical discharge, or spark, which signals the operator that a holiday has been detected. The operator can then mark the holiday for subsequent repair prior to acceptance.

Figure 12.29 High voltage holiday detector in use (a), low-voltage holiday detector (b), holiday testing with high voltage pulse DC holiday detector (c). (Courtesy of Tinker & Rasor.)



Holiday detectors must be selected for the thickness and type of coating being tested. Excessive voltage can stress or damage thin coatings if the detector has been set too high. Adherence to the manufacturer's instructions is recommended, including both the manufacturer of the coating and the manufacturer of the holiday detector. ASTM G62-07 Standard describes two test methods for holiday detection in pipeline coatings.

ASTM G62-0 Method A is designed to detect holidays such as pinholes and voids in thin-film coatings from 0.0254 to 0.254 mm in thickness using ordinary tap water and an applied voltage of less than 100 V DC. This method is effective on films up to 0.508 mm thickness if a wetting agent is used with the water and may be considered to be a nondestructive test because of the relatively low voltage. But Method A will not detect thin spots in the coating, even those as thin as 0.635 mm. However, this can be achieved with ASTM G62-07 Method B because of the higher applied voltages, between 900 and 20,000 V DC. Method B is considered destructive because the high voltages involved generally destroy the coating at thin spots.