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The Voice of SSPC: The Society for Protective Coatings

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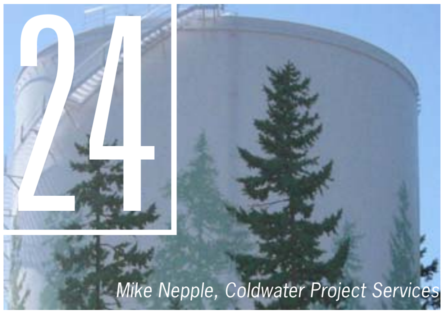
Features

24 Coatings Projects Honored at Structure Awards

By Charles Lange, JPCL

This photo essay recaps the eighth annual SSPC Structure Awards, held Monday, Feb. 10, 2014, during the Annual Business Meeting and Awards Luncheon at SSPC 2014 featuring GreenCOAT in Orlando, FL. Six awards were presented for outstanding coatings projects completed on a variety of interesting and complex structures.



Mike Nepple, Coldwater Project Services

32 When Undercover Agents are Tested to the Limit: Coatings in Action (CIA) and Corrosion Under Insulation (CUI) at High Temperature

By Mike O'Donoghue, Ph.D., Vijay Datta, MS, Adrian Andrews, Ph.D., and Sean Adlem, International Paint LLC; Linda G. S. Gray, MSc, Coating Consultant; Tara Chahl and Nicole de Varennes, CET, RAE Engineering and Inspection Ltd.; and Bill Johnson, AScT, Acuren Group Inc.

This article, the second in a series on coatings in action and corrosion under insulation, reports the results of accelerated laboratory tests to evaluate the performances of two coatings systems on both carbon steel and stainless steel pipes in the temperature range for CUI and at elevated temperatures approaching 600 C.

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48 Preparing and Lining Concrete for Immersion Service: Steps and Procedures to Avoid Failures

By Robert Maley, Corrosion Probe, Inc.

The author examines many of the common errors that often occur when rehabilitating concrete substrates, particularly for immersion service in wastewater treatment facilities, and it offers practical solutions for prevention of said errors.

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60 Shipyard Regulatory Update: What's Happening with Enforcement, Regulation, and New OSHA Guidance Documents

By Alison B. Kaelin, CQA, ABKaelin, LLC

This article reviews OSHA enforcement of shipyard activities and recent guidance on illumination and ventilation related to ship repairing, shipbuilding, and shipbreaking. It also discusses new OSHA information on abrasive blasting hazards and potential Cal/OSHA Lead Standard changes that are applicable to the shipyard industry and other industrial painting sectors.

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Also This Month

From the Offices of SSPC

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Orlando Was Outstanding

First of all, I want to thank everyone who attended SSPC 2014 at the Coronado Springs Resort in Orlando, Florida. This venue was one we had not used previously. It is a Disney property very close to all the attractions in the area—all potential distractions. It turned out to be an outstanding location for a conference of our size. Everything was accessible and there was minimal walking distance between all of the key conference areas. Both bars were hopping every night, and because Coronado Springs is a stand-alone resort, it gave all of us a chance to network, chat, and laugh with our friends and colleagues. If we didn't want to talk business, we were able to catch up on how each other is doing and talk about the events in each other's lives.

During this show, one previous SSPC Board member's granddaughter was born. He flew home for the birth and then flew back to Orlando. We talked at great length one evening about family, mutual friends, and SSPC. He also brought his two sons to the show—I had met his oldest, but I had never had the opportunity to meet his youngest son until that week. Being on a computer or conference call does not replace the opportunity to shake someone's hand and say, "It is great to finally meet you."

I want to thank all of the presenters and exhibitors. The strength of any conference is what you take back with you that might assist you in doing your work more effectively and efficiently. The technical presentations and what you learn by walking around the exhibit hall are the vehicles for you to make the most of your conference experience. I also want to thank the students who attended our classes and our excellent instructors who passed on their knowledge to them. These students will take this training back to their employers and will be better on the job, which naturally increases productivity. Lastly, I would like to thank the sponsors whose generous contributions made for an outstanding conference. To all of the above, I cannot thank you enough.

During the Annual Business Meeting and Awards Luncheon, current SSPC President Ben Fultz challenged all attendees to get involved in technical committees, the Board, and in introducing young coating professionals to the industry. We want all members to provide input on standards development, instead of waiting until they are developed to complain about what is in them. The time to make a difference is early in the process.

As far as getting the younger generation involved, it was great seeing the SSPC scholarship winners come up on stage and be recognized. It was also fantastic seeing the students of the "Corrosion Squad" from the University of Akron at the show. All of these young people will be the future of this industry, and I cannot count the number of members who came up to me to say how great it was having these students at the conference. I want to echo what Steve Collins challenged the membership to do last year and what Ben Fultz did this year, and that is to bring a young person to the conference. They really do make a difference.

