# SSPC, the Chemical Safety Board (CSB), and Another Matter

On October 2, 2007, in Georgetown, Colorado, there was a fire in a penstock (conduit or pipe for water) owned by Excel Energy. This terrible accident left five workers dead and three injured. The Chemical Safety Board (CSB) asked SSPC and the American Public Power Association (APPA) to publish safety guidance addressing the hazards and controls for using hazardous materials, including flammables, in confined spaces and the unique hazards of penstocks.

The resultant Fact Sheet was developed in response to the CSB's Final Report. The Fact Sheet provides guidance in addressing the hazards present and controls necessary when working in confined spaces. It is also meant to reinforce the importance of conducting a job-site safety analysis; developing project-specific safety plans and training field personnel; communicating the key information about jobs to the local authorities; and having a trained attendant in place and qualified and informed rescue teams nearby. The Fact Sheet further stresses that you must follow OSHA's guidance for fire protection and avoid confined space hazards altogether whenever possible. The Fact Sheet contains a special section on the unique hazards of penstocks, including requirements that they are always to be managed as permit-required confined spaces and that alternative escape routes or refuge chambers are to be provided. It concludes by discussing OSHA's General Industry Standard for permit-required confined spaces.

The Fact Sheet was published in last month's *JPCL* on pg. 53; on our website, sspc.org; in *PaintSquare News*, and on paintsquare.com (Jan. 11, 2011). Our Fact Sheet was also sent to all SSPC certified contractors. We take our role in informing our members very seriously on all matters. But that responsibility is magnified when it concerns the safety, health, and welfare of a worker. We will give that mission the highest priority.

A few weeks ago I was watching "Face the Nation," a Sunday morning CBS show, and the guests were two sitting Democratic members of Congress, a sitting Republican member of Congress via video conferencing, and a newly-elected Republican member of Congress, who had not yet served a day in Washington. Harry Smith was the moderator. As Mr. Smith asked questions of the guests the political rancor became just overwhelming. By the end of the show they were accusing each other's party of mismanagement, overspending, and anything else that came to mind in our charged-up political climate. Mr. Smith lost control because they would not stop finger pointing and making accusations, and at the very end they were literally shouting at each other.

When I turned off the television, I thought to myself, "Are these the folks whom we have elected to fix our problems?" I was trying to see which guest had an answer to the issues brought up by Mr. Smith, but I suddenly became sidetracked watching these professional politicians yelling at each other. I was not looking for, nor expecting, "quick fix" solutions, but meaningful dialogue on where compromise could be achieved.

I don't know where this great nation will go in the future, but until we have meaningful dialogue between both parties, I doubt if we will go anywhere. Compromise is necessary and I hope it can be achieved. Most of all, Congress needs to come up with some answers to fix the economy, address social security, Medicare, our trade imbalance, and the many other problems we face.

On Monday morning, I e-mailed my Congressman and told him that I was tired of the rancor and I wanted to see results. I did this because I was sick and tired of the way Congress does business, and I wanted to have my voice heard. This is the third or fourth time I have e-mailed him about a particular issue, and I suggest that all of you do the same. If you go to their webpage, it is easy and only takes a few minutes. I have even been contacted by one of his staffers, by telephone not e-mail, that my concerns had been heard.

I wish all of you a safe, prosperous, and, most of all, a healthy and happy 2011.


Bill Shoup
Executive Director, SSPC

# Allan DeLange to Present Confined Space Safety Webinar

Allan DeLange, vice president of CL Coatings and North American Coatings, LLC, and past president of SSPC, will present the SSPC/*JPCL* Education Series Webinar, "Confined Space Safety," on March 9 at 11 a.m. EST.

*Allan DeLange*

The webinar will describe regulatory requirements and accepted industry practice in entering confined spaces and conducting surface preparation and coating work inside them. The hazards of confined spaces will be clearly described and safety controls will be explained.

The webinar is co-sponsored by Larson Electronics/Magnalight and Air Systems.

Education Series Webinars provide continuing education for SSPC recertifications as well as technology updates on important topics.

Participation in the webinar is free, but for those who wish to receive continuing education credits from SSPC, a test is available after the webinar for $25. All participants will receive a free certificate of completion.

Register online at paintsquare.com/education.

Allan DeLange has a strong history of participation in SSPC governance, technical committees, education, and publications. He has also been active in NACE, NBR, ASTM, and the Finishing Contractors Association. He holds a BS from Calvin College, a MS in technology from Illinois Institute of Technology, and an MBA from the University of Chicago.

See the "Training Days" article below for more webinars.

## Vernon Added to SSPC Board

SSPC has announced that L. Skip Vernon has been appointed to the Board of Governors by SSPC President Russ Brown.

Vernon has over 25 years of industrial coating application experience, and his current role is as a consultant and advisor to coating manufacturers, contractors, owners, engineering firms, DOTs, and attorneys on coatings-related technical issues. He has a bachelor's of individualized studies with emphasis in chemistry from New Mexico State University and a Juris Doctor degree from the University of New Mexico School of Law.

*L. Skip Vernon*

He is a certified SSPC Protective Coatings Specialist, SSPC Instructor, and SSPC Master Coatings Inspector. Vernon also has certifications from several other associations. He holds or has held licenses for several states in the building and painting trades and was an EPA-Certified Lead Inspector and Risk Assessor.

Vernon replaces Steve Roetter, whose participation on the Board began in 2000. Roetter left the coatings industry in 2010 and resigned his position in accordance with the SSPC by-laws. The by-laws state that the SSPC President must fill the position by appointment.

## SSPC/*JPCL* Training Days Coming Up

Five SSPC/*JPCL* Education Series Webinars will be presented during the semi-annual Training Days on February 22-24. They are listed below.

- February 22, 11:00 a.m.-Noon: Containment and Disposal of Wastewater in UHP Operations, Rich Burgess, KTA-Tator, Instructor
- February 22, 1:15 p.m-2:15 p.m.: Advances in Polyurethane and Polyurea Technology, Jayson Helsel, KTA-Tator, Instructor
- February 23, 11:00 a.m.-Noon: Developing an OSHA-Compliant Respiratory Protection Program, Stan Liang, KTA-Tator, Instructor
- February 23, 1:15 p.m.-2:15 p.m.: Monitoring Environmental Conditions for Cleaning and Painting Operations, Bill Corbett, KTA-Tator, Instructor
- February 24: 11:00 a.m.-Noon: Assuring Fall Protection When Working from Heights, Stan Liang, KTA-Tator, Instructor

## DuPont Shifts Leadership Team

DuPont Performance Coatings has made several changes in its leadership.

B.C. Chong, previously vice president of the Performance Coatings business in Asia Pacific, has succeeded Richard C. Olson as president of Titanium Technologies. Chong will lead the global business from Asia.

*B.C. Chong*

No successor has been named for Chong.

Olson was named to lead the productivity improvement and business process simplification programs across the company. He has served in a range of roles worldwide since joining the company in 1978, and led the Titanium Technologies business since 2005.


*Richard C. Olson*

Thierry F.J. Vanlancker is now vice president of Performance Coatings for the company's Europe-Middle East-Africa (EMEA) region. Vanlancker, who had been global business and market director for DuPont Fluorochemicals, joined the company in 1988.


*Thierry F.J. Vanlancker*

Jeffrey L. Keefer, executive vice president, retired Dec. 31, after more than 34 years of service. His most recent responsibilities included overall cost and working capital productivity programs, corporate strategy, and the Performance Coatings business.


*Jeffrey L. Keefer*

## Sto Corp. Loses Michael Sweeney

Michael E. Sweeney, media relations manager for Sto Corp. (Atlanta, GA), passed away unexpectedly Jan. 4 at age 47. No cause of death was released.


Mr. Sweeney was a 10-year veteran of Sto and was well-known throughout the coatings industry. He was responsible for public relations and advertising at the company.

"His skills in developing a web of relationships with vendors and the media will be missed, but his humor and good nature will be missed even more," said Julie Chalpan, a colleague. "He was dedicated to Sto's future, and worked hard to create a better company and even more enjoyable working environment for all."

Mr. Sweeney had a long career in the building products industry. He had served as communications director for the Greater Atlanta Home Builders Association; associate publisher and trade show manager of PK Marketing Inc., where he was editor of *Georgia Builder* magazine; marketing manager for Hebel Building System; and editorial director for *Electronic Packaging and Production* magazine. He was a long-time member of the Public Relations Society of America.

Mr. Sweeney was active in the Knights of Columbus at St. Pius X Catholic Church in Conyers, GA. He enjoyed camping with the family and teaching his daughter, Suzanna, how to play tuba. Contributions may be made to the Sweeney Memorial Fund at Wells Fargo (Account #6938543219) at any Wells Fargo location.

Mr. Sweeney is survived by his wife, Joyce; daughters Abigail and Suzanna; his parents; and a sister.

## KTA-Tator Sold to Employees

After 61 years as a family-owned company, global coatings consultant KTA-Tator, Inc. (Pittsburgh, PA) announced that it officially became an employee-owned company Dec. 21 via an Employee Stock Ownership Plan.

The company's management team remains the same, as does its professional staff.

Ken Tator, former owner and CEO, remains with the company in an advisory role and as chairman of the board of directors, and will maintain a coatings-consulting practice. Tator's father, Kenneth, founded the firm in 1949.

Ken Trimber continues as president. Other senior executives are Dan Adley, chief operating officer/chief financial officer; Eric Kline, executive vice president; and John Konopka, vice president-finance.

KTA provides independent assessments of the quality and performance of protective coatings used in corrosive environments.

Visit kta.com for more information.

## Dur-A-Flex Appoints Ferris President and COO

Dur-A-Flex has announced the appointment of Peter Ferris as president and chief operating officer, effective Jan. 1, 2011.

Ferris was formerly president of Charter Medical, Ltd. in Winston-Salem, NC, a business unit of Lydall, Inc. He also served seven years with Princeton, NJ-based Tyco Internation-al, Ltd., where he was vice president of strategic marketing.

Dur-A-Flex is a manufacturer of epoxy, urethane, methyl methacrylate, and colored aggregates, offering a complete line of high-performance polymer flooring and wall systems.

## Asian PPG to Add Protective Coatings

PPG Industries and Asian Paints Ltd. will expand their transportation coatings joint venture and launch a new protective coatings joint venture in India, the companies have announced. The new venture will serve the protective, industrial powder, industrial containers, and light industrial coatings markets.

The companies say they will restructure their current 50-50 joint venture, Mumbai-based Asian PPG Industries, and create a second 50-50 joint venture. The restructuring is subject to Indian regulatory approvals and is expected to be completed this year.

# On Removing Coatings from Concrete Floors

## *What are the pros and cons of using shotblasting to remove a coating system from a concrete floor?*

**From Remko Tas**
**Futuro SRL**

Shotblasting, compared to other abrasive blasting, of a coated concrete floor will generate a lot less dust, but the shotblasting will likely be done with a portable wheelblasting and recovery unit. With this method, you are not able to see when the coating has been removed and when the abrasive has begun to eat away the concrete surface, creating an irregular base. Before applying the new coating, you may have to fill up the holes, which might be costly. As an alternative, wet abrasive blasting with a high-pressure hot-water unit will reduce the damage because the operator will keep the lance in one place only until he removes the paint, and then he will move on.

**From Lee Edelman**
**CW Technical Services Inc.**

Using a shotblast system peens the surface and does not give an angular profile. Also, it will not get close to the edges. You can damage the concrete if close attention is not given to the process.

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*Editor's Note: This question was posted on the daily electronic newsletter, PaintSquare News (PSN), on behalf of* JPCL. *Responses, including the ones here, were solicited through the PSN posting. The answers have been selected and edited to conform to* JPCL's *style and space limitations. To read other Forum questions and responses, click the JPCL Problem Solving Forum of any issue of PSN. If you would like to receive PSN, visit www.paintsquare.com.*




# The Case of the Ship Paint That Wasn't All It Was Cracked Up to Be

By Rick A. Huntley, Senior Coatings Consultant, KTA-Tator, Inc.
Richard A. Burgess, KTA-Tator, Inc., Series Editor

The application of silicone alkyd finish coats to exterior surfaces on marine vessels provides an economical alternative to polyurethane, polysiloxane, or fluorourethane finish coats. Silicone alkyds provide good barrier protection, retain their color and gloss (provided they contain 30% or greater silicone in the formulation), and are easily touched up during maintenance operations. In this Case from the F-Files, however, a silicone alkyd finish coat failed prematurely on the exterior of a U.S. Coast Guard vessel. Although the finish coat should have provided long-term corrosion protection and aesthetics, it displayed widespread, premature cracking and delamination. What caused the finish coat to prematurely fail? Was it the wrong coating for the environment, mis-formulation, or application related? And why were areas containing vessel markings in good condition?

The exterior surfaces of a U.S. Coast Guard vessel built by an American shipbuilder was protected with a coating system that consisted of an organic epoxy zinc-rich primer (gray), an epoxy mid-coat (off-white), and a white silicone alkyd finish coat. After the white silicone alkyd coating was applied to the entire freeboard area, a red and blue colored silicone alkyd coating was applied over portions of the white silicone alkyd to create the characteristic Coast Guard vessel markings. Within one year of coating application, the white silicone alkyd finish began to crack and delaminate from the epoxy mid-coat on 10–15% of the exterior surfaces (Fig. 1). The shipyard requested an independent investigation of the coating problems to determine the cause.

## Site Investigation

The vessel was examined while in port. At the time of the examination, the vessel was docked with the starboard side facing the dock. The port side of the freeboard area could be examined only by looking over the side while standing on the vessel's main deck. The following observations were made during the site investigation.

