

COATING FAILURES: CONSEQUENCES AND CASE STUDIES

8

Introduction

Protective coatings are the principal materials used on many industrial structures for corrosion protection. It should be recognized though that all protective coatings have a finite service life, and that independent of how well the coating system was originally applied, coating breakdown will eventually occur. Oftentimes the service life of a protective coating system can be extended by performing maintenance painting once the onset of deterioration takes place, reducing life cycle costs.

The aspect to consider then should be “time to failure,” not whether the system will fail. Some coating systems fail long before the anticipated service life is over. These are known as premature coating failures. Premature coating failures can be caused by improper surface preparation or coating application procedures, improper coating system selection, improper formulation or poor quality raw materials, or the design of the structure itself. When a premature failure occurs, an investigation can be undertaken to uncover three important discoveries:

1. The cause of the premature coating failure,
2. The party was responsible for the failure, and
3. The level of repair required to ensure corrosion protection and integrity of the facility/structure.

This module describes the consequences of coating failure, the field and laboratory investigative processes undertaken to diagnose coating failures, and explores several case studies, including the cause, the parties responsible, and repair/replacement options. Most importantly, the role of the coatings inspector in failure avoidance is described for each case history described. The participants learning outcome for this module is to describe how coatings inspection can help prevent premature coating failure

Consequences of Coating Failures

There are many consequences of coating failure, not the least of which is the financial impact on all parties involved. In many cases, some form of litigation is involved, which impacts all parties, independent of fault or the outcome of the litigation. Some of the more technical consequences are listed and described below.



Substrate replacement or repair

When a coating failure goes unnoticed, the substrate may be exposed to the prevailing environment for extended periods of time, which may cause the substrate to corrode and result in possible section loss. If the coating failure goes unnoticed for extended periods of time, the integrity of the structure may be compromised. The cost to repair the substrate adds to the cost of the coating failure

Costly rework and downtime

The costs associated with remobilization, surface preparation, coating application and inspection of the repair or rework can be time consuming and costly, especially when shop-coated steel has already been erected in the field, since many shops are not equipped to conduct field surface preparation and painting, and may be located thousands of miles from the project site. Determining the extent of the rework can also be problematic. While a knee-jerk reaction may indicate total removal, it is possible that the system can undergo spot repair. The owner must carefully weigh how the extended downtime associated with total replacement affects operations.

Aesthetics

The poor appearance of a coating may not reduce the service life, but may be undesirable from an owner's perspective. Examples include runs and sags, orange peeling, blushing, color shift, loss of gloss, etc. The impact of aesthetics on site personnel (e.g., in a plant) and the public (a water tank in a neighborhood) must be considered.

The Role of the Coatings Inspector in Failure Avoidance

How can an inspector prevent coating failures from occurring? The coatings inspector can play a key role in helping to prevent premature coating failure. The opportunity for failure is significantly reduced when a properly trained and equipped coatings inspector verifies that each step in the surface preparation and coating/lining installation process meets the requirements of the project specification. The knowledgeable inspector identifies deficiencies as they occur, then works with the contractor to bring the deficient areas into conformance with the specification before additional work progresses. These are known as hold point inspections. The purpose of hold point inspections was described in Module 2 of this course. In addition, a knowledgeable coatings inspector will identify "problem areas" on a structure that are prone to coating failure despite the efforts put forth by the contractor. Alternative methods of corrosion protection can then be explored by the facility owner/specification writer (i.e., caulking of crevices) to help avoid premature breakdown of the coating.

The Role of the Coatings Inspector in a Failure Investigation

Despite efforts put forth by all parties on a coatings project (the owner/specifier, the contractor, the coating material supplier and the inspector), coating failures occur. A coatings inspector can play a key role in helping to determine the cause of the failure, as well as what can be done to prevent the failure from reoccurring. The coatings inspector will not typically investigate the failure, but rather cooperate during the investigative process. The importance of thorough, complete inspection documentation was discussed earlier in this course. These inspection records will be scrutinized during the

failure investigative process, and may become a key component to the litigation process. Conversely, incomplete or inaccurate records can be a detriment to the investigative process and can reflect poorly on the coating inspector. For example, if the failure is related to incorrectly manufactured batches of coating and the inspector's records do not indicate batch numbers, or do not reflect what batch was used on what portion(s) of the structure, the failure investigation may become increasingly difficult. Or simply recording that ambient conditions "met" the specification requirements without actually recording the temperatures, conditions, date and time will be essentially useless in the failure investigation.