I would like to give a special acknowledgement to Karen Kapsanis, former editor of the *JPCL* and winner of the Executive Director's Award; Derrick Castle of the Kentucky Transportation Cabinet, winner of the John D. Keane Award; and to John B. Conomos of John B. Conomos, Inc., the winner of the Honorary Life Member Award, SSPC's highest honor. They are all very deserving of these awards.

Again, I want to thank the presenters, instructors, students, exhibitors, sponsors, and all the attendees for their support of SSPC 2014. We cannot do it without you, and we know it.

Bill Shoup

Bill Shoup
Executive Director, SSPC

New Webinar on Abrasive Blasting Safety Offered

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Webinar Education Series

The 2014 SSPC/*JPCL* Webinar Education Series kicks off next month with the offering of a new, free webinar.

"Safety in Abrasive Blasting," will be presented on Wednesday, April 2, from 11:00 a.m. to 12:00 noon, EST.


Thomas E. Enger

Abrasive blasting is a uniquely effective and commonly required industrial process used in the coatings industry. While effective, it presents numerous dangerous and unavoidable hazards to the workforce. As such, specific safety measures must be implemented to protect blast operators and others working in the vicinity of blasting. Among the most dangerous hazards is the inhalation of toxic substances. This webinar will focus primarily on the inhalation hazards associated with abrasive blasting and will discuss the NIOSH and OSHA requirements pertaining to respiratory and hearing protection during

Stopaq Enters U.S. Market

Nearly two years after purchasing its pipeline corrosion protection technologies, Evansville, IN-based Berry Plastics is ready to begin distributing Stopaq products in the U.S.

Berry announced in June 2012 that its Corrosion Protection Group had completed the acquisition of Frans Nooren Beheer B.V. companies, which include Stopaq.

Earlier this month, Midsun Specialty Products Inc. of Berlin, CT, announced that it had entered into an exclusive distribution agreement with Seal for Life Industries, a newly restructured division of Berry Plastics, to bring the Stopaq line to the northeastern U.S.

Stopaq's corrosion prevention technology, invented in the Netherlands, has been used for more than 20 years on pipelines and other infrastructure across Europe, the Middle East, and Asia.

Stopaq supplies a wide range of green visco-elastic coatings and sealants to protect assets from corrosion and water ingress. Its products are produced in the Netherlands and Saudi Arabia. Applications for the systems include onshore and offshore, field- and factory-applied, in extreme environments subsea and above ground.

Last fall, Stopaq won a long-running legal effort to block Canusa Systems Ltd. from bringing its corrosion-protection Wrapid Bond product to the German market, already occupied by Stopaq's anti-corrosion product, Wrappingband.

Midsun Specialty Products is a manufacturer of self-fusing silicone tape in the retail and commercial markets. Its portfolio includes self-fusing MSP Industrial Wrap for a variety of applications.

MSP says the addition of the Stopaq line will enhance its current product lines. MSP's territory includes the U.S. northeast, from Maryland to Maine. The company serves the oil and gas pipeline, refinery, and water and wastewater markets.

abrasive blasting. The webinar will also address the number one reason why employers should create and maintain an effective safety program.

Presenting this webinar will be Thomas E. Enger of Clemco Industries Corp. Enger has over 25 years of academic and practical experience in heavy construction and construction safety equipment manufacturing, and an extensive background in applying federal, state, and local regulations, as well as in using industry standards to safely prepare surfaces for today's coatings.

This webinar is sponsored by Clemco Industries Corp. and Abrasives Inc.

Registration, CEU Credits

This program is part of the SSPC/*JPCL* Webinar Education Series, which provides continuing education for SSPC re-certifications and technology updates on important topics.

SSPC is an accredited training provider for the Florida Board of Professional Engineers (FBPE), and Professional Engineers in Florida may submit SSPC Webinar Continuing Education Units to the board. To do so, applicants must download the FBPE CEU form and pass the Webinar Exam, which costs $25.

Register for this online presentation at

SSPC Offers Scholarships for 2014

SSPC is pleased to announce that the application is now available for the 2014–2015 college scholarship program.

The program is open to any student who is beginning or continuing his or her education at an institution of higher learning in the U.S. or Canada. To be considered for the scholarship, candidates must be high school seniors planning to enroll full-time, or students already enrolled full-time at an accredited institution of higher learning that has a three- or four-year curriculum. The candidate also must be a member of SSPC in good standing, or a child of an SSPC member in good standing.

To apply for the scholarship, candidates must submit a completed application form, two letters of recommendation, high school or college transcripts, and a personal letter expressing why they deserve the scholarship and what they plan to do in their field of study. Scholarship funds will be applied to the direct costs of the student's courses. Once awarded, SSPC will work with the financial aid offices of each institution to ensure proper use of the funds.