*Fig. 1: Appearance of the starboard side where the alkyd silicone finish coat has cracked and peeled, exposing the underlying epoxy coat. All photos are courtesy of KTA-Tator, Inc.*

- The coating on the freeboard area appeared to be in poor condition. In many areas, the white finish coat had delaminated from the off-white epoxy intermediate coat. Approximately 30% of the topcoat had delaminated from the starboard freeboard area (Fig. 2).
- The silicone alkyd topcoat delamination was minimal on the aft portion of the freeboard area, where an engine exhaust port deposited a significant quantity of soot on the surface of the hull.
- There were several areas on the freeboard where the white silicone alkyd was either topcoated with a blue or red silicone alkyd coating or black lettering was applied. No coating delamination was evident in areas where the white silicone alkyd had been topcoated with the red, blue, or black markings (Fig. 3).
- In one area, an approximate one-inch-long, thin strip of a gray epoxy deck coating had inadvertently been applied over the silicone alkyd finish coat. Although all of the finish coat around this strip of deck coating had delaminated, the deck coating and the underlying white finish coat were well adhered.
- Close examination of the finish coat revealed that it had severely cracked. The cracking was found in all areas where there was coating delamination. Micro-cracking was evident (when the surface was viewed through a 25X field microscope) in many areas where no cracking was visible to the unaided eye. When the cracked coating was removed, it was found to be extremely brittle.
- The adhesion of the coating was measured in many areas in accordance with ASTM D3359, "Measuring Adhesion by Tape Test," Method A (X-cut). This method involves making two intersecting cuts through the coating to the substrate with a sharp blade. The smaller

*Continued*

angle of the cuts is between 30 and 45 degrees. A special pressure-sensitive tape is then applied to the X-cut area and rapidly removed. The adhesion is rated according to the amount of coating removed by the tape. The adhesion was found to vary considerably from good in some areas (3A or better) where no delamination was visually evident, to poor in areas of moderate coating delamination (2A or lower).

- Although the boathouse was reportedly coated with a similar system, no cracking, delamination, or other coating failure was noted on the structure.
- A cursory examination of the port side freeboard area revealed that it was in a condition similar to that on the starboard side freeboard area.

*Fig. 2: The lighter color coating was all that remained of the exposed silicone acrylic finish coat on this freeboard section.*

## Laboratory Analysis

Samples of the coating were removed for forensic analysis. The laboratory investigation consisted of infrared spectroscopic analysis. The infrared spectra of the coatings taken from the failing areas were unusual and somewhat different from the non-failing coating. Although most of the spectral peaks of the samples were similar, those of the failing coating produced a relatively large band associated with hydrogen-oxygen stretching with a peak near 3400 $cm^{-1}$; the spectra of the non-failing coating produced a much smaller band in the same area. The hydrogen-oxygen band is generally large in spectra of aged alkyd coatings, but the failed coating was less than a year old.

The site investigation and the laboratory analysis indicated that the cracking and delamination of the white silicone alkyd topcoat was most likely a defect in the coating material itself. There was no evidence of any application deficiencies that would cause the cracking and delamination, and no forensic evidence of chemical attack.

## Summary of Facts and Failure Mechanism

The silicone alkyd topcoat was delaminating from the majority of the free-

*Continued*


*Fig. 3: The silicone alkyd beneath the black letters and markings did not delaminate or peel.*

board area. According to shipyard personnel, the entire freeboard area was topcoated with the white silicone alkyd coating. After the silicone alkyd topcoat was allowed to dry, red and blue stripes of silicone alkyd coating and black lettering were applied over portions of the topcoat. In all areas where the white silicone alkyd coating was marked with a different silicone alkyd (red/blue striping or black lettering), no cracking or delamination was noted. There was also a small area noted where a spot of gray deck coating was inadvertently applied to the freeboard; however, the silicone alkyd coating under it had good adhesion.

If the silicone alkyd coating had been applied in inclement weather or over a contaminated surface, delamination of the coating would have occurred even in areas where it had been subsequently marked with striping and lettering. In fact, additional topcoat thickness would likely have exacerbated the problem by adding stress to the underlying layers. In this case, however, the addition of the markings (red/blue stripes and black lettering) appeared to prevent the cracking and delamination of the white finish coat.

Chemical attack of the silicone alkyd topcoat was also unlikely. Although alkyd coatings are prone to chemical attack by both solvents and alkaline materials, no physical evidence of chemical attack was observed. Solvent attack of the alkyd will generally expand the coating, causing it to form irregularly shaped blisters. Attack by solvents generally does not lead to the cracking phenomenon that was noted on the freeboard.

Similarly, no alkaline attack was observed forensically. When alkaline attack of an alkyd coating occurs, a carboxylic acid salt is produced that forms a characteristic band on the infrared spectrum. No such band was evident in the spectra of the failing finish coat. Additionally, the red and blue sili-

*Continued*

cone alkyd coatings would be equally susceptible to the damage by exposure to chemical agents, yet they displayed no problems.

The white silicone alkyd topcoat was extremely brittle in the areas of delamination. Extreme brittleness is typical for a silicone alkyd under normal exposure conditions until it has aged for more than 10 years. The brittle, cracking finish coat was similar to alkyd coatings that have oxidized for 20 years or more. Alkyd coatings cure by a reaction with oxygen in the air (oxidation). This reaction continues throughout the life of the coating until the resin system is fully oxidized, unless it is overcoated. (The oxygen necessary to further the cure is hindered from reaching the coating.)

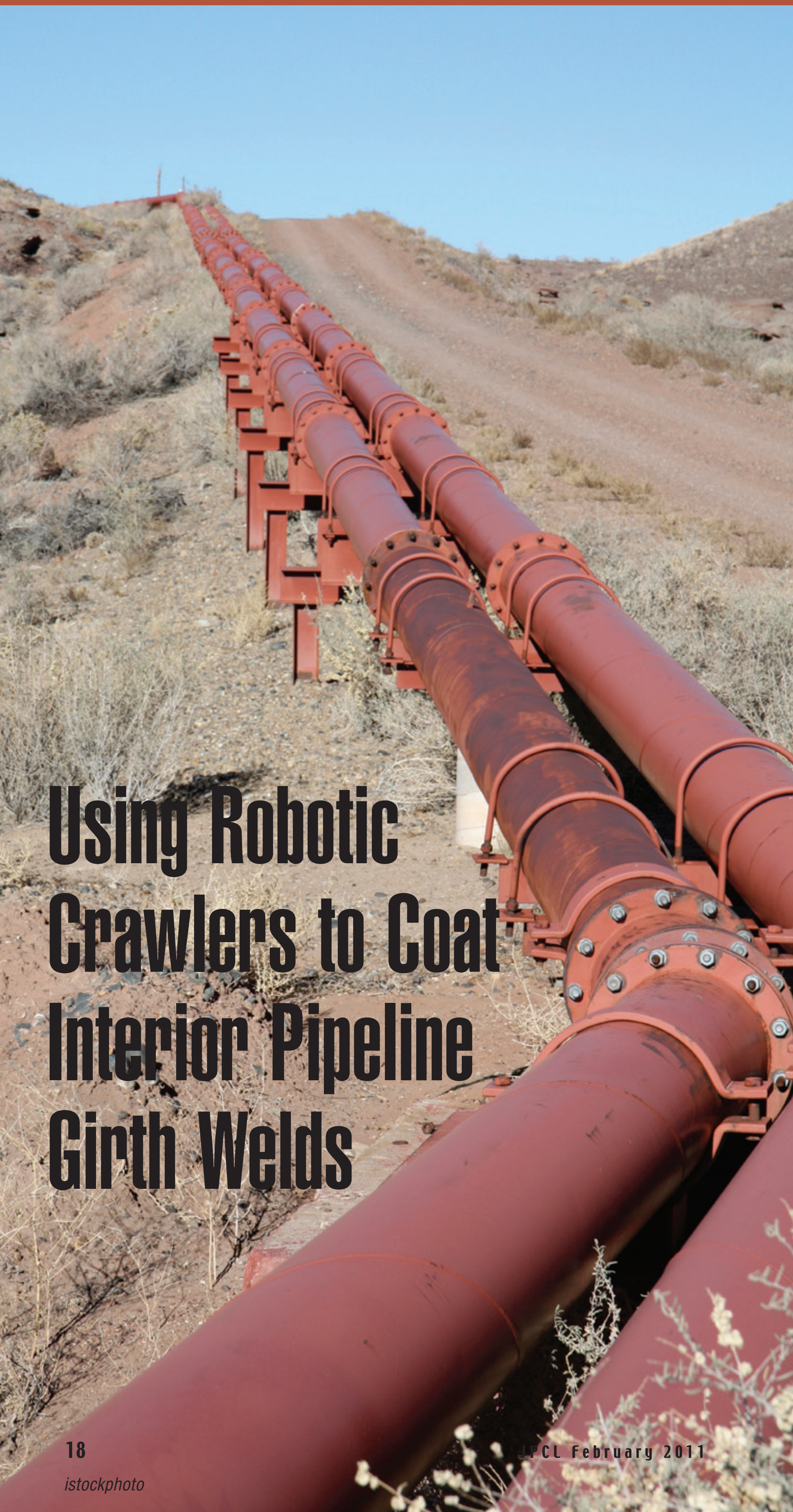
The white silicone alkyd finish coat used on the freeboard area appeared to have oxidized or weathered in an unusually short time, to the point where it became brittle, cracked, and eventually delaminated. In areas where the coating was topcoated with another colored coat of silicone alkyd (red/blue striping or black lettering), no cracking or delamination occurred, likely because the cure of the coating was inhibited due to reduced (limited) access to oxygen.

The reason for the accelerated oxidation of the finish coat was not determined. Accelerated cure can be the result of improper formulation, usually related to the amounts and types of driers used in the coating formulation. Again, alkyd coatings cure by a reaction with oxygen in the air. The reaction is quite slow, but is intentionally accelerated by the use of chemical driers. The chemical reaction continues extremely slowly after the initial cure. If improperly formulated, driers can cause the coating to rapidly continue the curing reaction until the coating becomes brittle. The coating then develops excessive internal stresses that will eventually cause it to crack and delaminate.

## Repair of the Failure

Repair of the coating was limited to the boot top area of the vessel where premature cracking was present. Since the silicone alkyd coating on the topside was not cracking and was well adhered, no repair was performed in that area. The failed topcoat on the boot top was removed by brush blasting using a fine abrasive and 60 psi blast nozzle pressure. An additional intermediate coat of epoxy was then applied to all areas where the topcoat was removed by brush blasting. A new batch of the silicone alkyd paint was then applied to the entire area, and there have been no reports of additional failure.

**JPCL**



# Using Robotic Crawlers to Coat Interior Pipeline Girth Welds

By Mana H. Al-Mansour and Abe Suller,
Saudi Aramco

The construction of pipelines normally starts with coating pipes in the shop. Exterior coating is a general requirement. If the pipeline requires interior coating, the interior is also coated in the shop, but the interior and exterior ends are left uncoated to allow for girth welding in the field. The uncoated portion is called cutback. After the pipe pieces are positioned over the ditch, they are girth welded together in lengths of about 200 to 500 meters, forming pipe strings. After stringing the pipes, the cutbacks are coated both externally and internally, when required.

To field coat the interior of girth welds of onshore pipeline strings, remote-controlled robotic crawlers are used. Crawlers are especially useful when the pipe diameter is small and not spacious enough for abrasive blasters and coating applicators to work safely. In the past, the robotic crawlers were not equipped with sufficient testing tools to verify the quality of coating application. Because leaks developed in as short as one year after construction, the crawlers were improved to integrate complete testing tools for every weld area coated. The methods of coating application and align-

*Editor's Note: This article previously appeared in* Protective Coatings Europe.

istockphoto

ment of the crawler to the weld have also been improved. With these improvements, premature leaks at the weld areas have been minimized and are almost negligible.

This article describes the development of these robotic crawlers and details the sequence of preparing and coating internal girth welds today.

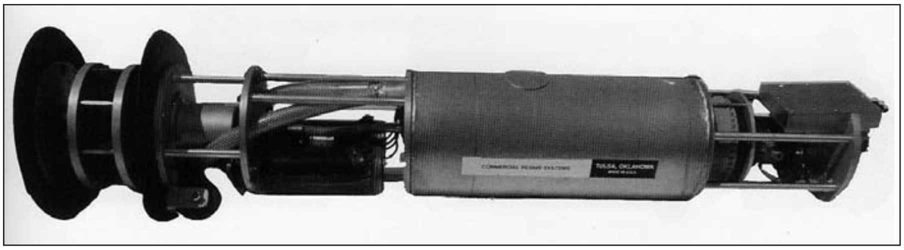


Fig. 3: Simplified photo of a centrifugal blast cleaner with two inflatable seals.

Fig. 1: Cutback portion that was abrasive blast cleaned. The lighter portion of the coating shows what was "feathered" (roughened).

### Old Method of Robotic Crawler Operation

In the early 1980s, the first generation of robotic crawler systems started to be used in the Middle East. The system was brought about by the need to coat the girth weld interior of pipes after the stringing procedure in the field. In the beginning, the crawler was equipped with crude tools with no thought to the disastrous implications of poor surface preparation and coating application. The robotic crawler was equipped with a weak radio-active isotope, and a hand-held isotope detector was used to align the equipment to the girth weld. However, detecting the isotope and, subsequently, accurately positioning the blasting/application heads were subject to human error, which resulted in incomplete coating of the cutbacks and eventually to premature pitting and leaks.

Because the robotic crawler was not equipped with testing tools to check the quality of the coating work, unreliable coating application continued until leaks developed in as little as a year after coating application. Because of the leaks, an alternative method of full-encirclement steel sleeve jointing was used, but at the same time, the robotic crawler was being upgraded and modified.

### Improvements Made on the Robotic Crawler

The upgraded version of the robotic crawler has some significant changes to ensure a reliable coating application. Not only has the robotic system changed,

Fig. 2: A typical pipe string being prepared for the launching of a robotic crawler.

but also the understanding of the capability of the robotic has changed. The upgrade and its use are a far cry from the old days when all coating applications were deemed as meeting the specification without the benefit of quality control. Now there are controls for dry film thickness (DFT), holidays, and appearance. The welding process was also designed to prevent "excess root pass penetration," limit the height of the weld root, and prevent weld spatters. The improvements can be summarized as follows.

- The use of a real-time camera to align the equipment and tools mounted on the crawler. Previously, isotope detection was used but was not completely effective.
- Introduction of a holiday detector and DFT gauge to check coating quality.
- Capability for liquid epoxy and polyurethane coatings in addition to FBE.
- Increase in the band width of the blast cleaning and coating application from 4 in. to 8 in., allowing wider cutbacks to be coated properly.
- Ability of the operator to select the blast cleaning and vacuuming cycles required as seen by a real-time camera.
- Direct transmission of the view of the actual operation to the operator via monitor, using a real-time camera.
- Redesigned coating system to allow more coating to be applied at the 12 o'clock position. In the past, application at the top was thin while the coating at the bottom had excess thickness.
- Upgraded fusion-bonded epoxy (FBE) coating system to avoid overheating at the delivery lines and clogging at the application head.
- Holiday repair by applying a liquid coating after sweep blasting the whole cutback. This sequence avoids having to cut out welds whenever there are holidays in the coating.