The failure investigator will often interview the coatings inspector and request copies of inspection records, photographs and other project documents to aid in the investigative process. The value of these documents is directly related to their inherent completeness and accuracy.

A coatings inspector must realize that inspection records, photographs, and written correspondence with the contractor, owner and material supplier are all "discoverable" items in the legal process. The inspector may be required to give a deposition and may need to testify and be subject to cross-examination in court if a coating failure is litigated. The quality of the inspection on the project and the completeness and accuracy of inspection records is a direct reflection on the credibility of the coatings inspector.

Case Studies of Coating Failure

Each of the following case studies describes a coating failure. The background information is presented and the cause, responsible party and repair procedures are described. The role of the inspector in helping to prevent the failure from occurring is also discussed for each.

Case Study Failure 1

A contract was let to remove and replace the existing lead-based coating system on a large bridge structure. The specification required abrasive blast cleaning to achieve a near-white blast (SSPC-SP10), followed by two coats of a polyamide epoxy and one coat of polyurethane topcoat. Six months after the contract was completed,

corrosion was observed as illustrated in the photograph.

Cause:

Corrosion products remained on the back side of the rivets that were not subjected to direct impact by the abrasive stream during blast cleaning. The coating was also applied from one direction, causing thin areas on the back side of the rivets and the adjacent flat areas of the steel plate. Inadequate attention was given to the coating along the edges.

**Responsibility:**

Painting contractor

Repair:

The repair recommendation included power tool cleaning of corroded areas and subsequent touch-up. Abrasive blast cleaning may cause damage to the surrounding coating that remains in good condition.

Avoidance Through Inspection:

The inspector should have carefully examined the “difficult access” areas after surface preparation and application of each coating layer. As a general rule, if the inspector has difficulty accessing the areas, then the contractor’s personnel likely had difficulty as well. Proper use of an inspection mirror would have revealed the missed areas. Stripe coat application in these areas would likely have helped to protect the edges.

Case Study Failure 2

The project specification required abrasive blast cleaning (to achieve a near-white blast per SSPC-SP10) and the application of a single coat of an inorganic zinc primer to piping. Surface preparation and coating application were performed in the shop. Once the piping was installed in the field, damaged areas (caused by the installation) were abrasive blast cleaned and touched-up with an organic (epoxy) zinc-rich primer, as illustrated by the darker gray patches in the photo. All of the touch-up areas performed well. Within one year, the piping showed extensive

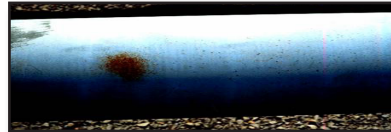
pinpoint rusting and rust-through. A closer examination of the pipe (second photo) shows one of the rusted areas, with the edge of a repair area also shown (top left). As illustrated, the repair area is performing well, but the surrounding area is exhibiting rusting.

Cause:

When repairing damaged areas, the laborer failed to start and stop the flow of abrasive from the blast nozzle when moving from one damaged area to another. Instead, the blast nozzle was moved to the next location while the abrasive was still flowing at maximum pressure, which caused considerable damage to the coating. This is apparent in the second photo, where a round patch of coating had been effectively removed



by the abrasive impact, with the surrounding area nicked by the abrasive. Since the zinc primer is essentially the same color as the steel, the damage went unnoticed until the electrolyte (water) contacted the surface and caused the formation of corrosion.



Responsibility:

Field painting contractor who performed the repairs

Repair:

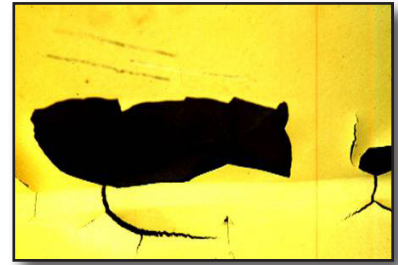
The repair recommendation included cleaning the pipe by pressure washing and the rusted areas repaired by hand or power tool cleaning per SSPC SP2/SP3. Application of a full overcoat to all piping will help prevent formation of additional corrosion products.

Avoidance Through Inspection:

The Contractor's QC inspector should have observed the abrasive blast cleaning operations, recognized the potential for over blast damage and discussed the issue with the foreman prior to the laborer continuing the work.