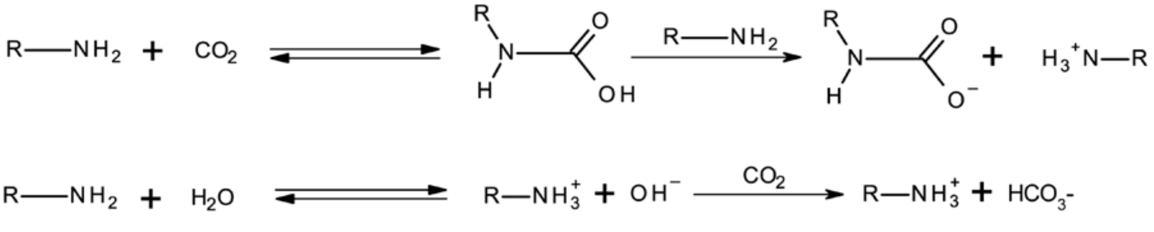
A panel consisting of three members of the SSPC Board of Governors (designated by the entire Board) will choose the scholarship recipients.

There are six $2,500 scholarships available for the 2014–2015 school year.

Visit sspc.org to download the application form.

Correction

On p. 56 in the February 2014 *JPCL* article, "High-Solids Epoxy Systems for Protective and Marine Coatings," *Scheme 1: Amine blush chemical reactions*, should have appeared as follows. *JPCL* regrets the error.



The BUZZ on PaintSquare.com

By Anita Socci, JPCL

Happy Birthday, *JPCL!*

SSPC 2014 included a very special birthday, as *JPCL* notched its 30th year of publication. The *Journal* threw itself a party in the Exhibition Hall, with new Editor-in-Chief Anita M. Socci presiding over the birthday cake. Artist Nathan Graham captured several dozen exhibit attendees in free caricatures, including Tommy Alvarez of Schmidt Engineered Abrasive Systems, Fresno, TX.

Courtesy of Technology Publishing Co.

Courtesy of SSPC

This Month

HOT: Coal combustion residuals (EPA green-lights two beneficial uses); UK paint sales; Keystone XL (thumbs up from State Department)

NOT: AkzoNobel's 2013 revenues; workers getting paid for time spent to put on PPE; Bay Bridge's new east span (leaks and controversy)

What's Got Us Talking

New Bay Bridge Span Leaking

"Just another example of what low bid projects get ya. You get what you pay for."

Chuck Pease

"Chuck, we didn't save a dollar. We overspent millions of them."

James Albertoni

"In Europe, bids are awarded on the best bid, not low-bid principle. That is why there are so many construction disasters locally."

Peter Gibson

Quart of Paint May Cost Amazon $78K

"I am aware of 2 shippers that have done time in prison for willfully violating transportation regulations (underscore 'willfully'). Amazon dodged a bullet."

Gene Kube

"We ship paint offshore in emergency only. The paperwork, packaging, and general grief along with the exorbitant cost make this an option of last resort."

Simon Hope

"This is why we don't ship by air."

Eric Rosenthal

PSN TOP 10

Bridge Worker Killed on Stadium Project
S-W Sued in $3.7M Bomb-Paint Cleanup
'Willful' Citation in PPG Worker's Death
TBT Ban Lets Girl Snails Be Girls
Quart of Paint May Cost Amazon $78K
AkzoNobel Sees Losses in 2013
Epic Fail: $195K Paint Job Washes Out
2 Plead Guilty in Painting Kickback
Inquiry: Bay Bridge Concerns Quashed
USAF Investigates Foam System Death

STUMPER OF THE MONTH

(from the *PaintSquare News* Daily Quiz)

True or false: Though not described in a standard, one check for oil contamination of abrasives involves putting abrasive in a clean glass jar with clean water, putting a lid on the jar and shaking it, and then checking for an oil film on the surface of the water or coloration or cloudiness of the water itself.

Answer: False. This test is described in a standard, ASTM D7393, Standard Practice for Indicating Oil in Abrasives.

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On deteriorated tank linings after one year in service

What percentage of deterioration is acceptable at a one-year warranty inspection of water tank linings before a contractor must repair the coating?

Erik Andreassen, CFPS

No percentage is acceptable where an internal lining has been carried out. The warranty should have been a back-to-back warranty with the coating supplier for at least 3–5 years, but once defects are found, it is better to upgrade and replace the complete system. Also request a report from the coating supplier as to the cause of the breakdown after such a short period of time.

Keith Holdsworth, Eastern Tank

It's not uncommon for some areas to show deterioration after one year of service, especially if the previous substrate had extensive pitting or rough surfaces due to corrosion. It is important, however, after one year of service, that the lining is inspected and areas found are touched up, repaired, and retested to ensure adequate repairs were made. Holiday testing isn't always 100% perfect, especially in extremely large vessels with prior steel deterioration.

Problem Solving Forum questions and answers are published in *JPCL* and *JPCL*'s sister publication, *PaintSquare News*, a daily electronic newsletter. To subscribe, go to paintsquare.com. Occasionally, PSF questions and answers are republished, and participants' company affiliations are listed as they were when the answers were initially submitted.

Steven Ivanick, LA City Department of Water and Power

You needed to include in your specification a one-year inspection warranty to repair all holidays that are present after one year. You should also install a CP system to get maximum life out of your steel water storage tank. By monitoring your CP system, you can determine how well your protective coating system is doing.