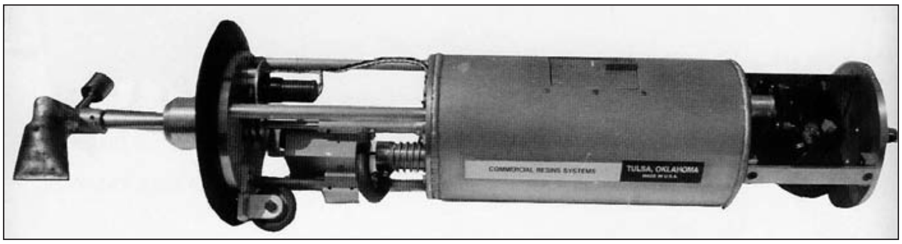



Fig. 4: Simplified photo of an FBE coating applicator.

### Current Procedure

The internally coated pipes are sent to the site with their ends covered or capped to prevent contaminants from reaching the bare cutbacks. To ensure proper coating application, the cutbacks on both ends of the pipe are once again abrasive blast cleaned to Near-White Metal (Sa 2½). The cutback is normally about 2 to 3 in. from the pipe end. Garnet abrasive is the preferred abrasive. Conventional air blasting equipment is used by pointing the nozzle at the cutback. For the internals, a rubber bung is placed further inside to prevent damage to the existing coating on the regular pipe body and for selective cleaning and alignment.

After the internal has been blast cleaned to Near-White Metal, the rubber bung is moved about half to one inch inward on the coated pipe portion for feathering (roughening). This step ensures proper adhesion between the existing coating and the coating that the robotic system will apply (Fig. 1). Several pipes are arranged and lined up one after the other for blast cleaning in preparation for the next step.

Girth welding follows the blast cleaning. A number of pipes are welded until the length of the welded pipes reaches 200 to 400 meters—the pipe string. Welding is a meticulous operation with specific requirements to avoid excess metal penetration and weld spatters. Semi-automatic or fully automatic welding equipment is used and supported with an internal line-up clamp with backing shoes. Before welding the pipe, a pup piece (a trial piece) is used for trial and tune-up. After welding, the girth weld is X-rayed to check for metal flaws. Normally, the welding is performed by a different contractor from the robotic crawler contractor. After a pipe string has been welded, tested, and approved, it is ready for the robotic crawler system.

A series of robotic crawlers, with specialized functions, are launched in sequence at one end of the pipe string (Fig. 2). The crawler does its intended function on each bare cutback/girth weld area until it reaches the other end, where it is taken out.

Fig. 5: Heating of a pipe string girth weld area.

The first robotic crawler (Fig. 3) is equipped with abrasive blast cleaning equipment and supported with video cameras, lights, and a vacuuming system. The purpose of the camera is to make a quick evaluation of the height of the weld cap and severity of weld penetration. The camera is also used to determine the presence of weld spatters on the pipe bottom position. The video images are sent in real time to the monitor, which the operator watches so that he or she can make adjustments if needed. For a clear image, the lighting system is adjusted and positioned properly on the crawler to assure that the lighting is uniform.

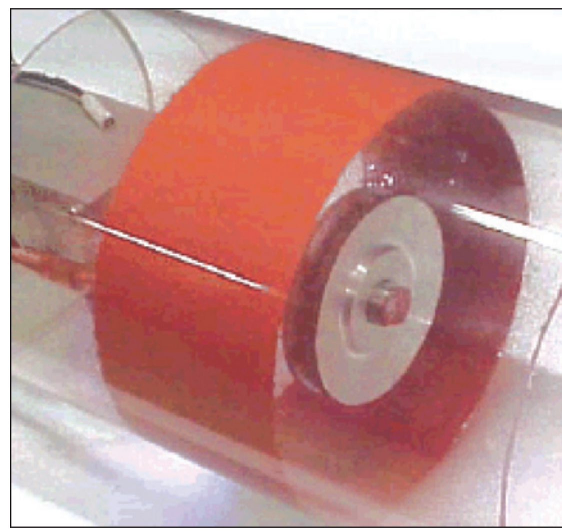


Fig. 6: Application of liquid coating on a clear pipe with the use of a rotary atomizer.

The same video camera is used to align the blast cleaning machine to the girth weld. When the camera is aligned to the girth weld, the operator instructs the crawler to move at a pre-programmed distance so that the blasting equipment will be aligned to the girth weld area. Centrifugal blast cleaning is used, mainly to remove welding debris such as weld flux, slag, smoke, soot, and loose spatters. To enable abrasive recycling without affecting the surface profile, steel grit is used. Two inflatable seals are used to confine the blast cleaning within the girth weld area.

After blast cleaning, the vacuuming system of the crawler scoops and removes abrasives, slag, spatters, and

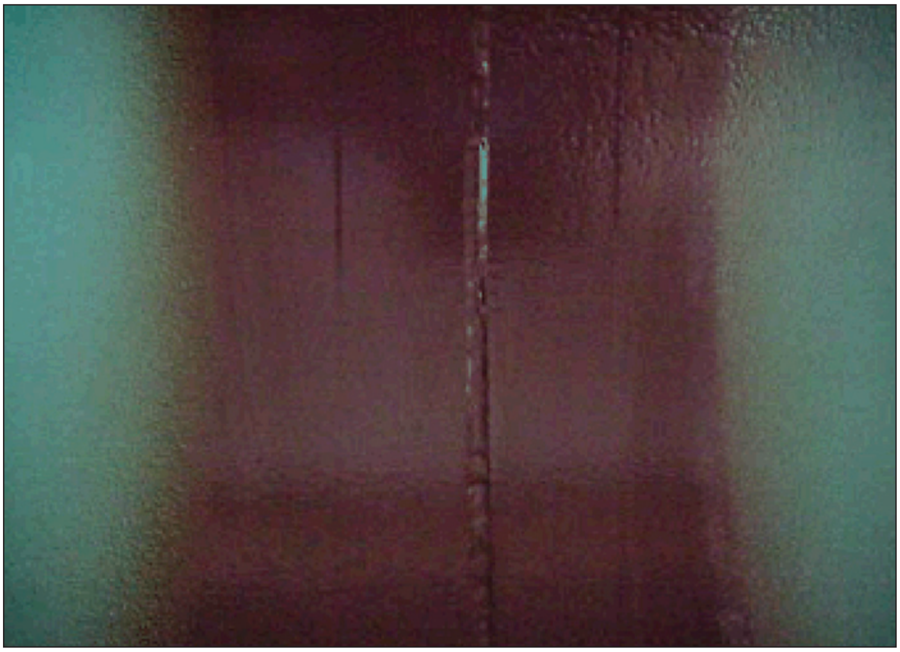


Fig. 7: Close-up of liquid coating applied on girth weld area of carbon steel pipe.

other foreign particles from the cutback bottom. These materials are then passed through separators and screens within the crawler to retain clean steel grit for reuse while segregating slag, flux, and fines for disposal. Two separate holding tanks are used. The video camera is once again used to determine if the used abrasives and other particles are completely removed from the cutback. The blast cleaning and vacuuming operations are repeated if the results are not satisfactory. If the weld is determined "uncoatable" because of sharp roots of excessive penetration, the weld is cut off, and welding is repeated. (Fortunately, there have been no reports of "uncoatable" welds to date.) Blast cleaning and vacuuming are performed successively on all bare cutbacks of the pipe string. When the robotic crawler reaches the opposite end of the pipe string, it is removed and signals the use of the next robotic crawler.

The second robotic system is equipped with the coating application equipment, coating material, camera, and lighting system. Either FBE or liquid coating can be applied, depending on the need and the application equipment used. (See Fig. 4 for the FBE coating applicator.)

Before regular coating application, a pup piece is coated with the robotic system for tune-up. The applicator is adjusted for the required DFT, uniformity, and fan pattern (particularly for liquid coatings). After adjustment, the robotic is ready for the pipe string.

The robotic crawler is introduced at the launcher end of the pipe string. Just like the first crawler, the lighting system of this crawler is used for alignment to the girth weld and as a guide to the operator. However, this crawler moves in reverse so its wheels do not damage the wet/tacky coating. The application of FBE requires pipe exterior pre-heating and post-heating with an induction heater (Fig. 5). Before the coating application, the machine is aligned, with the use of the camera, to the girth weld. Once the camera is aligned, the crawler moves to the pre-programmed distance to align the coating application nozzle/head to the girth weld area. The coating is sprayed on the entire circumference covering the cutback areas, including the girth weld and feathered overlap. (See Fig. 6 for an inside look at the coating application.) The camera captures any visible defect and sends it, via remote monitor, to the operator for remedial action.

The remaining blast cleaned areas are coated successively until the robotic crawler reaches the other end of the pipe string (Fig. 7).

An FBE coating is cured for inspection at a temperature below 80 C, but the curing temperature of a liquid coating varies, depending on its formulation. After the coating has cured enough, another robotic crawler that carries the quality control tools is inserted in the launcher end. This crawler is the final one regularly used. In addition to video cameras and a lighting system, the crawler is equipped with a holiday detector and DFT gauge (Fig. 8). Pre-programmed control for the cutback area is again performed with the camera. The camera is used to span the circumference of the coated pipe for remote visual inspection.

DFT is measured on the four quadrants (top, bottom, and sides) of the pipe, at about one inch from the girth weld. The operator views the measurement readings in real time, and they are printed automatically for documentation. The camera is also used here to identify the weld numbers where the DFT measurements were taken.

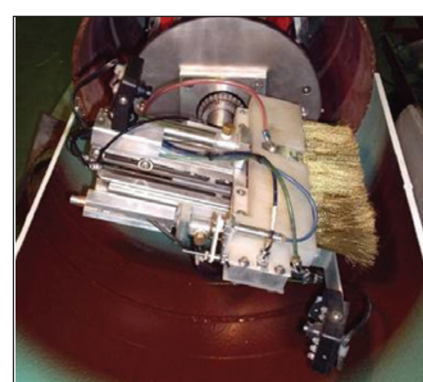


Fig. 8: Setup of a typical holiday detector

High voltage holiday detection is done by grounding a very thin and flexible cable to the bare end of the pipe string. The other end of the cable is connected to the holiday detector that is carried

Fig. 9: Close-up of steel that was perforated in service due to a coating holiday.

along with the robotic crawler as it travels inside the pipe string—which could be longer than 500 meters. To face this challenge, the wire is Teflon-coated, and a wire spool is employed. The voltage is 100 volts for every mil of DFT. A copper wire brush that completely circles the coated girth weld area is used as the conductor. The brush is wide enough to sweep the whole bandwidth of the coated area in one rotation. If a holiday is detected, a signaling device, normally a flashing light, alerts the operator.

Holidays are not allowed because they could lead to severe, localized corrosion (Fig. 9). The change of microstructure of the steel pipe, as a result of heat from welding and potentially slightly anodic welding material, could also exacerbate the severity of corrosion. If holidays are detected, the robotic crawlers with blast cleaner and coating applicator are used again. First, the robotic crawler with blast cleaner roughens the existing cutback coating on the whole pipe circumference. After roughening, the robotic crawler with the liquid coating applicator is used. A compatible and suitable liquid coating is sprayed on the whole circumference. Instead of FBE, liquid coating is used to avoid the use of heat, which could damage the existing coating. (Additionally, a higher curing temperature would be needed to compensate for the DFT of the existing FBE coating.)

## Conclusions

The current robotic crawler technology is an improved version of the technology from the 1980s, which had resulted in widespread premature leaks in the pipelines. The improvements in the process and methodology of robotic crawler systems in coating girth weld interiors have tremendously decreased the leaks and severe corrosion previously found in water injection pipelines. With proper equipment on the improved robotic crawler, coupled with proper welding procedure, premature pipeline leaks can be avoided because the coatings can be applied holiday-free. The improved system has restored confidence to pipeline owners, so much so that the robotic crawler system is now also used on pipelines constructed offshore.

It should be noted that other benefits come from the improved robotic crawler technology in other ways. Because of the considerable reduction in premature pipeline leaks, the current systems can help provide pipeline owners with savings in labor and money. Futhermore, the improved robotic crawler can be used to apply liquid coatings as well as FBE.

Different generic coating types can be applied by changing the coating application machine and the attachments that go with it. And pipeline construction time has been reduced through more efficient use of robotics and remote control mechanisms.

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JPCL

# Painting Practices for Floating Production, Storage and Offloading Systems

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The use of floating production, storage and offloading (FPSOs) vessels has rapidly increased in recent years. The advantage of FPSOs over other floating production facilities is the ability to store produced fluids, which can be later offloaded to a shuttle tanker. The components of an FPSO include the vessel (which is either a new build or a tanker conversion), the mooring system, the processing facilities, and the storage tanks. A riser system is usually attached to the FPSO to permit produced fluids from subsea fields to be processed on the topsides equipment. FPSOs differ from mobile ships in that they are positioned in a stationary condition over the production field for years at a time.

An FPSO is a complex structure when it comes to corrosion control. Numerous types of coatings are utilized to protect surfaces from corrosion. Cathodic protection is included to protect the external hull from corrosion caused by the seawater. Cathodic protection is also applied to the internals of many tanks that can contain water such as ballast, slop, and cargo tanks. This article will focus primarily on the coating requirements at the new build stage for the FPSO hull, ballast tanks, cargo tanks, and topsides equipment. This article is not intended to be a comprehensive discussion of all companies' FPSO painting practices but is an overview based on those of the authors' company and their knowledge of common industry practice.

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## Method of Corrosion Protection for FPSO Hulls

Generally, the preferred form of corrosion control for an FPSO hull exposed to seawater is a combination of coatings and cathodic protection. The offshore industry has long-term experience selecting and applying hull coatings. Typically, the hull coating system includes various layers of epoxy paint. The epoxy needs to be compatible with

Photos courtesy of the authors.

the preconstruction primer (PCP) normally applied during hull plate fabrication. Often, an antifouling topcoat is used. Not all operators use an antifouling paint because its performance in eliminating fouling under static conditions is not well documented and proven. However, it is commonly accepted that the antifouling paint may not fully eliminate all marine fouling but will assist with underwater hull inspection by allowing easier fouling removal.

Finally, the hull coating system needs to be compatible with the cathodic protection system. Typically, a cathodic protection potential of -1.100 volts (versus Ag/AgCl reference electrode) is accepted by the industry as the limit where hull coating damage via cathodic disbondment may occur. Any cathodic protection potential more negative may impact the hull coating system. If the hull cathodic protection system is by galvanic anodes, coating disbondment is not normally an issue because the anode cannot produce values more negative than -1.100 volts. However, if an impressed current cathodic system is used, close monitoring of the cathodic protection system is required because quite negative potentials can be developed. The key point is that the compatibility of the hull coating system with the expected cathodic protection should be confirmed.