Case Study Failure 3

The project specification required abrasive blast cleaning (to achieve a near-white blast per SSPC-SP10) and the application of an inorganic zinc primer to structural steel I Beams in the fabrication shop. Application of the intermediate coat was also performed in the shop, while the topcoat was scheduled for application in the field after erection and bolting of the steel. The fabricator's quality control specialist kept documentation revealing that they had conformed to the thickness and recoat times recommended by the coating manufacturer's technical representative, who visited the shop during coating application activities. The steel was loaded onto trucks and shipped to the site. Spontaneous cracking of the coating along the fillet weld (where the web and flange are joined) was evident, as illustrated by the photograph.



The second photo illustrates the spontaneous cracking and lifting along the fillet, and the poor adhesion of the coating system on the web. Examination of a disbonded coating chip revealed the presence of zinc primer on the back side of the chip and on the steel surface, indicating that the location of break was cohesive within the zinc primer.



Cause:

Ethyl silicate type inorganic zinc-rich primers require moisture to cure. In this case, an insufficient length of time was allowed before the application of the epoxy midcoat. Once the epoxy was applied, no more moisture could react with the primer, since it was effectively sealed off by the epoxy. The zinc primer remained in a dry, but uncured (and weakened state). The solvents from the epoxy midcoat penetrated the uncured primer, and the contractive curing stresses imparted by the epoxy caused the zinc primer to cohesively split. Since the web and flange are adjacent to one another, the thickness of the epoxy was slightly higher along the fillet weld area. The higher thickness exacerbated the problem and resulted in the cracking and detachment. When other areas were evaluated, it became evident that the entire system was at risk for failure.

Responsibility:

The fabrication shop (for the excessive thickness along the fillet weld and for recoating too soon) and the coating manufacturer (for allowing the shop to recoat the zinc primer too soon). Even though the fabricator had records showing that they complied with the recoat time, the curing conditions inside the shop did not match those on the product data sheet. During periods of low humidity (e.g., winter months), the shop floor or the primer itself must oftentimes be wetted down with clean water a few hours after application, in order to increase the humidity in the shop and hydrolyze the zinc-rich primer. This recommendation is sometimes listed on the PDS. Note that this practice only applies to inorganic zinc-rich primers. Other coatings may be harmed by an increase in humidity levels or the application of water mist to the coating while in the curing stages.

Repair:

The repair procedures can take either of two approaches. The areas exhibiting spontaneous failure can be repaired by hand or power tool cleaning (SSPC-SP2/SP3) followed by the application of the epoxy to the repair areas. This assumes that once the steel is erected and is left undisturbed, additional detachment will not occur. If this approach was selected, then maintenance painting work over the following few years would be necessary. The other approach is to totally remove and replace the existing coating system. The owner may exercise this option if he does not want to take a “wait and see” approach and face monitoring performance and the potential for maintenance painting work on the structure for several years to come (based on the rate of failure).

Avoidance Through Inspection:

Inorganic zinc-rich primers dry very quickly, however they may not cure for hours or even days if the humidity is too low within the prevailing environment. The key is to *verify* the cure, rather than relying on cure time tables provided by the coating manufacturer, as they cannot address every curing condition variable on a PDS. Inspection could have included a curing test specifically designed for the type of coating described by this case study (ASTM D4752, Measuring MEK Resistance of Ethyl Silicate (inorganic) Zinc-Rich Primers by

Solvent Rub). Once a resistance rating of “4 or 5” is achieved (burnished appearance in the rubbed area or no effect after 50 double rubs), the zinc-rich primer can be considered cured and ready for recoating. Additionally, measurement of coating thickness in accordance with SSPC-PA2 may have detected the excess coating thickness along the fillet weld area.

Case Study Failure 4

The project specification required abrasive blast cleaning to achieve a Commercial Blast (SSPC-SP6/NACE No. 3) and the application of a single coat of alkyd primer in the joist fabrication shop. The joists were shipped to the project site, where they were stored outdoors (on the ground) for six months. Corrosion was visibly evident within six months.



Cause:

SSPC-SP6/NACE No. 3 requires removal of all mill scale. The surfaces may have staining from mill scale (provided it does not exceed 33% of each 9 square inches). In this case, the “pock marks” in the photo clearly indicate that mill scale was left on the surface and coated over. The “hollow” areas represent those locations where the mill scale was removed, while the surrounding areas contain mill scale. The areas containing mill scale exhibit corrosion products. In a mild environment (and with the proper thickness), this system should have lasted longer than six months. However, the application of a thin film alkyd primer combined with damp storage conditions lead to water permeation of the alkyd. The result was the formation of a corrosion cell at the mill scale/steel interface. Mill scale is cathodic to steel, which means that the base steel becomes the anode in the corrosion cell and begins to deplete, generating the corrosion products.