Jesse Chasteen, Schriener Construction

If the final inspection was done correctly and meticulously, you should expect zero deterioration after one year's service life. Most coating manufacturers stand by their product for at least one year and warrant their product to provide serviceability for that time frame, if applied correctly.

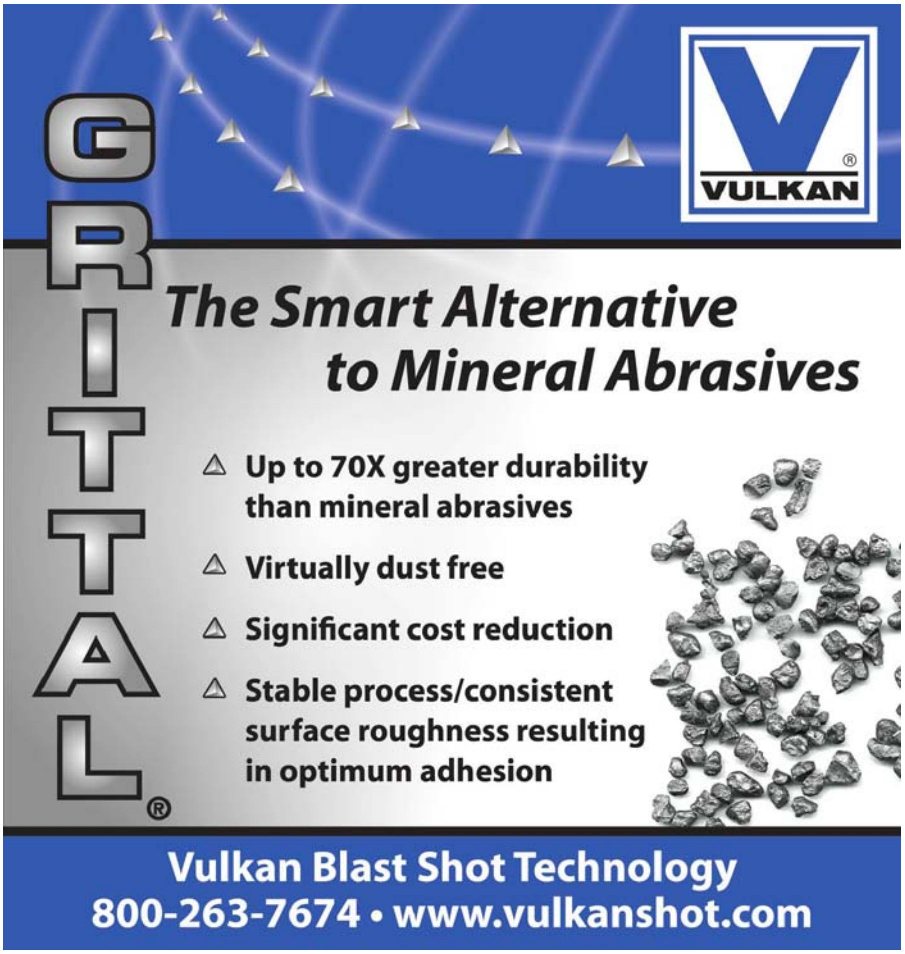
Remko Tas, Futuro SRL

No deterioration is acceptable after one year below the waterline in a steel water tank, and repairs should be done immediately. If not, damage to the substrate will only get worse, and at a fast pace. Above the waterline, you could apply some flexibility for minor flaws.

Daniel Luder, Woodside Energy
Zero. Heavily corroded areas should be mapped and brought to the owner's attention to allow for substrate repair prior to coating application. If no remedial actions are taken at this point, it remains a weak point. A paper trail is important in case people leave jobs. Each tank will have an inspection record file with all local wall thinning recorded for compliance with the American Petroleum Institute's API 653, Tank Inspection, Repair, Alteration, and Reconstruction, for example.

Upcoming questions in *JPCL* include the following.

- Which single type of paint system can be used to protect both stainless steel and carbon steel welded together?
- What do you do when the surface profile is higher than the dry film thickness of the specified primer?
- Which type of abrasive blasting media is suitable for preparing the more "exotic" stainless steels, such as Inconel or Monel?
- How does abrasive recycling affect cleaning rates when steel is blast-cleaned in the field?
- What is the best way to remove thick film elastomers from floors and ship decks?
- When a food plant runs 24/7 even during coating maintenance, tiny food particles floating in the air can contaminate a prepared surface. How do you prevent such contamination, or identify and remove it before coating?
- How can you justify the cost of installing an auto-blast machine and a paint booth in a fabricator's shop, and what resources are available to do such an analysis?