**Surface Preparation**

During fabrication of an FPSO hull, several different forms of surface preparation will be utilized. Often, these are referred to as primary and secondary surface preparation. Table 1 presents an example of various surface preparation procedures. The “block stage” construction represented in Table 1 will be discussed later in this article.

**Primary Surface Preparation**

Typically, the hull structural steel plates and sections fabricated at the yard, as well as other plates and shapes, would be shotblast cleaned to Sa 2½ and immediately coated with a single coat of an inorganic zinc primer PCP. The PCP should be qualified for the welding procedures and should provide short-term corrosion protection until secondary surface preparation and topcoat application.

**Secondary Surface Preparation**

Generally, the secondary surface preparation is completed after fabrication. The abrasives normally used for secondary surface preparation work are generally non-ferrous. Abrasives should be able to provide the average surface profile on the blast-cleaned surface as specified by the coating manufacturer. Normally, specific surfaces require extensive removal of the PCP during the secondary surface preparation. Typical surfaces that generally require extensive removal of the PCP include ballast water tanks, slop tanks, off-spec tanks, deckheads and bottoms of cargo tanks, bottoms of diesel oil tanks, methanol tanks, hydraulic oil tanks, fresh water tanks, potable water tanks, and jet fuel tanks.

Thus, the surfaces that normally need extensive PCP removal are the tanks. Often for other areas, intact preconstruction primer may be sweep-blasted, provided that it can be demonstrated that the required anchor profile is present before applying the coating system.

*Fig. 1: Example of a hull block during fabrication*

### Table 1: Typical Surface Preparation Requirements

| Symbol | At Block Stage | | At Dock Side & Quay Stage | |
|---|---|---|---|---|
| | **Pre-construction primer (PCP)** | **Burnt / damaged spots on PCP (1)** | **Block joint welds** | **Burn-through / damaged areas** |
| A2 | Sweep Blasting – 40% removal (2) | Sa 2½ | Sa 2½ | SSPC-SP 11 |
| B3 | Sweep Blasting | Sa 2½ | Sa 2½ | Sa 2½ |
| B2 | Sweep Blasting | Sa 2½ | SSPC-SP 11 | SSPC-SP 11 |
| T3 | St 3 (3) | St 3 | St 3 | St 3 |
| NP | No Treatment | No Treatment | No Treatment | No Treatment |

Notes:
(1) Cut plate edges require grinding to provide radius and remove hardened surface layers before spot blasting to Sa 2½ to achieve the anchor profile.
(2) The entire surface shall receive a heavy sweep blast cleaning targeted at removal of at least 40% of the pre-construction primer.
(3) Visible zinc salts on intact shop primed surfaces shall be treated with a disc sander, wire brush or other appropriate methods.

### Table 2: External Hull Coating Selection Guidelines

| Item | | Shop Primed | Second Preparation | Coat | Generic Name of Paint And Color | D.F.T (μm) |
|---|---|---|---|---|---|---|
| Flat Bottom, Side Bottom Below the Tow Draft | Before Erection | Yes | B3 | 1<br>2<br>3<br>4<br>5 | Marine Epoxy (Aluminum)<br>Marine Epoxy (Bronze)<br>Marine Epoxy (Aluminum)<br>Epoxy Tie-Coat (Gray)<br>Slow Polishing A-F ( Red) | 175<br>175<br>175<br>75<br>125 |
| | Before Launch | | | 6 | Fast Polishing A-F (Std. Blue) | 125 |
| Side between the Tow Draft Line and Design Draft Line | Before Erection | Yes | B3 | 1<br>2<br>3<br>4 | Marine Epoxy (Aluminum)<br>Marine Epoxy (Bronze)<br>Marine Epoxy (Aluminum)<br>Epoxy Top Coat (off Blue) | 175<br>175<br>175<br>75 |
| | Before Launch | | | 5 | Epoxy Top Coat (Blue) | 75 |
| Topside and Fender Area (Above Design Draft Line) | Before Erection | Yes | A2 | 1<br>2<br>3<br>4<br>5 | Inorganic Zinc Primer (Olive)<br>Epoxy Mist/Tie Coat (Red)<br>Marine Epoxy (Aluminum)<br>Marine Epoxy (Bronze)<br>Epoxy Top Coat (off Red) | 75<br>30<br>200<br>200<br>75 |
| | Before Launch | | | 6 | Epoxy Top Coat (Red) | 75 |

**External Hull Coating Selection**

Because the FPSO hull is normally fabricated in blocks, different coating systems are needed for different sections. Table 2 shows an example of the different generic coating systems that can be used for various parts of the external hull. Also covered is when during the fabrication sequence the coating should be applied: either before erection or before launch. As discussed earlier, the secondary surface preparation needs are also covered. For much of the

*Fig. 2: Example of coated hull*

**Table 3: Example of Coating Description Generic Products**

| Generic Name | Coating Description | Product | Remarks |
|---|---|---|---|
| Pre-Construction Primer (PCP) | Thin film, weldable inorganic zinc shop primer | | |
| Epoxy Zinc Rich | Re-coatable, zinc epoxy primer with scribe creep resistance | | |
| Inorganic Zinc Primer | Inorganic zinc silicate primer with 85% zinc in dry film | | |
| Marine Epoxy | Pure epoxy coating qualified to NORSOK requirements for ballast water tanks, capable of 150 µm minimum single coat build | | |
| Slow Polishing A-F | TBT free, slow self polishing copolymer anti-fouling as 1st coat capable of 100 µm minimum single coat build | | |
| Fast Polishing A-F | TBT free, fast self polishing copolymer anti-fouling as 2nd coat capable of 100 µm minimum single coat build | | |
| High Build, Epoxy | Low VOC, epoxy intermediate coat, matte finish, capable of 200 µm minimum single coat build | | |
| Epoxy Phenolic | High solids, chemically resistant epoxy phenolic tank lining capable of 150 µm minimum single coat build | | |
| Silicone Acrylic | High heat silicone modified with acrylic available in colors | | |
| Fireproofing | Intumescent epoxy mastic fireproofing with nonmetallic reinforcement capable of project specified thickness/rating | | |

external hull, the coating is typically completed in the block stage (e.g., Fig 1).

As sections of the blocks are fabricated, they are typically individually coated in a controlled environment. This approach normally leads to a high-quality coating application. Figure 1 also shows the presence of two sacrificial anodes that will help provide the needed long term corrosion protection. Figure 2 shows a completed hull with an antifouling coating applied. Numerous anodes are also visible. A tug is also present, which indicates that the hull is moved several times during fabrication.

### Generic Coating Selection

To assist with coating selection, the approach used is to list the specific product to be utilized for the work on a form submitted by the paint supplier. This form is reviewed and finally approved. Only the specific products listed may be used. Table 3 is an example of the form used to list the approved coatings. For each project, the approved paint vendors supply the specific product names and numbers as required by the specification. The submittals are reviewed to be sure reasonably equivalent high-performance coatings are being proposed. This process may take several iterations to assure high-quality coatings are being proposed. Once the specific products from the approved suppliers are fully accepted, the contractor can proceed with bidding the coating supply. Modifications from the approved product list cannot be made by the contractor without an approved deviation request. The deviation request would normally describe the following.

- The proposed change
- Why the change is being proposed
- Any cost or schedule implication

If approved, the deviation request would become part of the project documentation. As part of the lessons learned process, deviations are normally reviewed and considered for future incorporation into the corporate practices.

## Method of Corrosion Protection for FPSO Tanks

An FPSO will normally contain several types of tanks, including cargo, slop, water, methanol, diesel, and other chemical tanks. Coatings for each of these types of tanks should be evaluated independently because the tanks have different requirements. For example, some tanks typically need only tank bottoms coated; others need all surfaces; and some have tank bottoms and tank tops coated.

Table 4 summarizes a suggested coating approach for

**Table 4: Typical Tank Lining Generic Coatings**

| Type of Tank | Surfaces Coated | Generic Coating | When during fabrication is coating applied |
|---|---|---|---|
| Ballast | All | Aluminum pigmented marine grade pure epoxy | Deckhead and sides during block construction. Bottom and lower 1.5 m at final stage after block welding. |
| Slop & Off Spec | All except bottom and lower 1.5 m | Aluminum pigmented marine grade pure epoxy or epoxy phenolic | Deckhead and sides during block construction. |
| Slop & Off Spec | Bottom and lower 1.5 m | Epoxy phenolic | At final stage after block welding. |
| Water | All | Aluminum pigmented marine grade pure epoxy | Deckhead and sides during block contruction. Bottom and lower 1.5 m at final stage after block welding. |
| Methanol | All | Inorganic zinc silicate | |
| Cargo | Bottom and lower 1.5 m | Epoxy phenolic | At final stage after block welding. |
| Cargo | Deckhead and down 2 m only | Aluminum pigmented marine grade pure epoxy | During block construction. |

**Table 5: Generic System Description of Specified Coatings**

| A SP 10 | C SP 10 | D SP 5 | E SP 10 | I SP 5 | J SP 10 |
|---|---|---|---|---|---|
| Inorganic Zinc Silicate | Epoxy Zinc Rich | Thermal Spray Aluminum | Inorganic Zinc | Temp. Resistant Epoxy | Inorganic Zinc Silicate |
| 3B Epoxy | 3B Epoxy | Silicone | Silicone | Temp. Resistant Epoxy | |
| HB Epoxy | HB Epoxy | | | | |
| Urethane | Urethane | | | | |

several types of tanks. The project specification should include more details on the surfaces, coatings, number of layers, and surface preparation. It is usually best practice to coat the tanks after all internal and external welding and fit-up are completed. However, that approach would considerably slow down fabrication, so some trade-offs are necessary while not impacting quality. For example, during block-to-block welding, scaffolding and other equipment are normally necessary inside the tanks. This equipment is typically located on the tank bottom, sitting on the tank floor. Thus, a coating on the floor would get damaged. Therefore, it is suggested to consider installing the bottom coating after the block welding has been completed. The shell and deckhead coatings, if required, could be part of the standard block coating activity.

### Block-to-Block Weld Coating

Another critical tank coating issue involves coatings for the block-to-block weld. During the construction process, fabricated hull blocks are welded together and then combined with other blocks via welding. The blocks are typically coated, but the weld seam area is left uncoated. After the blocks are all welded together, the uncoated seams are then coated. Typically, the fabrication yards want to utilize a power tool method for surface preparation for the weld seams because mobilizing abrasive blasting equipment is difficult. As with any coating, the surface preparation of these weld seams is critical to help achieve good coating performance. Most tanker operators at some time have experienced premature coating breakdown at the weld seams with newly constructed vessels. Thus, lessons learned have shown to require a better surface preparation than a power tool process. It is suggested to consider use of vacuum blasting equipment to prepare the weld seam. This approach will provide an excellent Near-White or better surface preparation while minimizing over-blast damage and cleanup.

### Cathodic Protection for Tanks

It is normally considered standard practice to use anodes in tanks that contain water or could have water bottoms. These tanks include ballast, cargo, water, and slop tanks. The cargo tanks may have water only on the bottom, so anodes would be used to cathodically protect only the bottom and perhaps 1 to 2 meters up, normally to the top of the hull bottom reinforcements. The other tanks may contain water on all surfaces (except the deckhead), so anode calculations should consider all potentially water-wetted surfaces. It should be noted that there may be Class Society stipulations on allowable anode types and locations. Normally, zinc anodes installed are permitted. For more details, investigation of the Class requirements is suggested.

**Inspection for Tank Coatings**

Details on inspection requirements will be covered later in the article. In general, however, holiday testing is an important portion of the quality needs for the tank linings. When the block construction process of the FPSO is considered, conducting a full holiday test is quite difficult. If holiday testing can be done without damaging the tank lining, it would be beneficial. However, if scaffolding, bucket truck, or some other form of lifting device is going to be used, it may damage the coating, thus making the inspection process force additional coating repairs. An alternative approach is to consider focusing on the lower portions of the tank that can be reached by hand. These may include the bottom and around 2 meters up. It should be noted that the anode design does consider some damage present for immersed portions of the tanks. Also, it would be good practice to enter the tanks after a year or so and repair any damaged areas. There are also unique coatings available on the market that allow for ultraviolet examination of fluorescing coatings.

## Method of Corrosion Protection for Topsides Equipment

Topsides equipment requires robust coatings because it is subject to the marine environment and possibly elevated temperatures. There is also insulated equipment; thus, corrosion under insulation can be an issue. It is somewhat common knowledge that care should be exercised when coating insulated equipment to help minimize and even eliminate corrosion under insulation from occurring. Some equipment is fabricated from stainless steel and may need coating. Certain equipment may be hard to shut down for future maintenance and may need an extremely robust coating such as thermal spray aluminum (TSA). Table 5 (p. 32) presents a generic description of some of the coating systems that can be used. The coating systems are described by a letter. Thus, the painting practice describes the required coating systems by letter designation. This will be covered later in the article.

**Table 6: Coating Requirements for Carbon Steel Fabricated Piping**

| Carbon Steel Fabricated Piping | | |
|---|---|---|
| Uninsulated, to 110 C | A or C | ExxonMobil Gray |
| Uninsulated, 110 C to 200 C | D or I | For I, Coating Manufacturer's Standard Gray |
| Uninsulated 200 C to 400 C | D or E | For E, Coating Manufacturer's Standard Aluminum |
| Insulated, to 200 C | I or D | No Color Requirement |
| Insulated, 200 C to 400 C | J | No Color Requirement |
| Insulated, Cyclic Service | D | No Color Requirement |

**Table 7: Coating Requirements for Carbon Steel Vessels**

| Carbon Steel Vessels | | |
|---|---|---|
| Uninsulated, to 110 C, Including Supports & Skirts | A or C | ExxonMobil Gray |
| Uninsulated, 110 C to 200 C | D or I | For I Coating Manufacturer's Standard Gray |
| Uninsulated, 200 C to 400 C | D or E | For E, Coating Manufacturer's Standard Aluminum |
| Insulated | D | No Color Requirement |

**Coating for Topsides Piping**

Table 6 shows some typical coating systems for topsides piping. The typical coating system used in an offshore marine exposure for uninsulated piping operating up to 110 C is shown for System A or C. System A is the standard, and the use of the zinc-rich epoxy-primed System C can only be substituted for inorganic zinc silicate System A as a deviation request from the contractor. It should be noted that within company practices for painting an FPSO, there are many other coating systems used; however, this discussion is primarily focused on the common ones.