Responsibility:

The joist fabricator is responsible for the failure, since it did not comply with the specification to remove the mill scale prior to primer application. Note however that even if the mill scale was completely removed, some deterioration may have been evident due to the storage conditions and length of storage

prior to installation. This is beyond the responsibility of the fabricator.

Repair:

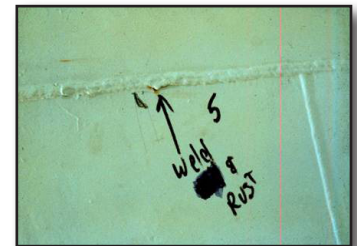
The existing alkyd primer and the mill scale must be removed by abrasive blast cleaning to achieve the specified level of cleaning (SSPC-SP6/NACE No. 3), and the alkyd primer reapplied.

Avoidance Through Inspection:

Careful visual inspection of the steel surfaces after surface preparation (in conjunction with the use of SSPC VIS 1) would have revealed the presence of mill scale, which is not permitted by the specified cleanliness standard. Additional surface preparation prior to application of the primer would have required additional labor and more abrasive, but could have been done at a significantly lower cost than the cumulative costs associated with the failure investigation, transportation of the joists back to the fabrication shop (and then back to the project site once the rework is done), the material and labor costs associated with re-application of the primer, and potential for liquidated damages due to project schedule delays.

Case Study Failure 5

During the anniversary inspection of the interior of a water storage tank, an area of rust was visible evident along one of the weld seams. The substrate was prepared to achieve a Near-White blast (SSPC-SP10/NACE No. 2) and the application of two coats of an approved polyamide epoxy system.



Cause:

A poor quality weld that could not be properly coated caused the rusting in that area. The weld “roll” should have been removed by grinding, followed by re-welding as necessary prior to surface preparation and painting. Most thin film coatings (less than 20 mils) cannot penetrate and seal crevices.

Responsibility:

The painting contractor should have either ground the area, or alerted the owner of the condition so it could be prepared by another party if the responsibility goes beyond the scope of work bid by the contractor, especially if re-welding was necessary.

Repair:

The area should be ground and re-welded (if necessary), and the two-coat system reapplied to the area. Welding will cause damage to the coating system in the adjacent area, so additional surface preparation of the adjacent surfaces may also be required.

Avoidance Through Inspection:

Careful visual inspection may have revealed the weld roll after surface preparation was complete. Low voltage, wet sponge holiday testing after application of the coating system (and prior to placing the tank into service), especially along the weld seams could have revealed the “holiday” beneath the weld roll.

Case Study Failure 6

Galvanized and coil coated, corrugated white metal roofing was installed on a new low rise motel in the southeast. Within a few weeks of installation, excessive pinpoint rusting was visible. During the investigation, solvent was used to clean an area of the coated surface. Substantial rubbing of the coating with the solvent revealed a small area of bare galvanizing beneath the coil coating. The galvanized layer was in excellent condition, with no indication of red rusting.

**Cause:**

This was not a coating failure at all. In fact, the coating itself was in good condition. The presence of pinpoint rusting was a surface phenomena caused by the presence of iron filings that had collected in the “troughs” of the roofing and rusted when contacted by moisture. The iron filings were generated

by the cutting and drilling operations during installation of the roof. The hot metal shavings on the hot metal roof attached themselves to the coating, so that did not become dislodged by rain water.

Responsible:

The installation contractor should have employed better housekeeping to remove the iron filings daily during the roof installation.

Repair.

Since there is nothing wrong with the surface preparation or the coating, the roof can be thoroughly scrubbed to remove the rust staining.

Avoidance Through Inspection:

While an inspector may be present in the coil coating shop to verify proper electro-galvanizing and application of the coil coating, it is highly unlikely that inspection would have been employed during the installation of the corrugated roofing. Therefore, this “aesthetics” problem would likely have occurred anyway. However, this case demonstrates that quality is everyone’s responsibility. Daily visual inspection and subsequent removal of the iron filings by the installation contractor would have saved the cost of the failure investigation and the cleaning procedures that were eventually employed.

Case Study Failure 7

The project specification for the interior of a fire water storage tank required a “White Metal” blast (SSPC-SP5/NACE No. 1) and the application of a three-coat vinyl system. The vinyl coating was applied during cold weather (35-

40°F), but within the allowable range stated on the PDS. The tank was placed back into service within 24 hours, in the event that a fire quenching water was required. The interior of the tank was examined a few months later and extensive blistering was evident. Blister caps were removed, revealing properly prepared steel beneath the blisters.