Q&A with Tolga Diraz

By Charles Lange, JPCL

Tolga Diraz is a technical manager at Akis Paint A.S., a licensee of Carboline Company in Turkey. He is responsible for carrying out performance and corrosion testing, arranging corporate meetings with new potential national and international customers, and organizing technical training about protective coatings and corrosion for customers and employers. He has taught two SSPC PCI courses in Turkey in the past year and is currently promoting SSPC training through Carboline's Corrosion School, a free, monthly technical training session available to customers. He is an SSPC Level 2-certified Protective Coatings Inspector and a NACE Level 3-certified Coatings Inspector, and he holds a degree in chemical engineering from Bosphorus University (formerly Robert College) in Turkey.

JPCL: How did you get your start in the protective coatings industry?

TD: During my final year at the university in 2001, I was keen on reading business- and economics-related magazines and newspapers. While reading, I noticed that there is a lack of specialists in the field of metal and concrete surface protection in Turkey (and later I'd learn that it is not just in Turkey). I was not aware that this field was generalized as "protective coatings" or "corrosion engineering" until I came across SSPC in 2005. From that moment, SSPC has become my second home, and its staff is like my second family.

JPCL: What kinds of structures do you specialize in? (i.e., bridges, water tanks, marine structures, etc.)

TD: At my past career as a steel contactor for eight and a half years, I had mainly supervised wind towers and pressurized vessels, along with structural steel projects like stadiums and highway and pedestrian bridges.

JPCL: You are in the process of starting an SSPC chapter in Turkey. Why do you think it is important to have an SSPC chapter in your region?

TD: SSPC is a one-of-a-kind society. Its aim is to help protective coatings professionals without the aim of gaining profit. Since it is such a unique technical association, it is already gaining popularity here in Turkey. I believe it is open to all, and it has a friendly, wise, and humble base of professionals who know international business and are very benevolent. I can tell you many positive stories I've experienced over my nine years working with SSPC.

JPCL: You recently attended SSPC 2014 in Orlando. What was your favorite part about attending the conference? (i.e., networking, technical sessions, exhibit hall, etc.)

TD: I really can't differentiate networking, the technical sessions, the exhibit hall, and other events at SSPC, since they are all connected to each other to form one big picture.

JPCL: Is it difficult finding qualified, competent coatings workers in your area? What is the best way to go about making sure that young people coming into the industry have a solid knowledge base and are capable of completing the work required?

TD: Like most trades in Turkey, finding qualified, competent coatings workers is quite difficult because there are so few technical and training opportunities. One usually needs to go abroad to participate in technical training or a certificate program. However, this was before the SSPC

Instructor Tolga Diraz (left) presents a certificate to Erstin Destebasi, a student in Carboline Company's Corrosion School in Turkey.

Turkey chapter had been established, so hopefully the new generation will be luckier than mine.

JPCL: What are some of the biggest challenges that coatings professionals face on a regular basis in your area?

TD: Because Turkey is surrounded by ocean (Mediterranean, Aegean, and Black Seas) and quite a lot of days are sunny here, climate is not a big issue. The real issues are economics, funding issues, and workforce quality, because the coatings business is not as popular in Turkey as it is in the U.S. There is somewhat less awareness of the industry due to international companies and projects. Also, although there are certified inspectors in the field, there are no certified applicators or contractors for now.

JPCL: What has been the highlight or proudest moment of your career thus far?

TD: Certainly, completing the SSPC PCS certification and being an internationally certified protective coatings specialist is a moment that I will never forget.

Second is taking part in SSPC training in Turkey and paving the way for SSPC to establish a new international chapter here.

JPCL: Is there a particular project or job that you worked on in the past that is especially memorable to you, and if so, why is it so memorable?

TD: My first workplace at Cimtas-ENKA, one of the largest steel fabricators in Turkey, was very memorable for me because I supervised so many different stages of coatings projects, such as pressurized vessels for clients like Bechtel, BP, Honeywell UOP, and PFD; wind-towers for Enercon and GE; heat exchangers for Axsia Howmar, Siemens, and KBR; and structural steel for Alstom, IHI Corp., Hitachi, and Mitsubishi Heavy Industries. I have also built up so many good friendships in nine years that still last today—we meet on special nights periodically.

JPCL: What is your favorite thing about the work that you do?

TD: If you are a member of a technical society like SSPC, you are confident that you can solve almost any problem, no matter how difficult it is, because there is an enormous amount of knowledge and experience. In addition, most of the certified people in SSPC are the humblest professionals I've ever met. I think this is a culture that the SSPC staff is continuously passing on to coatings professionals.

JPCL: What are some of your interests outside of work? How do you like to spend your free time?

TD: I really enjoy reading books and magazines about new technologies and attending commercial fairs (i.e., cars, electronics) to see them with my own eyes. Going to concerts and the theater with friends are my favorite parts of my social life. Apart from my social life, I love listening to and singing music, especially songs like pop-operas or hit R&B songs. It's like meditation for me.

The "Whoas" of Solvent Entrapment and Release

By Rich A. Burgess, PCS, KTA-Tator, Inc.; Series Editor

Whoa! Hold on! How much thinner do you plan to add? What thinner do you plan to add? The data sheet says you can add up to 10% by volume.