If uninsulated piping operates above 110 C and up to 200 C, System D or I can be used. The two-coat paint system (I) is more common than the TSA coating system (D) because application of the TSA to the weld joints is difficult and not always practical. Insulated piping that operates up to 200 C is coated with System I or D. Insulated piping that operates above 200 C and up to 400 C is coated with a single layer of inorganic zinc silicate (System J). For insulated piping subject to cyclic service, TSA (System D) is specified under these conditions.

**Table 8: Coating Requirements for Stainless Steel Fabricated Piping**

| Stainless Steel Piping | | |
|---|---|---|
| Uninsulated:<br>Austenitic to 65 C,<br>Duplex to 110 C,<br>Super Duplex to 120 C,<br>Super Austenitic to 130 C | I | Coating Manufacturer's Standard Gray |
| Insulated:<br>Austenitic to 65 C,<br>Duplex to 110 C,<br>Super Duplex to 120 C,<br>Super Austenitic to 130 C | I | No Color Requirements |

**Coating System for Topsides Vessels**

A similar coating approach for vessels has been developed. The coatings systems for uninsulated vessels are identical to those for uninsulated piping. Table 7 lists the standard coating used for vessels. However, TSA is the standard requirement for insulated vessels, regardless of operating temperature. This is practical since the TSA application to vessels is a shop activity. TSA application in a controlled location such as a shop will likely result in a high quality application versus TSA application on piping that entails application in a pipe rack for the weld seams. It is also generally accepted that TSA would be expected to provide excellent long-term protection against corrosion under insulation.

**Coating System for Stainless Steel Equipment**

Based on previous experience and what is considered good corrosion protection practices, all stainless steel equipment is coated. However, the material selection aspect of stainless steel is considered when specifying coatings. According to company and standard industry practice, there are temperature limits above which stainless steels are susceptible to chloride stress corrosion cracking (CSCC). For CSCC to occur, the stainless steel must be subject to chlorides, which are present in the marine environment of all FPSOs; stress; and operation above the temperature limit. The stress can be from operation, design, or residual stresses. Thus, it is likely all stainless steels installed on an FPSO are subject to CSCC when they operate above the temperature limits. Companies have, through experience or lab testing, developed the temperature limits. The company utilizes these limits:

- Austenitic Stainless Steel (i.e., 316 or 304 SS) to 65 C
- Duplex (i.e., 22 Cr Stainless Steel) to 110 C
- Super Duplex (i.e., 25 Cr Stainless Steel) to 120 C
- Super Austenitic (6 Mo Stainless Steel) to 130 C

Many operators choose to use these materials above these limits and depend on coatings to act as a barrier to prevent the chlorides from reaching the surface, thus preventing CSCC. However, the coatings will likely degrade and require renewal during the equipment design life. The company limits the use of stainless steels to the CSCC temperature limits. Thus, in the coating practices, no coating would be shown above these limits. Table 8 presents that practice. Also, experience has shown uninsulated stainless steels may pit in the marine environment. To eliminate this problem, a coating is applied to all insulated and uninsulated stainless steel. A temperature-resistant epoxy is the coating of choice for the various stainless steels.

## Coating Selection and Application Design Details

There are numerous design issues that are described in our company's Global Practices that may help improve the long-term performance of coatings. The goal of the design issues is not only to help improve coating performance but to limit coating application difficulties, thereby improving quality. Some of the major items are listed below.

- All coatings should be suitable for the maximum design temperatures and other conditions of exposure (e.g., cycling).
- The coating system for all parts of the hull and tanks should be based upon a continuous service for the hull's design life.
- The coating system proposed should be of the highest quality available to achieve effective corrosion protection over the hull life with minimal maintenance.
- Proposed coatings systems should be repairable and maintainable in the field if required. A coating repair specification and procedure should be included with project documentation.
- Coating systems should be acceptable to the classification society. A performance qualification or certification document should be provided where required.
- Anodes should be placed as required to provide additional corrosion protection in all tank compartments that could contain water. All class requirements regarding anodes should be met.
- The coating manufacturer should document the compatibility of its product with the material to be stored and the service conditions for all tanks.
- Edges should be ground or machined into a radius of 2 to 3 mm. Three grind cuts of edges normally provide enough of a radius to help improve coating performance.

### Coating Repair During Fabrication

Because the fabrication process for the hull is quite lengthy and includes a fair amount of movement and fabrication of previously coated components, any FPSO new construction coating project should include a detailed explanation of coating repair during the fabrication. Several general coating repair design details that are highlighted in the Global Practice are summarized below.

During block erection welding, previously coated surfaces should be protected from weld spatter and mechanical damage during completion of the block assembly and erection welds. The area of special concern is the tank bottom. Damaged coating areas and uncoated block erection joint areas may need repair. Damaged coating can be removed by abrasive blasting or power disk sanding. The exposed surfaces should be abrasive blasted to Sa $2\frac{1}{2}$ finish (or Sa 3, if required by original coating application). The repair coating should be applied in accordance with the original coating manufacturer's repair procedures. All damaged coating areas removed will likely need to be feathered into the previous coat, and all coatings in the repair system will likely need to be applied to the original specified thickness. The original coats and thickness of repairs should be the same as the coating for the area specified.

Particular care is necessary in repairing the block joint erection areas in the ballast tanks, slop tanks, cargo tank bottoms, and off-spec tanks. It is a good practice to develop a complete procedure for the block joint coating repair for approval with the contractor. The procedure should include access, environmental conditions, surface preparation, stripe coating, paint spraying, and QC requirements. In general, specific details should be covered such as the use of power tool cleaning to

**Table 9: Inspection and Testing Requirements**

| Test Type | Method | Frequency | Acceptance Criteria | Consequence |
|---|---|---|---|---|
| Environmental conditions | Ambient and steel temperature Relative humidity Dew point | Before start of each shift + min twice per shift | In accordance with specified requirements | No blasting or coating |
| Visual examination | Visual for sharp edges, weld spatter slivers, rust grade, etc. | 100% of all surfaces | No defects, ref. specified requirements | Defects to be repaired |
| Cleanliness | a) SSPC VIS 1 or ISO 8501 | a) 100% visual of all surfaces | a) In accordance with specified requirements | a) Re-blasting |
| | b) ISO 8502-3 | b) Spot checks | b) Max quantity and size rating 2 | b) Re-cleaning and retesting until acceptable |
| Salt test | ISO 8502-6 and ISO 8502-9 | a) Immersion surfaces: 6 samples/2000 $m^2$ of fabrication | a) Average conductivity corresponding to $\leq$ 20mg/$m^2$ and Max conductivity corresponding to $\leq$ 30mg/$m^2$ NaCl. | Steam or clean water washing and retesting until entire 2000 $m^2$ test area is acceptable |
| | | b) Atmospheric surfaces: 4 samples/2000 $m^2$ of fabrication | b) Average conductivity corresponding to $\leq$ 30 mg/$m^2$ and max conductivity corresponding to $\leq$40 mg/$m^2$ NaCl | |
| Roughness | Comparator or Stylus Instrument (ISO 8503) | Each component or once per 10 $m^2$ | As specified | Re-blasting |
| Visual examination of coating | Visual to determine: curing, contamination, solvent retention, pinholes/popping, sagging, surface defects | 100% of surface after each coat. | According to specified requirements | Repair of defects |
| Holiday detection | NACE RP0188 Voltage, ref. Table 1 | As per system specification | No holidays | Repair and retesting |
| Film thickness | SSPC PA 2 calibration on smooth surface | SSPC PA 2 | SSPC PA 2 | Repair, additional coats, or recoating as appropriate |
| Adhesion | ISO 4624 using equipment with an automatic centered pulling force, and performed when system is fully cured | Spot checks | Min 5 MPa for epoxy; Min 3 MPa for zinc primed systems | Coating to be rejected |

remove imperfections such as weld spatter and to feather previously coated areas. It is suggested to consider the use of vacuum blasting or mini-blasting of welds and bare steel areas to an Sa 2½ finish without impacting adjacent surfaces. The block joint coating procedure should also include surface cleanliness inspection and testing. Details should be included to cover application of the specified paint system and inspection in accordance with the manufacturer's requirements. Experience has shown that paint application should include three stripe coats in the block joint weld area, with at least the first two applied by brush. Finally, to help assure a high-quality paint job, ballast tanks, cargo tanks, slop tanks, and off-spec tanks should not have been contaminated with saltwater before repairing the block erection joints.

## Inspection for FPSO Coatings

As with any coating job, it is beneficial to achieve a high-quality application. There is an old saying in the coating business: "People do what you inspect, not what you expect." Consequently, most coating engineers focus heavily on the need for inspection of applied coatings. Table 9 presents the coating inspection and testing requirements that should be considered when conducting an FPSO coating project. The table includes the type of test, the specific method, and the test frequency. Also included are the acceptance criteria and the consequence of not complying with the acceptance criteria. The test methods are typical industry standard procedures. Before any coating work is conducted, the inspection and testing requirements should be reviewed by the contractor and all inspectors. The applicator and/or inspectors should prove their capability in conducting all required testing. The facility where the work is being done should have on hand all required inspection test equipment. The inspection test equipment should be in good working order with all calibrations up-to-date. The inspector should be certified by an agency or regulatory body. Before any work begins, a pre-production meeting should be conducted to ensure that all relevant parties understand and agree to the specification requirements.



Finally, all inspection results should be properly documented, and appropriate hold, witness, and monitor points in the inspection test plan should be agreed upon.

## Conclusions and Observations

There are many complex aspects of applying high-performance coatings to a new build FPSO. A well developed project specification is a must to help assure a high-quality coating application. It is suggested that the specification should include the following:

- coating tables spelling out coating needs for various surfaces, including what should not be coated;
- a list of approved coatings;
- a procedure to qualify the coatings;
- the surface preparation requirements;
- inspection and testing requirements in a section that also describes test procedure, frequency, acceptance criteria, and remediation needs;
- safety, health, and regulatory requirements;
- the need to have a preproduction meeting to review the specification requirements;
- the requirement that the contractors develop a coating procedure for approval that will spell out the contractor's work processes; and
- a deviation acceptance and review process.

The above list isn't intended to be all-inclusive but simply summarizes the salient points needed in a well-written FPSO coating specification.

The block fabrication method is intended to simplify construction and may have a side benefit of improving coating quality. But the blocks need to be handled, and coating damage can occur. Also, the blocks need to be welded together, and the weld seams need to be coated. Industry experience has shown that the weld seam coating will provide the least performance when compared to the adjacent coating. Therefore, the use of abrasive blasting to prepare the surface of the weld seams will help assure a longer coating life and better long-term performance. Since adjacent surfaces have been previously coated, care needs to be observed so that the coatings are not damaged by the abrasive blasting. Utilizing a vacuum blasting technique will help prevent damage to the adjacent coating.

Finally, as with most large coating projects, the need for inspection is paramount to help assure a high-quality coating job. The inspectors—and there should be many because the hull is usually quite large—need to be highly experienced in shipyard work. They must be fully aware of the inspection requirements and be given the responsibility to alert the proper staff if they see problems occurring. The inspectors should be certified to the appropriate international standard applicable to where the work is being completed.

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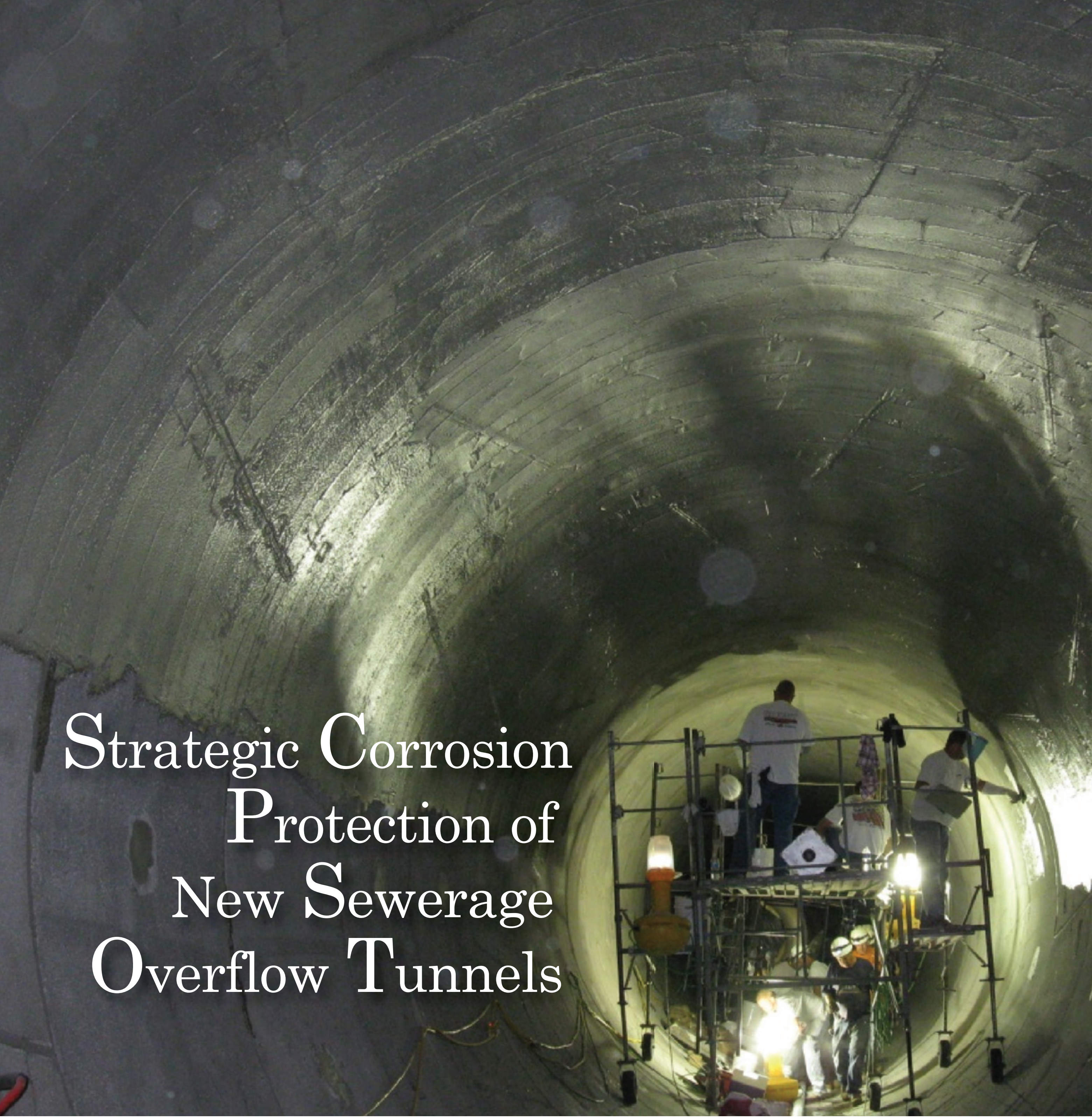

# Strategic Corrosion Protection of New Sewerage Overflow Tunnels

*Editor's Note: This article is based on a paper the authors presented at SSPC 2011 featuring GreenCOAT, the conference of SSPC: The Society for Protective Coatings, held January 31–February 3, 2011, in Las Vegas, Nevada.*

A large Midwestern city, astutely aware of the potential for accelerated corrosion within its wastewater collection and treatment system, prudently embraced the concept of comprehensive corrosion protection for two newly constructed segmented tunnels.