Cause:

While vinyl coatings can be applied in cooler temperatures, they require an extended dry time to allow ample time for the solvents to evaporate from the film. Most vinyl coatings are formulated with 60% or more solvent. In this case, residual solvent in the coating film (which was water soluble) pulled water through the coating film (by osmotic forces) causing a build-up of water and pressure beneath the coating, resulting in blistering of the lining.

Responsibility:

The tank owner, who refilled the tank too soon was responsible for the coating failure.

Repair:

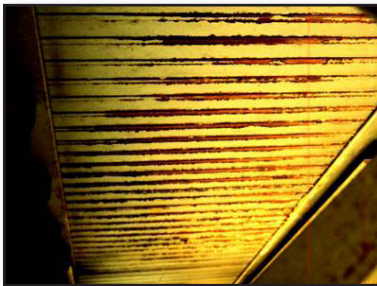
The entire coating system inside the fire water tank had to be removed by abrasive blast cleaning and replaced. In some cases, blistered areas can be repaired. However, the blistering in this tank was too extensive for repair. By putting the tank back into service too quickly, the tank was actually out of service much longer due to the failure investigation and the rework required. Costs also escalated much higher than budgeted for the project because of the rework.

Avoidance Through Inspection:

Even if inspection was implemented and performed properly, the coatings inspector may not have had any authority to say when the tank can be placed back into service. This was the owner's decision. Further, since the coating cures by solvent evaporation, a solvent rub cure test would not have provided any indication of cure. A dry time test (per ASTM D1640) may have revealed inadequate drying. Ultimately, the manufacturer of the coating should have been engaged to prepare a written statement regarding the length of curing (drying) required prior to service, based on the site conditions, size of the tank, ventilation, availability of forced heat, etc. Ventilation of the tank during the drying process (ambient or force drying) is also critical when high concentrations of solvent are present in an enclosed space.

Case Study Failure 8

The underside of a viaduct containing an aged lead alkyd coating (first photo) was brush-off abrasive blast cleaned to remove loosely adhering corrosion and paint (according to SSPC-SP7/NACE No. 4), followed by the application of an epoxy mastic overcoat. The second photo illustrates the condition of the coating prior to abrasive blast cleaning. The third photo illustrates lifting of the old alkyd by the epoxy mastic overcoat. The number “10” is written on the coating in an area where the epoxy mastic was applied directly to the steel, rather than the aged lead alkyd. Directly beneath that area is an area where the mastic had lifted the alkyd, and was removed by scraping during the failure investigation. The area beneath the hand in the same photo represents epoxy mastic applied over the aged lead alkyd. This area was not probed during the investigation.



Cause:

The aged lead alkyd coating was in poor condition, as illustrated by the second photo. While brush-off abrasive blast cleaning removed the loosely adhering materials, the impact of the abrasive on the “intact” alkyd weakened (fractured) it, but did not affect it sufficiently that it would be considered “loose.” Application of the epoxy mastic imparted curing stresses that proceeded to weaken the cohesive strength of the aged lead alkyd, causing it to lift and disbond from the surface.

Responsibility:

The specification is responsible for the failure. Despite all efforts afforded by the contractor, the existing coating was not salvageable, and should not have been considered a candidate for overcoating. Prior to preparing the specification, a coating condition assessment should have been conducted, which would have revealed poor adhesion of the aged lead alkyd. The

specification should have required removal and replacement of the coating system.

Repair:

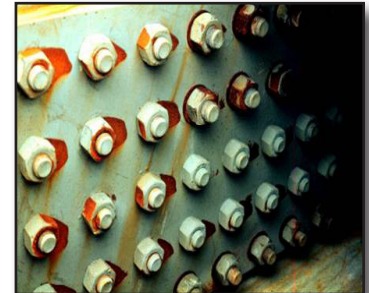
The entire coating system (the remaining aged lead alkyd and the epoxy mastic overcoat) must be removed by abrasive blast cleaning, followed by the installation of a new coating system.

Avoidance Through Inspection:

Since the inspector does not have the authority to change the specification, this project was doomed from the minute the work was awarded. Even though the inspector may have questioned the specification, it is doubtful that it would have been altered by the owner unless the fracturing of the aged lead alkyd was visible, and the inspector informed the owner of the damaged coating.