Even so, it is not uncommon to see painters (or painters' helpers) estimating thinner addition. It takes an experienced applicator who can save precious time by estimating thinner additions. After all, the reducer is going to evaporate from the applied coating film anyway. Should it matter that the solvent is supplied by "Universal Solvent," and the coating is supplied by "Not-So-Universal Resin?" Of course it matters, just as it matters when adding 15% thinner when 5% will produce the desired viscosity. When was the last time you actually saw a bridge painter measure viscosity? And who actually mixes the paint? The person with twenty years of experience or the person who has had one year of training twenty times?

Solvents in Coatings

Solvents are among the liquid components of coatings commonly referred to as the volatile vehicle. Upon application, and for some time afterward, the solvents evaporate, leaving the vehicle solids behind, which form the dry and cured coating film. The volatile vehicle(s) should be understood to be transitory components used in liquid coatings because of two principal properties: solvency and release rate. The first, solvency, relates to the ability of any given solvent to dissolve a resin and produce a homogeneous solution. Solvency is also an important property because it controls the coating's viscosity for application purposes.

The second property, release rate, is important for the film-forming properties of the coating. The applied coating film may require both rapid and slow solvent release. Rapid release is primarily due to evaporation, the first stage of solvent release. Slow release is primarily controlled by solvent diffusion from the applied coating film. Evaporation allows the film to build and achieve the targeted wet film thickness (WFT) without running or sagging. However, slower release (diffusion) allows the coating to wet-out on the substrate (promoting adhesion) and also allows the atomized coating to flow-out into a uniform film. Therefore, solvents are formulated into coatings to provide for a liquid application that "dries" at a rate that determines film build and surface wetting.

We are all aware that additional solvents (typically called thinners) are sometimes added during the mixing of coatings prior to application. Thinning is typically done to improve the application properties of the coating by reducing its viscosity. However, thinning is not always necessary, and in some cases, it is frowned upon, as some instructions specify, "Do not thin coatings without approval of the engineer." Coating manufacturers may clearly state that thinning is not normally necessary for application of their product, but if you must use thinner, instructions often read: "Use no more than X% by volume of thinner Y." Coating manufacturers not only advise about how much thinner to add, but also which solvent product(s) may be used. Several products may be listed for the same coating. Determining solvent selection will depend on the resin type, the ambient temperature, and the volatile organic compound (VOC) content (which is limited by regional regulatory standards). The most critical of these influences is resin type. The thinners to be added must fall within a solvency window for dissolution. All thinners are not suitable for all resins, and vice versa.

Ambient temperature is also important to solvent selection. For example, a product data sheet might require that in temperatures less than 80 F, use thinner "L", and at temperatures higher than 80 F, or for windy conditions, use thinner "H." The key property is related to the rate of solvent evaporation. Such requirements demonstrate that there are different solvents available for thinning a given coating resin system. The difference is related to temperature and its influence on the evaporation rate and diffusivity of "fast" and "slow" solvents. Use of solvent "L" in aliphatic polyurethanes on hot days or surfaces can result in a film with hundreds of small pinholes. It is possible that the solvents used may be the same in both cases, their ratios may be quite different. Therefore, one can easily conclude that there must be different solvent blends or "packages" available. One coating manufacturer's solvent blend may be slightly different than the solvent blend from a different manufacturer, hence coating manufacturers' recommendations to use only their own thinners.

Hopefully, the discussion above sheds some light not only on why we see limits on the types and amounts of thinner recommended by coating manufacturers in product data sheets, but also on why thinning may be further limited or even prohibited in project specifications. We assume that the solvents added during the manufacture of coatings are correct in type and amount and, as a general rule, that coatings thinned and applied per the manufacturer's instructions will form the desired film properties. Yet somehow, solvent use still can cause problems, and solvent entrapment can be a significant one.

Types of Solvents

There are numerous types of polymers (resins) used in the manufacture of coatings, and nearly all polymers must be synthesized in organic solvents. The solubility of the polymer in the appropriate solvent (and/or solvent blend) is necessary for the coating to be properly manufactured and applied. There are three major classifications of solvents used in coatings: petroleum hydrocarbon solvents (aliphatic solvents such as hexane and mineral spirits and aromatics solvents such as xylene and toluene), terpene solvents (derived from pine trees by solvent extraction and distillation), and oxygenated solvents (ketones, esters, alcohols, and glycol ethers). The solvent strength as well as the polymer solubility are key parameters.

Waterborne coatings differ from solvent-borne coatings because polymers in waterborne coatings are not actually dissolved in water. For example, waterborne latex coatings are actually dispersions of high molecular weight polymers throughout the water.