The corrosion protection specified in the tunnel contract documents was a "co-lining system." The cost to install the corrosion protection in both tunnels, including the cost of essential support staff and equipment, was in excess of $30 million. Installation of the co-lining system began

*(Left) Trowel application of corrosion filler surface to crown area of new tunnel.*
*Photos courtesy of the authors*

By Bob Maley,
Corrosion Probe, Inc. and
Steve Kelso,
Sauereisen, Inc.

on the larger tunnel (14 feet in diameter) in early Spring 2007 and continued until late Fall 2007, when the owner evaluated the installation and progress, and eventually abandoned the co-lining system and explored alternative corrosion protection methods.

This article will discuss the pros and cons of the alternative corrosion protection methods considered; the rationale for the system(s) selected; and the challenges overcome during the 10-month installation period.

### Why Tunnels Were Constructed

As in many communities across the U.S., age and capacity issues plagued the city's collection and treatment systems. They could not keep pace with the explosive demands caused by population growth. In addition, when the original systems were designed and built, untreated wastewater from sanitary and storm water sewers was often discharged or overflowed into local waterways, particularly during wet weather. Years ago, such discharges were common and deemed acceptable. In recent times, however, public opinion and the promulgation of environmental regulations to protect the waterways have required system owners to increase treatment and storage capacity for wastewater effluent, thus reducing and ultimately eliminating overflows.

The two new tunnels provide a combined storage capacity of over 34.2 million gallons, which, with numerous other system-wide upgrades and additions, comprise a 40-year, $5.4 billion master plan to eliminate all potential discharges/overflows.

### Initial Design for Corrosion Protection

Recognizing the potential for structural degradation as a result of biogenic sulfide corrosion, the design engineers specified that both tunnels and many of the appurtenant structures be lined with PVC sheeting adhered to the substrate with a structural polymer urethane—a co-lining system. Simply stated, biogenic sulfide corrosion occurs when dissolved hydrogen sulfide is stripped from the wastewater stream as a result of turbulence. Provided sufficient moisture and oxygen exist, sulfur oxidizing bacteria found above the wastewater stream metabolize the hydrogen sulfide gas and react with oxygen to form sulfuric acid. The sulfuric acid subsequently attacks cement paste, as well as uncoated metals, resulting in rapid corrosion. Several months into the installation of the co-lining system, adhesion problems became evident. It was suspected that inadequate surface preparation along with unsuitable application conditions contributed to the adhesion problems. After attempts to remedy the problems were unsuccessful, the city ordered the contractor to cease work until a viable solution could be engineered.

### Physical Characteristics

Many factors, including access to the work areas, needed to be considered while exploring alternative corrosion protection systems. Figure 1 (p. 44) is a plan view of both tunnels.

Access to the tunnels could be obtained via 12 shafts, the wastewater treatment plant, and an interconnect structure (ICS) at the north end of the 12-foot diameter tunnel. Primary access was achieved through M/S 1, M/S 8, and the ICS because they provided the largest surface openings. Table 1 (p. 44) provides detailed physical characteristics of each tunnel.

Another physical aspect, the specified mix design for both tunnels, was Type II Portland Cement with limestone coarse aggregate. Additionally, 5% silica fume was added to the 168-inch tunnel, while metal reinforcing fibers were embedded in the 144-inch tunnel. The compressive strength mix designs were 5,000 and 8,000 psi, respectively.

Additional physical aspects had to be considered. Each five-foot tunnel "ring"

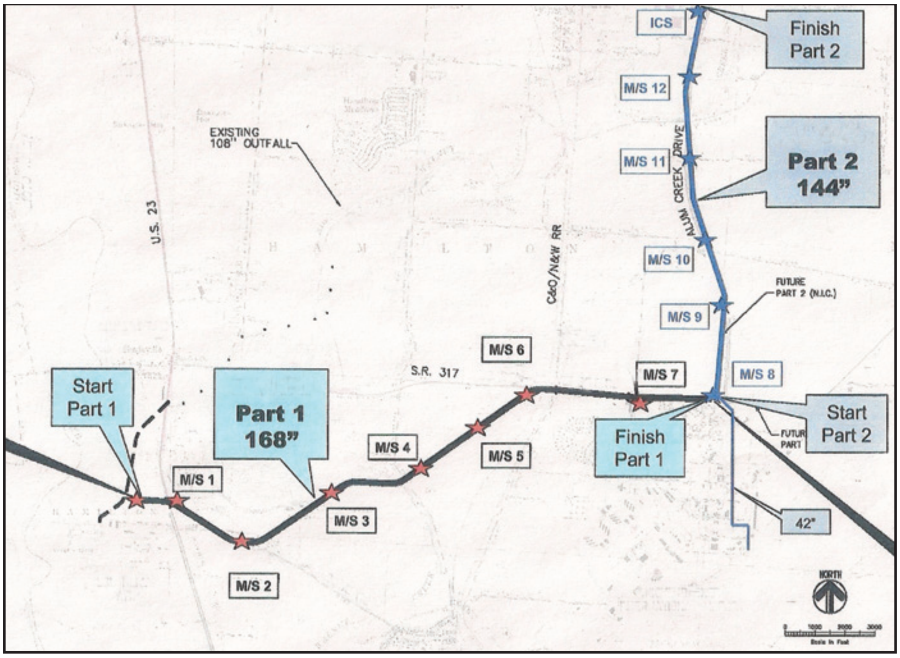


*Fig. 1: Plan view of both tunnels. Access to the tunnels could be obtained via twelve shafts, the wastewater treatment plant, and an interconnect structure (ICS) at the north end of the twelve-foot diameter tunnel. Primary access was achieved through M/S 1, M/S 8, and the ICS because they provided the largest surface openings.*

### Table 1: Detailed Physical Characteristics of Each Tunnel

| | Diameter | Length | Sq. Ft. | Capacity | Wall Thickness | Depth Range |
|---|---|---|---|---|---|---|
| **Part 1 Tunnel** | 168” | 21,063 LF | 926,000 | 24.0 MG | 9” | 30-78 Feet |
| **Part 2 Tunnel** | 144” | 13,320 LF | 440,000 | 11.3 MG | 9” | 44-78 Feet |
| **Connections and Shafts** | N/A | N/A | 45,000 | N/A | N/A | N/A |
| **Total** | N/A | 34,383 LF | 1,411,000 | N/A | N/A | N/A |

### Table 2: Areas Believed to be Subjected to Greatest Corrosion Activity

| Area/Surface | Corrosion Mechanism | Surface Area |
|---|---|---|
| 15 feet upstream of drop connection | Hydraulic Scour/Erosion | 3,300 |
| 15 feet downstream of drop connection | Hydraulic Scour/Erosion | 3,300 |
| 30 feet upstream of drop connection[1,2] | Biogenic Sulfide | 17,400 |
| 300 feet downstream of drop connection[1,2] | Biogenic Sulfide | 109,000 |
| Head space of shafts and CIP structures | Biogenic Sulfide | 42,000 |

1. Exclusive of the 15 feet identified as susceptible to hydraulic scour/erosion
2. Coating application limited to 320° as invert would be constantly immersed and not subject to biogenic sulfide attack

consisted of six precast segments and incorporated approximately 70 linear feet of gasketed segment seams, six grout ports, and 12 bolt pockets. Water infiltration, primarily due to hydraulic pressure, was omnipresent but considered manageable for installation of corrosion protection. The vast majority of water infiltration occurred at the segment seams.

Other substrates within the tunnel complex included

- fiberglass-reinforced pipe (dropshafts),
- cast-in-place concrete,
- shotcrete,
- carbon steel, and
- stainless steel.

### Corrosion Protection Options Evaluated

The city evaluated nine types of corrosion protection:

- anchored thermoplastic linings;
- adhered PVC sheet linings;
- acid-resistant cementitious linings;
- liquid-applied, polymer-based protective coatings;
- cured-in-place pipe (CIPP) linings;
- deformed pipe linings;
- segmental thermoplastic sheet linings;
- sliplinings; and
- spiral-wound pipe.

The options were screened against a comprehensive set of performance and constructability criteria (21 categories) and given a final weighted score. The three highest ranked alternatives were spiral-wound pipe; sliplinings; and liquid-applied, polymer-based protective coatings. Although spiral-wound pipe and sliplinings would have provided longer service lives, both options were eliminated because of constructability, cost, and time concerns. Ultimately, the areas and surfaces believed to be subjected to the greatest corrosion activity were identified and selected for coating application (Table 2). The surface area selected was approximately 175,000 square feet, less than 13% of the aggregate surfaces.

The protective coatings selected were based on blended amine-cured, Bisphenol A epoxy technology with a small amount of novolac added for greater cross link density and low pH resistance. Low permeability and biogenic sulfide corrosion resistance were additional desired characteristics of the technology.

### Specification of Coating System

Because many of the tunnel areas had unique problematic conditions, the idea of designing a single coating system to handle all areas was abandoned. Instead,

*Fig.2: Existing shortcrete surface ready to be resurfaced and protected with fiber-reinforced lining. One of four conditions (Table 3, p. 46).*

after surveying the areas to be protected, the specifying engineer identified four basic conditions or applications (Table 3, p. 46; and Fig. 2 above), and a unique lining system was designed for each (e.g., Fig. 3, p. 46).

Each of the coatings selected for this project was based on a hybrid epoxy lining system that had successfully passed the rigorous testing parameters of the *County Sanitation Districts of Los Angeles County* (John Redner Test), considered by many as a benchmark for high-performance corrosion lining systems in wastewater service. Beyond superior corrosion resistance, each of the four systems specified was chosen to capitalize on specific physical properties of each material providing the best opportunity for long-term success in the specific environments. Table 4 (p. 48) reflects the four identified lining conditions as well a summary of the final material specifications for each.

As with any coating system, proper surface preparation is paramount to the enduring success of the system. For the coating systems protecting precast and poured-in-place concrete for conditions “A” and “B,” SSPC-SP 13 was specified with a minimum visual profile of concrete surface preparation comparator CSP 5 to be achieved per ICRI Guideline No. 310.2-1997 (formerly ICRI 03732). For shotcrete surfaces identified as condition “S” with extremely porous and rough surfaces, a minimum 5,000 psi, abrasive-free hydroblast was

**Table 3: Problematic Conditions Identified in Tunnel Areas**

| Condition | Substrate to be Protected | Area or Condition of Concern |
|---|---|---|
| "A" | **Concrete** (precast or poured in place) | "Corrosion Zones"– Tunnel sections preceding and following areas of turbulence with elevated $H_2S$ levels, biogenic corrosion, and tangential impingement abrasion |
| "B" | **Concrete** (precast or poured in place) | "Scour Zones"– Highly turbulent zones such as areas around and beneath drop shafts with direct impingement abrasion and biogenic corrosion |
| "D" | **Metal** (carbon or cast steel surfaces) | Biogenic corrosion |
| "S" | **Shotcrete** (slurry wall construction) | "Slurry Wall"–12-14" thick shotcrete construction with extremely porous and rough surface (see Fig. 2, p. 45) subject to biogenic corrosion conditions |

*Fig. 3: Application of fiber-reinforced 100% solids epoxy coating*

accepted along with mandated pull testing to confirm the bond of resurfacing materials to substrate. And for all metallic surfaces designated condition "D," cleaning to a Near-White Metal blast, SSPC-SP 10, was required, with minimum surface profile of 2.5 to 3 mils, followed by a 100% solids epoxy holding primer.

### Unique Challenges for the Coating Application

Few projects of a sizable nature are completed without quirks that set each apart from other jobs. Items such as the filling of segment joints, bolt pockets, and grout ports for this project were not difficult or unique, but they became daunting because of the sheer quantity of work and the time allotted for it. Before the coating application could begin, the crew had to fill more than 9 linear miles of segment joint; resurface and reinforce over 4,000 grout ports; and address nearly 3,000 bolt pockets. The crew had to be able to perform these tasks dependably and efficiently with minimum turnaround time to assure the quality of the final lining system to meet the coating schedule within budget. To help the crew meet these challenges, the specifying engineer customized solutions for each of these construction details, and the material manufacturer and installing contractor collaborated to increase jobsite efficiencies.

**Segment Seams**

The tunnel construction was comprised of a long series of segmented rings. The seams that border the segments ranged from as little as ½ inch wide to as much as 1¼ inch wide and were generally

*Fig. 4: Typical ring section*

*Fig. 5: Close-up of unfilled segment seam.*

about ¾ inch deep (Figs. 4 and 5). A highly thixotropic, pumpable epoxy material was formulated specifically for this application, allowing the material to be drawn into caulk-style guns. This application allowed placement of the material directly into the seams and then was quickly struck flush with minimal material wastage.