Case Study Failure 9

A new steel gusset plate was fabricated and shipped to the field for installation, abrasive blast cleaning and coating. The specification required abrasive blast cleaning to achieve a near-white blast (SSPC-SP10), followed by one coat of a gray epoxy mastic and. Six months after the contract was completed, corrosion was



observed as illustrated in the photograph. The pattern of the failure is erratic. At first glance, it appears as if the coating was applied from one direction. However upon closer examination, this may not be accurate, since the failure on the side of the nut does not correlate to the failure on the plate (it is on the opposite side). For example, the first nut in the second row does not show failure on the left side, but failure is evident to the right of the nut. In contrast, the third nut shows failure on the left side of the nut and to the right of the nut.

Cause:

The coating was in fact applied from one direction (left to right). The nut shadowed the application to the plate, leaving bare steel on the plate, which was not discovered until the rusting was evident, since the blast cleaned steel and the

gray epoxy mastic were similar in color. The erratic failure pattern was caused by tightening of the nuts after the coating was applied. Stripe coating of the nuts, bolt ends and areas between the nuts would have provided additional protection. It is unknown whether stripe coating was specified, but may be considered good painting practice for this type of configuration.

Responsibility:

Painting contractor.

Repair:

Since the failure is localized, the repair recommendation included power tool cleaning of corroded areas and subsequent touch-up with the epoxy mastic coating. If the failure was widespread, then abrasive blast cleaning and recoating all surfaces may be more efficient.

Avoidance Through Inspection:

Careful visual inspection of all surfaces (especially those that are intricate) by a knowledgeable inspector would likely have revealed the holidays, which could have been repaired. It is unlikely that the specification would have invoked holiday detection for this type of structure, which is why a careful visual inspection (with the aid of an inspection mirror and flashlight) is so critical.

Summary

Coatings can fail for a variety of reasons. When a coating failure occurs, an investigation is often performed to determine the cause, determine the party responsible and assess the degree of repair necessary to ensure the integrity of the substrate. The consequences of coating failure can include substrate repair or replacement, cost rework and down time, and aesthetics. Coatings inspection aid in coating failure avoidance by detecting problems and nonconformities (and verifying they are corrected) prior to putting the coating or lining into service. Coatings inspection however cannot aid in failure avoidance when a coating is improperly formulated or when a faulty specification is generated and work is completed based on the faulty contract.

The role of the coatings inspector can be critical in a failure investigation. Well-prepared, thorough records and photographic documentation can greatly help to narrow the cause of the failure.

	Module Eight
	Coating Failures: Consequences and Case Studies

	Introduction
	■ Protective coatings are the principal materials used for corrosion protection ■ All protective coatings have a finite service life. Coating breakdown will eventually occur ■ The service life of a coating system can be extended by maintenance painting

	Introduction (con't.)
	■ "Time to failure" is considered, not whether the system will fail ■ Some coating systems fail long before the anticipated service life is over (premature coating failures) ■ Premature coating failures caused by: ➢ Improper surface preparation or coating application procedures ➢ Improper coating system selection ➢ Improper formulation or poor quality raw materials ➢ Design of the structure

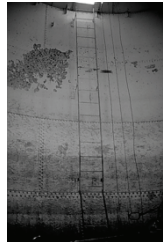
	Introduction (con't.)
	■ Failure investigations include: ➢ The cause of the failure ➢ The responsible party ➢ The level of repair required

	Introduction (con't.)
	■ Module 8 Content ➢ Consequences of coating failure ➢ Role of the coatings inspector in failure avoidance ➢ Role of the coatings inspector in a failure investigation ➢ Case studies

	Module Eight Learning Outcome
	■ Comprehension of Module Eight will enable the participant to describe how coatings inspection can help prevent premature coating failures

Consequences of Coating Failures	
	■ Substrate replacement or repair ■ Costly rework ➢ Shop application versus field repair ■ Downtime ■ Aesthetics

Consequences of Coating Failures	
■ Substrate replacement or repair ➢ Corrosion accelerates on unprotected surfaces ➢ Extensive corrosion may jeopardize structural integrity ➢ Cost of steel replacement can exceed cost to repaint – Replacement steel must be prepared & coated	

Consequences of Coating Failures	
■ Costly rework ➢ Field repair of a shop-applied system can be problematic ➢ Determining to what extent the existing system needs replaced can be challenging	

Consequences of Coating Failure	
■ Down time ➢ Can be more costly than the coating failure ■ Aesthetics ➢ May affect site personnel or public ➢ Examples include wrinkling, orange peeling, blush/haze, chalking, loss of gloss, etc.	