Solvent Release—Evaporation and Diffusivity

Solvent release from a coating should be viewed as a two-stage process. The first stage is related to evaporation rate, which is a function of volatility, temperature, and vapor pressure (of the solvent) at the surface. The second stage is the diffusivity rate. Solvent loss can be hindered by increasing the viscosity of the film and the degree of curing, such as in crosslinking, which is an ongoing process. Think of the film matrix as a room with many people dressed in black (curing resin) and some people dressed in white (solvent). In order for people dressed in white to leave the room, they must move between people dressed in black, from open space to open space (or in the case of solvents in coatings, from free volume to free volume). Add Velcro strips to the outside of the black clothes. When the people dressed in black congregate into a tight group, the open spaces become smaller in size. Because of "Velcro bonding," they begin to crosslink, making it more and more difficult for people dressed in white to reach the door. They have to squeeze their way through the tight group to get out. Some may take a very long time to get out, and some may never get out.

Waterborne coatings are somewhat of a different model. Instead of being dissolved, the resin is dispersed in water, but it still will not form a film until much of the water has evaporated. In addition to water, co-solvents are added to waterborne coatings to perform very specific functions. The evaporation rates of water and co-solvent (coalescing aid or agent) are equally critical. The co-solvents used are typically slow-evaporating solvents of glycol esters or ethers. It is important that these constituents be available, as the bulk of the water evaporates to aid in the coalescence of the dispersed resin. High humidity and low temperatures retard the evaporation of water, but not necessarily the co-solvent. With insufficient coalescence, many desired film properties are lost. Rapid loss of water also presents a problem because the amount of co-solvent relative to the amount of water becomes increasingly elevated, and the dispersion may collapse.

Solvent Entrapment

Solvents may become trapped in a coating film. The root cause may be low temperature, thus, a lower evaporation rate, or an overly thick coating film requiring high diffusivity. Simply put, much of the volatile vehicle fails to evaporate or diffuse from the film. The specific causes and consequences of solvent entrapment are discussed below.

Consequences of Solvent Entrapment

- Bubbling: Solvents that are trapped in coating films can form bubbles in the coating as it cures. When seen in cross-section, the bubbles actually are voids in the coating film (Fig. 1). In some instances, bubbles migrate to the surface and leave a crater, if the coating film has gelled too much to flow in behind and fill it. Overly thick moisture-curing or oxidation-curing coatings are susceptible to forming such bubbles because the surface of the coating film begins to "skin" over, making evaporation and diffusion increasingly difficult. Coating applications at high temperatures will cause bubble

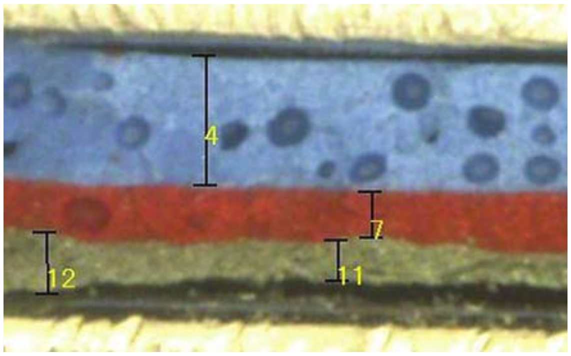


Fig. 1: Solvent voids in a coating film. Figures courtesy of the author.

formation, as will excessive amounts of slow-evaporating thinner in cool weather. Bubbling can be minimized by reducing the coating to the proper viscosity and applying it at the recommended temperatures.

- Pinholes: Pinholes may result from solvent bubbles that migrate through a partially gelled film that does not have sufficient flow to close in behind the trail that is made in the film (Fig. 2). As described for craters on the surface, the void left open in this case may extend through the coating system to the substrate. This void leaves an avenue for moisture and contaminants to cause corrosion. Even with the application of a second coat the pinholes may telegraph through to the next layer.
- Cracking: Cracking is typically recognized as a consequence of internal coating stress. There is more than one mechanism involved. The solvent-related mechanism is typically related to the surface of an overly thick coating that is gelling or skinning over while slow diffusion results in a softer matrix below the surface. The surface shrinks and splits as if a hard coating was applied over a softer, more flexible film. The related cracking can also result when a second coat is applied over a wet coat (wet on wet application). Diffusion path length is increased and free volume decreases from the top down. Coatings that cure by oxidation or moisture cure from the top down and are quite susceptible to solvent entrapment. Alligator cracking typically occurs at the sur-

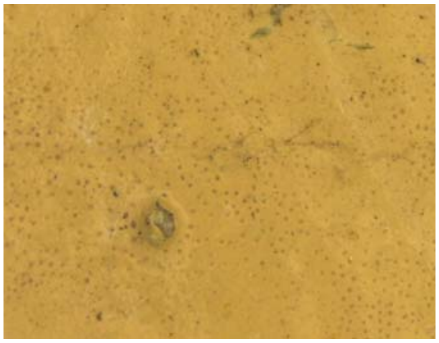


Fig. 2: Pinholes in a film due to solvent entrapment

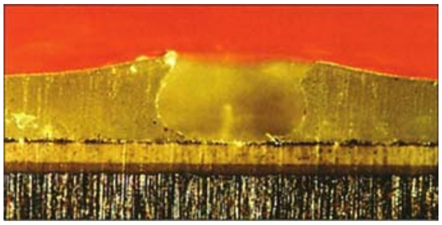


Fig. 3: Clear coat solvent pop in cross-section

face and extends into the softer coating layer beneath (Fig. 3).