**Bolt Pockets**

Construction of the segmented rings required that each individual segment section be mechanically pulled into compression with adjacent segment sections and locked together using bolts (Figs. 6 and 7, p. 50). These bolted connections

continued on p. 48

### Table 4: Identified Lining Conditions and Summary of Final Material Specifications

| Condition | Substrate to be Protected | Area or Condition of Concern | Summary of Selected Coating System |
|---|---|---|---|
| "A" | **Concrete** (precast or poured in place) | "Corrosion Zones"– Tunnel sections preceding and following areas of turbulence with elevated $H_2S$ levels and tangential impingement abrasion with biogenic corrosion | 63 mils (1⁄16") of 100% solids epoxy resurfacing material topped with 60 mils of spray-applied fiber-reinforced 100% solids epoxy coating system with ultra-low permeation properties and superior abrasion resistance in tangential impingement |
| "B" | **Concrete** (precast or poured in place) | "Scour Zones"– Highly turbulent zones such as areas around and beneath drop shafts with direct impingement abrasion and biogenic corrosion | 125 mils (1⁄8") of 100% solids epoxy resurfacing material topped with 125 mils of trowel-applied aggregate-reinforced mortar style 100% solids epoxy coating system plus 20 mils of a highly abrasion resistant epoxy glaze coat (per ASTM D-4060 Tabor Abrador test results, specified glaze topcoat is expected to double lifecycle of coating system against degradation due to abrasion) |
| "D" | **Metal** (all ferrous metal surfaces) | Biogenic corrosion | 3-5 mils of spray-applied 100% solids epoxy primer topped with 25-35 mils of spray-applied 100% solids epoxy topcoat |
| "S" | **Shotcrete** (slurry wall construction) | "Slurry Wall"– 12-14" thick shotcrete construction with extremely porous and rough surface subject to biogenic corrosion conditions | Trowel application of portland-based resurfacing material at ¼"-2" thickness topped with 60 mils of spray-applied fiber-reinforced 100% solids epoxy coating system with ultra-low permeation properties |

### Table 5: A General Sequence of Work Progression

| Activity | Responsible Party | Comments |
|---|---|---|
| Remove "failed" lining system | General Contractor | Only in areas scheduled for new coatings |
| Stabilize "failed" lining system | General Contractor | To prevent accumulation of "debris" at headworks |
| Remove rails and locomotives | General Contractor | Only in 168" tunnel |
| Remove ladders and brackets | General Contractor | At shafts and other access points |
| Initial pressure washing | General Contractor | To remove residual tunneling debris |
| Replace damaged grout port caps | General Contractor | From original surface preparation (UHPWJ) |
| Injection grouting | General Contractor | In isolated areas |
| Seal tunnel segment seams | General Contractor | In areas scheduled for coating application |
| Provide ventilation | General Contractor | OSHA requirement of 200 CFM/worker |
| Rigging | Coating Contractor | Rolling scaffolds, scissor lift, aerial lift |
| Install temporary air dams | Coating Contractor | To maintain appropriate environmental conditions for coating application |
| Surface preparation | Coating Contractor | Abrasive blast using coal slag (SSPC-SP 13/NACE No. 6 and ICRI Guideline No. 0372) |
| Filling of bolt pockets | Coating Contractor | Cementitious surfacing material |
| Covering grout ports | Coating Contractor | Embedded scrim cloth |
| Coating application | Coating Contractor | Trowel, spray, brush, and roll |
| Dry film thickness measurements | Coating Consultants | Per SSPC PA 2 and SSPC PA 9 |
| High voltage holiday detection | Coating Consultants | Per NACE RPO 188 |
| Adhesion testing | Coating Consultants | Per ASTM D 7234 |
| Remedial repairs | Coating Contractor | Identified via visual examination and destructive testing |
| Installation of SS Plating | General Contractor | Added abrasion resistance where waste stream enters tunnel from drop shafts (See Fig. 13, p. 53) |

*continued on p. 50*


Figs. 6 and 7: Bolted ring sections after installation in the tunnel. The dark discoloration on the left was typical of a leaking segment joint (left); bolt pocket ready to be filled (right).


Figs. 8 and 9: Photos show one of over 4,000 grout ports to be addressed before applying a protective lining. The discoloration around the port on the left indicates water infiltration before being covered. The grout port on the right has been covered and embedded with fiberglass, waiting for resurfacing topcoat.

were designed to hold the rings in place during installation and, ideally, to maintain the gasketed seal between the sections. To provide a smooth tunnel surface, thousands of "pockets" that housed these bolts were filled and struck flush using either the same high-build epoxy filler material utilized to fill the segment seams or a compatible, fast-setting portland-based cementitious resurfacing material.

### Grout Ports

After the individual segments were bolted together and the resulting ring section was in final position in the tunnel, grout was injected to fill the annulus behind the segments through grout ports and then capped with a thermoplastic cap (Figs. 8 and 9). Recognizing that the bond of any lining material to the thermoplastic caps would be weaker than desired, over 4,000 of these grout ports were covered with an epoxy filler compound (Fig. 10) and then structurally tied into surrounding resurfacing materials by embedding an oversized, 5-mil-thick fiberglass scrim cloth.

### Sequencing of Activities

Work began in late May 2009 within the 168-inch tunnel. The general contractor was responsible for all support (access, ventilation, materi-

Fig. 10: Filling chamfer area of segment joints and covering grout port caps.

al/equipment cartage), while the coating contractor was responsible for surface preparation, coating application, and maintaining appropriate environmental conditions. The tunnels were classified as a non-permit required confined space insomuch as no potential for atmospheric hazards was identified. A minimum of 200 CFM of airflow per worker was maintained at all times. Additional ventilation was employed during surface preparation and coating application activities (Fig. 11, p. 52). Coordination and sequencing of activities was paramount to meeting the nine-month construction schedule (Table 5, p. 48).

**Quality Control**

Because of the numerous problems and finger pointing associated with the original attempt at installing corrosion protection, the owner elected to secure full-time, independent quality control inspection for all aspects of the project. Working in conjunction with the coatings manufacturer, the parties fashioned a project specific quality assurance and quality control plan that was maintained throughout the entire project. Primary concerns included:

- Achieving an ICRI CSP 5 surface profile on concrete substrates
- Achieving an SSPC-SP 10 cleanliness

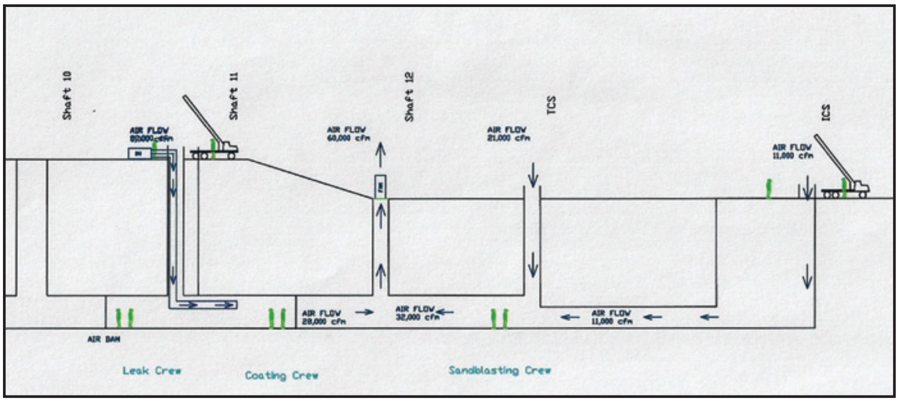

Fig. 11: Ventilation schematic

level on metal substrates

• Maintaining clean and dry substrates for coating application
• Maintaining suitable ambient conditions for the coatings to be applied
• Maintaining appropriate coating termination details
• Attaining the specified dry film thickness for each coating system
• Attaining completed coating systems that were well adhered to the substrate
• Attaining completed coating systems that were holiday free

Controlling the environment and limiting water infiltration proved to be the two most difficult tasks. Dehumidification equipment was necessary on a 24/7 basis to control the dew point and maintain relative humidity below 85%. A plethora of products and methods was field tested to prevent water infiltration (primarily through segment seams), the most effective being, a single-component hydrophilic urethane waterstop.

Destructive as well as non-destructive testing in accordance with SSPC, NACE, and ASTM standards was performed on a routine basis to ensure that the coatings


Fig. 12: Holiday detection being performed on the completed coating system

were applied at the specified film thicknesses; the coatings were well adhered to the substrate; and the lining systems were holiday (pinhole) free (Fig. 12).

In no small part, because of the steadfast efforts of all involved parties, the project was completed on schedule and within budget without compromising quality. It is anticipated that the applied coatings will extend the service life of the structure by an additional 15 to 20 years under the anticipated service conditions. Although the tunnels have been in service since April 2010, a performance evaluation has not been conducted. It is projected that an evaluation, albeit it likely limited due to flow conditions and

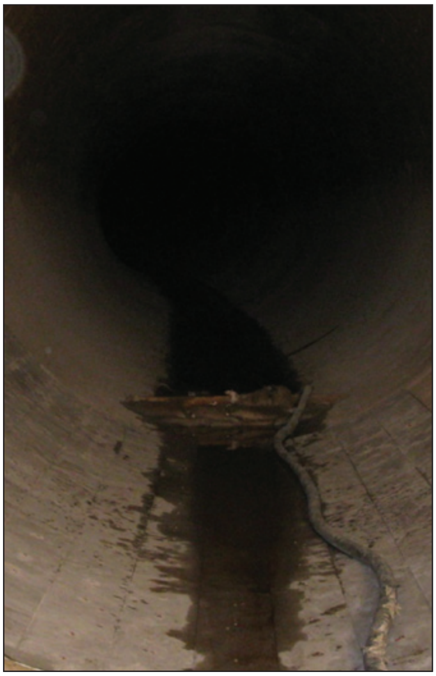

*Fig. 13: After remedial repairs, stainless steel plating was installed to protect against erosion from scouring (Table 5, p. 48).*

accessibility, can be accomplished in 2011.

Corrosion Probe, Inc. provided design and engineering support, consulting, and QA/QC inspection services for the project. Sauereisen, Inc. formulated, manufactured, and supplied the coating systems. Martin Painting & Coating Co. performed the surface preparation and coating application, and Jay Dee Contractors, Inc. served as the general contractor.

Bob Maley is a Senior Consultant based in Port St. Lucie, FL, for Corrosion Probe, Inc. He has 34 years of experience in the protective coatings industry. Maley is SSPC PCS certified; an SSPC member who sits on several committees; and an SSPC-C3 instructor. He is also NACE CIP Level III Certified and a member of NACE. He has written and presented several papers for SSPC, *American Painting Contractor*, AWWA, and *Canadian Construction Journal*.

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# The Next Generation of High-build, Aliphatic Moisture-Cure Coatings

By Ahren Olson, Bayer MaterialScience

Current commercial aliphatic moisture-cure urethane (MCU) topcoats have been limited by their film build and by the conditions in which they can typically be applied successfully. They are usually applied at dry film thicknesses (DFT) between 2 and 3 mils and generally in cool and damp climates. A new aliphatic prepolymer, engineered specifically for high-build MCU coatings, allows formulators to develop MCU topcoats that can be applied at 6–8 mils' DFT (72 F and 50% humidity) with 10–12 mils' sag resistance.

This article first reviews how conventional MCUs cure, four common ways of formulating them, and their strengths and limitations, including suitable application and exposure conditions. The article then describes the development and testing of a new aliphatic prepolymer for MCUs.

## Basics of Current MCUs: Content, Curing, and Formulation

A moisture-cure urethane coating is a one-component paint that consists of a polyisocyanate functional resin along with solvents, pigments, catalyst, and additives. After being applied to the substrate, the paint cures as the isocyanate resin reacts with ambient moisture. Figure 1 describes this curing mechanism in more detail. When the paint is applied to the substrate, solvent begins to flash off, and the paint absorbs some of the ambient moisture. The isocyanate (R-NCO) reacts with that moisture to form an amine (R-$NH_2$) and release carbon dioxide gas. (R denotes the rest of the organic molecule, which is not involved in the reaction.)

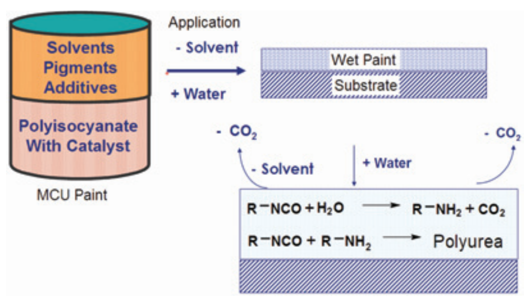


Fig. 1: Curing mechanism for MCU coating.

The isocyanate will then react with the amine to form a polyurea-cross linked network.

Aliphatic MCU topcoats have several advantages. They can cure at low temperatures as long as there is ambient moisture. They are very surface tolerant. And because they are a one-component paint system, there are no chances for mixing errors with multiple components in the field.

Manufacturing a MCU coating is not a trivial process. The water in the solvents and additives and on the pigments must be removed from the mill base before adding the isocyanate. If this process is not done correctly, the paint will begin to cure in the can, causing viscosity build, out-gassing, or even gelling. There are typically four ways to make a stable MCU paint. These four methods will be referred to as "conventional PTSI method," "vacuum method," "IPDI method," and "low functionality isocyanate drying."

The conventional PTSI method uses the highly reactive monomer PTSI (p-toluenesulfonyl isocyanate). This monomer reacts very quickly with free water in the mill base to form a nonreactive byproduct, p-toluenesulfonamide (PTSA), which is kept soluble in the liquid paint through correct solvent choice.

The vacuum method uses heat and a vacuum to azeotrope out (to remove) up to 80% of the water from the mill base. The residual water is then removed using PTSI. This manufacturing method produces a higher quality of paint when compared to the conventional PTSI method. PTSI is an expensive raw material, and by removing a large portion of the water through the azeotrope step, a reduced amount of PTSI is required. The reduction in PTSI leads to considerable cost savings and creates less of the PTSA byproduct. PTSA is acidic and can cause issues with weathering and will slow the curing of the paint.

The IPDI method uses isophorone

Continued

*Editor's Note: This article is based on a paper the author presented at PACE 2010, a joint conference of SSPC: The Society for Protective Coatings and the Painting and Decorating Contractors of America, held February 7–10, 2010, in Phoenix, AZ.*

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diisocyanate in large excess to overwhelm and react with the free water in the mill base. This is typically done under heat to expedite the process. The %NCO of the mill base is measured over time. Once the %NCO content stabilizes, the mill base is considered to be free of water, and the remaining free IPDI monomer is chain terminated using an OH-functional material.

The final method to make a stable MCU coating is to use a low functionality polymeric isocyanate, typically one functional to react with the free water in the mill base. The greatest benefit to using the low functionality isocyanate drying method is that it is a monomer free process with fewer handling concerns.

## Current MCU Market Status

In the mid 1990s, aliphatic prepolymers for the North American region were developed specifically for aliphatic MCU topcoats. Several different prepolymers have been developed, which generally resulted in topcoat formulas that could be applied at thicknesses between 3–4 mils dry film thickness (DFT) before blistering resulted and with a sag resistance of 4 mils. The aliphatic MCU coatings on the market today are applied at 2–4 mils DFT and are typically used in the regions of the northeast and the northwest where there are cooler and damper conditions.

The North American MCU market has reached its full potential with the current technology. This is due to the technical limitations of this technology and application difficulties. MCU coatings that are applied beyond the manufacturer's recommended film thickness have a strong tendency to run and blister, which result in field repair and a generally poor perception of MCU topcoats.