Role of a Coatings Inspector-Failure Avoidance	
	■ Opportunity for failure reduced ➢ Requires proper training and equipment ■ Identification of deficiencies as they occur (hold point inspections) ■ Identification of "problem areas" on a structure ➢ Implementation of alternative corrosion control procedures by the owner

Role of a Coatings Inspector-Failure Investigation	
	■ Coating failure will occur despite best efforts ■ Inspector plays key role in determining cause and resolution ■ Inspection reports and photographs scrutinized during an investigation ■ Inspection reports and photographs "discoverable" in litigation process ■ Coating inspector may give depositions/ testimony

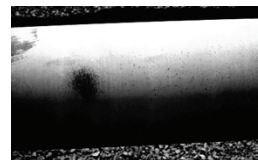
	Coating Failures - Case Studies
	■ What happened ■ Who's at fault ■ How should it be repaired ■ How coating inspection could have prevented the failure

	Case Study 1
	■ Remove & replace existing lead-based system ■ SSPC-SP10 ■ Two coats epoxy & one coat polyurethane ■ Six months later, corrosion evident (rivets & edges) 

	Case Study 1 Cause, Fault and Repair
	■ Blast and paint from one direction ■ Inadequate attention to edges ■ Contractor is at fault ■ Repair by power tool and touch-up

	Case Study 1 Avoidance Through Inspection
	■ Careful examination of "difficult access" areas after surface preparation and application ■ Use of inspection mirror would have revealed the missed areas ■ Stripe coat application would have helped to protect the edges

	Case Study 2
	■ SSPC-SP10 & one-coat inorganic zinc (shop application) ■ Pipe damaged during installation ■ Repair procedure: Abrasive blast damaged areas and coat with organic zinc (darker gray patches) 

	Case Study 2, con't.
	■ Within 1 year, rusting evident (organic zinc patches performing fine) ■ Photo depicts rusted area (center) and touch-up area (upper left) 

	Case Study 2 Cause, Fault and Repair
	■ Coating system sustained considerable over-blast damage during repair ■ Damage was not detected until the corrosion had formed months later ■ Contractor is responsible ■ Repair by cleaning pipe and applying full overcoat

	Case Study 2 Avoidance Through Inspection
	■ Inspector should have observed the abrasive blast cleaning operations ■ Immediate recognition of the potential for over blast damage and communications with the foreman/project supervisor

	Case Study 3
	■ SSPC-SP10 ■ Inorganic zinc & epoxy midcoat (shop application) ■ Fabricator's QC inspector maintained records of cure time and conditions, per manufacturer ■ Coating cracked and disbonded along fillet weld area enroute to jobsite 

	Case Study 3
	■ Poor adhesion also prevalent on the web and flange ■ Location of break was cohesive within zinc-rich primer ■ Manufacturer present during applications & confirmed recoat time/conditions per PDS 

	Case Study 3 Cause, Fault and Repair
	■ Inadequate curing of the zinc-rich primer prior to topcoating lead to a weakened film ■ Excessive thickness of the epoxy along the fillet exacerbated the problem ■ Coating manufacturer and fabricator responsible ■ Repair - total removal or localized repair (as failure occurs)

	Case Study 3 Avoidance Through Inspection
	■ <i>Verify</i> the cure, rather than relying on cure time tables provided by the coating manufacturer ■ Inspection should have included a curing test (ASTM D4752) ■ Measurement of coating thickness may have detected the excess thickness along fillet weld area

Case Study 4

- SSPC-SP6
- Single coat alkyd to joists (shop application)
- Joists stored on ground at jobsite 6 months
- Corrosion evident during erection

**Case Study 4
Cause, Fault and Repair**

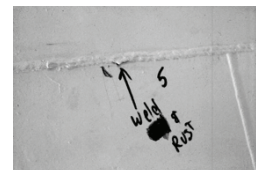
- Incomplete removal of mill scale
- Shop primer insufficient to withstand storage conditions
- Joist fabricator responsible
- Remove and replace the coating

**Case Study 4
Avoidance Through Inspection**

- Careful visual inspection after surface preparation (in conjunction with the use of SSPC VIS 1) would have revealed the presence of mill scale
- Cumulative costs include:
 - Failure investigation
 - Transportation of the joists (to/from)
 - Rework material and labor costs
 - Potential for liquidated damages

Case Study 5

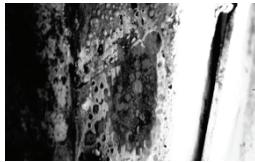
- Water tank interior
- SSPC-SP10 & two coats of approved epoxy polyamide
- Rusting evident at anniversary inspection