To advance the MCU technology and coating market, drastic improvements were required in coating performance. A more robust technology is expected to renew interest in moisture cure coatings across the various sectors of the light- and heavy-duty protective coating markets and possibly open new markets within the construction sectors because of the improved film build.

## New High-Build MCU Resin

After years of research, a new MCU resin has been developed. This resin is an HDI/IPDI prepolymer (referred to as HB resin) that was specifically engineered for high-build MCU topcoats. This resin is successful in making high-build MCU coatings because of its engineered reactivity towards moisture. The controlled reactivity is one of the keys to making high film-build MCU coatings. Table 1 gives data from three different MCU resins and a current commercial MCU. All three resins were formulated into the same base MCU formula, with the only variation being the substitution of the different resins.

The film-build-to-blister (FBTB), or maximum DFT before blisters, is measured on both a horizontal and vertically cured panel. The HB resin is able to produce much thicker coatings than either of the older technology resins or the commercial control MCU. The gloss of the HB resin-based MCU and its stability in the can are both acceptable when compared to the commercial control. The only drawback to using the new HB resin is the extended dry time. Extending this dry time is one of the keys to promoting high film build. Film build can be sped up through the use of more catalyst or by blending in some of the faster drying MCU resins at the cost of some film build.

## Field Trial with High-Build MCU

In September 2008, a field trial was conducted to test the next generation aliphatic MCU topcoat in Baytown, TX. This high-build topcoat was based on the HB resin discussed earlier. A commercial control MCU topcoat (Table 1) was also sent to be tested with the high-build MCU topcoat. A third-party contractor applied the paints.

Older weathering steel beams were blasted to SSPC-SP 6 (Commercial Blast),[6] which resulted in a blast profile of 2.7–3.6 mils.[7] A commercial organic zinc-rich MCU primer was first used to prime the blasted beams. The following day, both the commercial and new HB resin-based MCU topcoats were applied. The conditions at the time of the MCU application were 97 F and 50% humidity, with a 101 F metal temperature and a 95 F paint temperature. These conditions are very severe for application of MCU topcoats, which are typically applied in damp and cooler environments. The face of each beam was sprayed at a gradient film thickness so the point at which the coatings were going to blister could be measured. Data from this trial is shown in Table 2.

The high-build MCU topcoat was applied up to 5 mils DFT before blistering was noticed, while the commercial control MCU could be applied up to only 1 mil DFT before blistering. Compared to current MCU technology, the new high-build coatings can be applied at significantly thicker film builds, even in more severe environmental conditions where MCU topcoats have not been used.

## Summary

High-build aliphatic MCU topcoats have been developed with a new engineered aliphatic prepolymer. Compared to current MCU technology, which produces topcoats from 2–4 mils DFT, this new high-build MCU technology is able to produce aliphatic topcoats with DFTs of 6–8 mils (72 F and 50% humidity).

In a field trial, the new, high-build MCU topcoat was able to be applied at five times the coating thickness (5 mils versus 1 mil) before blistering, when compared to the commercial control, which was based on technology from the 1990s.

*Continued*

These advances in MCU resin technology will significantly advance aliphatic MCU coating technology in the maintenance coating market, possibly opening new markets within the construction sectors because of their improved film build. In short, it will allow specifiers and painters to use MCU technology in regions they never could before.

**Table 1: Two Old Technology MCU Resins vs. New HB Resin @ 72 F/50% Humidity***

| Resin | FBTB[1] Horiz. | FBTB[1] Vert. | Gloss[2] 60° | Sag[3] | Initial Viscosity[4] | Viscosity[4] 2 Week @ 50 C | Gardner Hard Dry[5] @ 6 mils DFT |
|---|---|---|---|---|---|---|---|
| HDI Prepolymer A | 2.1 mils | 2.1 mils | 61 | 12 mils | 89 KU | > 140 KU | 16.5 hr |
| HDI Prepolymer B | 3.3 mils | 2.3 mils | 89 | 10 mils | 80 KU | 93 KU | 18 hr |
| HB Resin | 8.0 mils | 7.1 mils | 85 | 12 mils | 83 KU | 100 KU | 32 hr |
| HB Resin (increased catalyst) | 5.8 mils | 5.0 mils | 85 | 12 mils | 82 KU | 112 KU | 24 hr |
| Commercial System | 2.3 mils | 2.1 mils | 93 | 4 mils | 70 KU | 81 KU | 9 hr |

*All superscript information can be found under "References."

## References


1. ASTM D7091-05, "Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals."
2. ASTM D523-08, "Standard Test Method for Specular Gloss."
3. ASTM D4400-99 (2007), "Standard Test Method for Sag Resistance of Paints Using a Multinotch Applicator."
4. ASTM D562-10, "Standard Test Method for Consistency of Paints Measuring Krebs Unit (KU) Viscosity Using a Stormer-Type Viscometer."
5. ASTM D-5895, "Standard Test Method for Measuring Times of Drying or Curing During Film Formation of Organic Coatings Using Mechanical Recorders."
6. SSPC-SP 6/NACE No. 3, "Commercial Blast Cleaning."
7. ASTM D4417—03, "Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel."
8. ASTM D1212-91 (2007), "Standard Test Methods for Measurement of Wet Film Thickness of Organic Coatings."


**Table 2: Data from the Baytown, Texas, Field Trial in September 2008**

| Topcoat | Total DFT[1] | Blast Profile[4] | Primer DFT[1] | MCU DFT[1] | Dry Time | Sag[8] |
|---|---|---|---|---|---|---|
| Commercial MCU | 3.2 mils | 2.7 mils | 2.2 mils | ~ 1 mil | ~ 20 hours* | 5 mils |
| High Build MCU | 6.2 mils | 3.6 mils | 1.2 mils | ~ 5 mils | ~ 20 hours* | 12 mils |

* The dry time was noted upon return to the paint site the next day, which happened to be ~ 20 hours after the application.

# SSPC, *JPCL* Present Editorial Awards

Earlier this month, SSPC and *JPCL* presented awards to recognize achievement in the protective coatings industry at SSPC 2011 featuring GreenCOAT. The awards were presented during the first Annual Business Meeting & Awards Luncheon on Monday, Jan. 31.

SSPC 2011 featuring GreenCOAT was held in Las Vegas, NV, from Jan. 31 to Feb. 3.

The Outstanding Publication Award and the *JPCL* Editors' Awards are described here. Other awards presented at the show will be featured in future issues of *JPCL*.


Robert Ikenberry


Vaughn O'Dea


Rick Schwab


Rob Francis


Karsten Mühlberg


Mike O'Donoghue


Vijay Datta


Mike Winter


Carl Reed

## Outstanding Publication Award

"Controlling Traffic on Highway and Bridge Painting Jobs," by Robert Ikenberry, PCS, of California Engineering Contractors, Inc., is this year's winner of the Outstanding Publication Award. The article appeared in the Jan. 2010 *JPCL* on pgs. 32-43.

## *JPCL* Editors' Awards

Four papers received this year's Editors' Award.

- "Hubble, Bubble, Tests, and Trouble: The Dark Side of Misreading the Relevance of Coating Testing," by Mike O'Donoghue, Ph.D.; Vijay Datta, MS; Mike Winter; and Carl Reed, International Paint, LLC; *JPCL*, May 2010, pgs. 30-45. The article also was the winner of the PACE 2010 Presidential Lecture Award.
- "Corrosion Protection of Offshore Wind Turbines—A Challenge for the Steel Builder and Paint Applicator," by Karsten Mühlberg, Hempel (Germany) Ltd.; *JPCL*, March 2010, pgs. 20-32.
- "Dry Film Thickness Measurements: How Many Are Enough?" by Rob Francis, Aurecon Australia Pty Ltd.; *JPCL*, Dec. 2009, pgs. 22-31.
- "Preparing Repair Mortars for Wastewater Service: Broom Finish or Blasted Surface?" by Vaughn O'Dea and Rick Schwab, Tnemec Company; *JPCL*, Sept. 2009, pgs. 32-45.

## SSPC Holds Modified C1/C2 in AZ

SSPC held a C1/C2 Modified class in Phoenix, AZ, on Dec. 6–10, 2010. The course was hosted by LINE-X Protective Coatings and taught by Joe Davis. Twenty-three students participated.

This is the third C1/C2 Modified class that LINE-X Protective Coatings has held.


LINE-X held its third C1/C2 Modified class.

## United Arab Emirates Chapter Held November Meeting

More than 150 individuals attended the SSPC UAE chapter meeting at the India Club at Dubai Coatings, reported Ravishankar Nagarajan, TSS Engineer at Jotun Paints and SSPC UAE Chapter Vice Chair.

The meeting was a mix of members from the industry including representatives from paint manufacturers, coating application contractors, and marine/offshore clients. The topic was Offshore and Marine Coatings.

Pradeep Radhakrishna, UAE Chapter Chairman and Director at WGI/IQC/Insignia FZE, gave a presentation on IMO/PSPC Regulations that was a follow up to the presentation given at the inaugural UAE chapter meeting in June 2010. Craig Woolhouse, Sales Manager at Elcometer, gave a presentation on "The Future Direction of the Coatings Inspection Industry."


Over 150 people attended the SSPC UAE Chapter's November meeting.

The technical portion of the meeting also included a recorded presentation of the SSPC/*JPCL* Webinar, "Coating Over Flash Rust in Marine and Offshore Environments," presented by Peter Ault of Elzly Technology Corp.

Nagarajan also gave a presentation about the courses available from SSPC, including SSPC-QP 1, Field Application of Complex Industrial and Marine Structures; QP 3, Shop Painting; and the SSPC Protective Coating Inspector (PCI) program and Protective Coating Specialist (PCS) program.

The UAE Chapter Board met and nominated officers for 2011.

# Coast Guard Awards Tank Painting Job

The United States Coast Guard Maintenance and Logistics Command awarded a contract of $44,500 to Western Industrial, Inc. (Mukilteo, WA), SSPC-QP 1- and QP 2-certified, to preserve potable water tanks on the Coast Guard Cutter Alert. The work on the 210-foot-long medium-endurance cutter will be performed while the vessel is moored in Warrenton, OR. The project involves repairing approximately 30% of the existing linings in a 6,990-gallon potable water tank and two 2,250-gallon potable water tanks. The corroded tank surfaces will be power-tool cleaned to Bare Metal (SSPC-SP 11) and recoated with an NSF or NEHC-approved potable water compliant system.

*Continued*

*Photo courtesy of US Coast Guard*

## Arkansas Highway Department Lets Bridge Coating Contract

The Arkansas Highway and Transportation Department awarded a contract of $1,111,320 to S&D Industrial Painting, Inc. (Tarpon Springs, FL) to recoat steel surfaces on 15 bridges in Howard, Nevada, Pike, and Sevier Counties. The contract, which required SSPC-QP 1 and QP 2 certification, includes recoating a total of 1,357 tons of steel. The steel will be coated with an inorganic zinc primer, an epoxy intermediate, and a urethane finish. The contract includes containment of the existing lead-bearing coatings.

## Farr Construction Wins Tank Recoat and Retrofit

Farr Construction Corp. (Reno, NV), SSPC-QP 1 certified, secured a contract of $401,172 from the Soquel Creek Water District (Soquel, CA) to perform coatings application, seismic retrofitting, and caulking on a 1.2 MG welded-steel, knucklehead-style, ground storage tank. The 96-foot-diameter by 24-foot-high tank was last coated in 1977, at the time of construction. The contract includes containment and removal of the lead and chromium-bearing exterior coatings and the coal-tar liner. The interior surfaces will be abrasive blast-cleaned to a White Metal finish (SSPC-SP 5); the shell and floor will be lined with a 100%-solids epoxy system, while the ceiling, knuckle, and rafters will receive an epoxy system. The interior work requires the use of dehumidification equipment. The exterior surfaces will be abrasive blast-cleaned to a Near-White condition (SSPC-SP 10) and coated with a zinc-epoxy-polyurethane system. The contract also includes performing seismic retrofitting and caulking on two additional tanks.

## Sandblast America Wins Coating Contract

Sandblast America, LLC (Manassas, VA) was awarded a contract of $75,443 by Stafford County, VA, to repair and recoat the trough, center support, and rake arm in a clarifier at the Abel Lake Water Treatment Plant. The project includes removing the existing coatings by ultra-high-pressure waterjetting. The trough will be lined with a 100%-solids epoxy primer and a 100%-solids polymer finish. The metal mechanisms will be coated with a 100%-solids polymer finish.

### Virginia DOT Lets Bridge Painting Project

The Virginia Department of Transportation awarded a contract of $3,836,095 to V.H.P. Enterprises, Inc. (Tarpon Springs, FL), SSPC-QP 1- and QP 2-certified, to recoat 17 bridges in Staunton County. The project includes abrasive blast cleaning and recoating a total of 3,496 tons of structural steel, which is currently coated with lead-based paint that will require containment and disposal.

### Llamas Coatings to Refinish 4.3 MG Tank

Llamas Coatings, Inc. (Smyrna, GA) secured a contract of approximately $300,000 from the Cobb County-Marietta Water Authority (GA) to brush-off abrasive blast clean and recoat the interior and exterior surfaces of a 4.3 MG steel water tank. The interior, last coated in 1985, will be lined with an epoxy system; the exterior, which was last painted in 1995, will be refinished with an epoxy-urethane system.

### Iowa DOT Awards Bridge Painting Bids

The Iowa Department of Transportation recently awarded three contracts for abrasive blast surface preparation and coatings application on bridges. Pacific Painting Company, Inc. (Munster, IN), SSPC-QP 1- and QP 2-certified, was awarded a contract of $117,000 to recoat a 210-foot-long by 36-foot-wide steel beam bridge and a contract of $362,000 to recoat dual 366-foot-long by 32-foot-wide bridges; all three structures are located in Pottawattamie County. Euro Paint, LLC (Lowellville, OH) secured a contract of $499,496 to recoat three steel beam bridges in Harrison County; the structure dimensions are 255 foot by 24 foot, 455 foot by 30 foot, and 455 foot by 30 foot.

### Blastco Wins Reservoir Repair Work

Blastco, Inc. (Gardena, CA), SSPC-QP 1- and QP 2-certified, won a contract of $632,500 by the Otay Water District (Spring Valley, CA) to perform interior and exterior coatings work and various structural upgrades on a 1 MG reservoir and a 0.87 MG reservoir. The contract includes removing the existing lead-bearing coatings, applying epoxy linings, and applying epoxy-urethane exterior coating systems, as well as providing a third-party coatings inspector as part of the quality control plan.