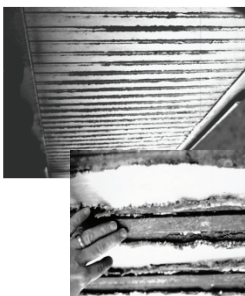
**Case Study 5
Cause, Fault and Repair**

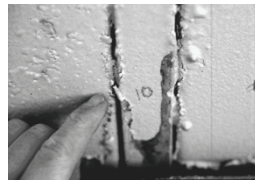
- Weld "roll"
- Coating not capable of sealing irregularity
- Contractor responsible
- Grind the weld and apply touch-up coating

**Case Study 5
Avoidance Through Inspection**

- Visual inspection may have revealed the weld roll after surface preparation was complete
- Low voltage (wet sponge) holiday testing after application of the coating system would have revealed the "holiday" beneath the weld roll

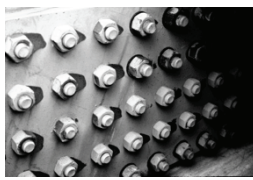
	Case Study 6 ■ Galvanized, coil coated corrugated white metal roof ■ Rusting evident a few weeks after installation ■ Solvent removed rusting ■ Galvanized layer in excellent condition 	Case Study 6 Cause, Fault and Repair ■ Coating was fine ■ Iron filings from drilling and installing the siding collected in the troughs and corroded ■ Installation contractor responsible ■ Scrub the surface
	Case Study 6 Avoidance Through Inspection ■ Unlikely that inspection would have been performed during the installation of the roofing ■ Case demonstrates that quality is everyone's responsibility ■ Daily visual inspection and removal of iron filings would have saved the cost of the failure investigation and the cleaning procedures employed	Case Study 7 ■ Interior fire water storage tank ■ SSPC-SP5 & three-coat vinyl system (35-40°F) ■ Tank filled within 24 hours ■ Tank drained for inspection & extensive blistering evident ■ Steel clean beneath blister caps 
	Case Study 7 Cause, Fault and Repair ■ Solvent entrapment caused osmotic blistering ■ Facility owner responsible for not allowing proper curing time ■ Remove and replace lining system	Case Study 7 Avoidance Through Inspection ■ The coatings inspector may not have the authority to say when the tank could be placed back into service ■ A solvent rub cure test would not have provided any indication of cure ■ A dry time test (per ASTM D1640) may have revealed inadequate drying. ■ The coating manufacturer should have been engaged to provide a written statement regarding the length of curing (drying) required ■ Dry time is based on the site conditions, size of the tank, ventilation, availability of forced heat, etc. ■ Ventilation of the tank during the drying process is also critical

	Case Study 8
	■ Underside of viaduct containing aged lead alkyd ■ SSPC-SP7 & application of epoxy mastic 

	Case Study 8, con't.
	■ Lifting and detachment of epoxy mastic and remaining lead alkyd ■ No. "10" on area of epoxy mastic on steel (remains intact) 

	Case Study 8 Cause, Fault and Repair
	■ Alkyd too weak to be salvaged ■ Specification is responsible ■ Remove and replace entire coating system

	Case Study 8 Avoidance Through Inspection
	■ The inspector does not have the authority to change the specification ■ The specification requirements would not have changed unless fracturing of the aged alkyd was visible, and the inspector informed the owner in time

	Case Study 9
	■ New steel gusset plate ■ SSPC-SP10 and epoxy mastic application in field ■ Corrosion evident after 6 months ■ Failure pattern somewhat erratic (left side of nut vs. right side of nut on plate) 

	Case Study 9 Cause, Fault and Repair
	■ The coating was applied from one direction (left to right) ■ Nuts were torqued after the coating was applied ■ Contractor is responsible ■ Spot clean and touch-up

	Case Study 9 Avoidance Through Inspection
	■ Careful visual inspection (with the aid of an inspection mirror and flashlight) would have revealed the holidays ■ It is unlikely that the specification would have invoked holiday detection for this type of structure

	Summary
	■ Coatings fail for a variety of reasons ■ A coating failure investigation is performed to determine: ➢ The cause ➢ The party responsible ➢ The degree of repair necessary ■ Consequences of coating failure include: ➢ Substrate repair or replacement ➢ Rework and down time ➢ Poor aesthetics

	Summary (con't.)
	■ On-site coatings inspection can prevent coating failure ■ On-site coatings inspection cannot prevent coating failure caused by improper formulation or faulty specification ■ Coating inspection records and photographs are frequently scrutinized during a failure investigation