- Orange Peel: Orange peel is the result of poor flow-out of the coating film. Insufficient solvent or incorrect solvent use can inhibit leveling of the coating surface, leaving a bumpy, dimpled texture that looks like an orange. Orange peel is often associated with thick films whose surfaces fail to flow out uniformly. This condition is not necessarily a cause for coating removal or repair because the film may still function properly. It is, however, an indication that thinning and/or application adjustments are needed.
- Flocculation: Flocculation occurs when resin polymers within the liquid coating agglomerate into large particles rather than remain in suspension or solution. Flocculation due to a solvent problem is most always associated with the use of an incorrect solvent. The polymers may not be soluble in the added solvent or the combination of the volatile vehicle results in a lower solvency. Polymer(s) drop out of solution generally resulting in growing clumps of a gelled or gelatinous matrix.
- Running and Sagging (Curtains): The development of runs and sags on vertical surfaces is related to low viscosity of the coating film. Runs are thin streaks of coating that flow down the surface and subsequently solidify. While this is primarily an aesthetic issue, the thick runs may also crack. Sags (or curtains) occur when an area of coating flows to form a thicker film at the base than the coating above. Although not solely caused by excessive thinning, sags are consequences of overly thinned coatings. The film build normally expected cannot be achieved, and running or sagging result. Incorrect mix ratio, overly warm coatings (which have a lowered viscosity), or coatings applied too thick can also lead to sags.
- Blistering: Blisters in coating films may be the result of several solvent-related issues. Baked coating films may form blisters or exhibit solvent "popping" because the free volume at the coating surface is reduced at an accelerated rate. Solvent release becomes much more dependent on diffusion than evaporation. Solvents accumulate within the available (decreasing) free volume of the curing film. The higher temperatures

of baking make solvents more active (resulting in increased internal pressure), and they will form blisters if unable to diffuse.

Osmotic blistering is typically associated with soluble salts trapped beneath a coating. The imbalance of ionic strength causes water to move through a semi-permeable membrane, effectively increasing the volume of trapped water resulting in a blister. The same phenomena results when solvents are trapped in a coating film. Just as soluble salts are hydrophilic, solvents that are hydrophilic may be included in coating formulations. The solvents (alcohols and glycol ethers and their acetates) become trapped, occupy volume, and draw water into the film (Fig. 4). The most severe occurrences are related to coatings in immersion service.

- Solvent Sensitivity: Two solvent-induced problems affecting aesthetics are bleeding and blooming. Bleeding is used to describe a discoloration of an upper layer coating layer as a result of coloring matter from a lower layer (which can also be the substrate) diffusing to the surface of the topcoat. It is most pronounced on lighter color topcoats but is not exclusive to light colors. The diffusion may be the result of solvents in the topcoat. However, in the case of waterborne coatings, moisture from the environment may be a contributing factor. Discoloration is the major problem. Blooming is related to bleeding but is associated with a reduction in gloss. Components in an applied film are leached into an upper layer of the topcoat by solvents. Upon reaching the surface, the solvents leave the film, leaving the leached products (exudate) on the surface. Solvent-sensitive pigments can result in a splotchy appearance on the surface with a corresponding change in gloss and modest or negligible color change. There is a bloom that is characteristic of waterborne latex formulations where the exudate is attributed to surfactants and/or dispersants in the film.

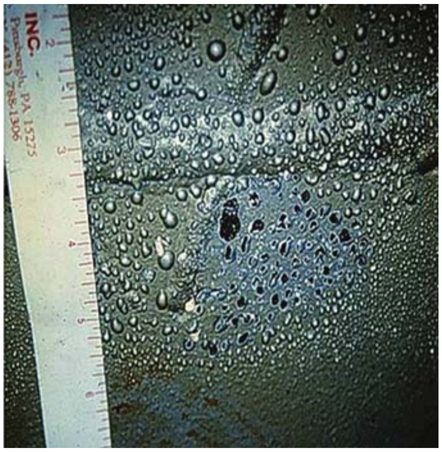


Fig. 4: Liquid-filled blisters

Sampling and Testing for Entrapped Solvents

Testing for residual solvents in a coating may be as simple as sniffing the coating chip or

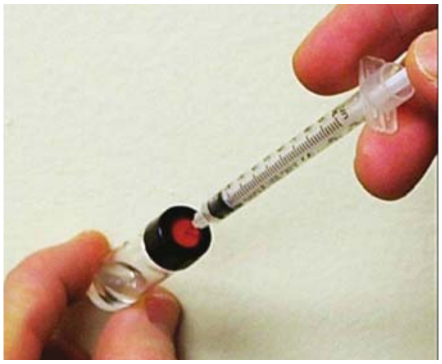


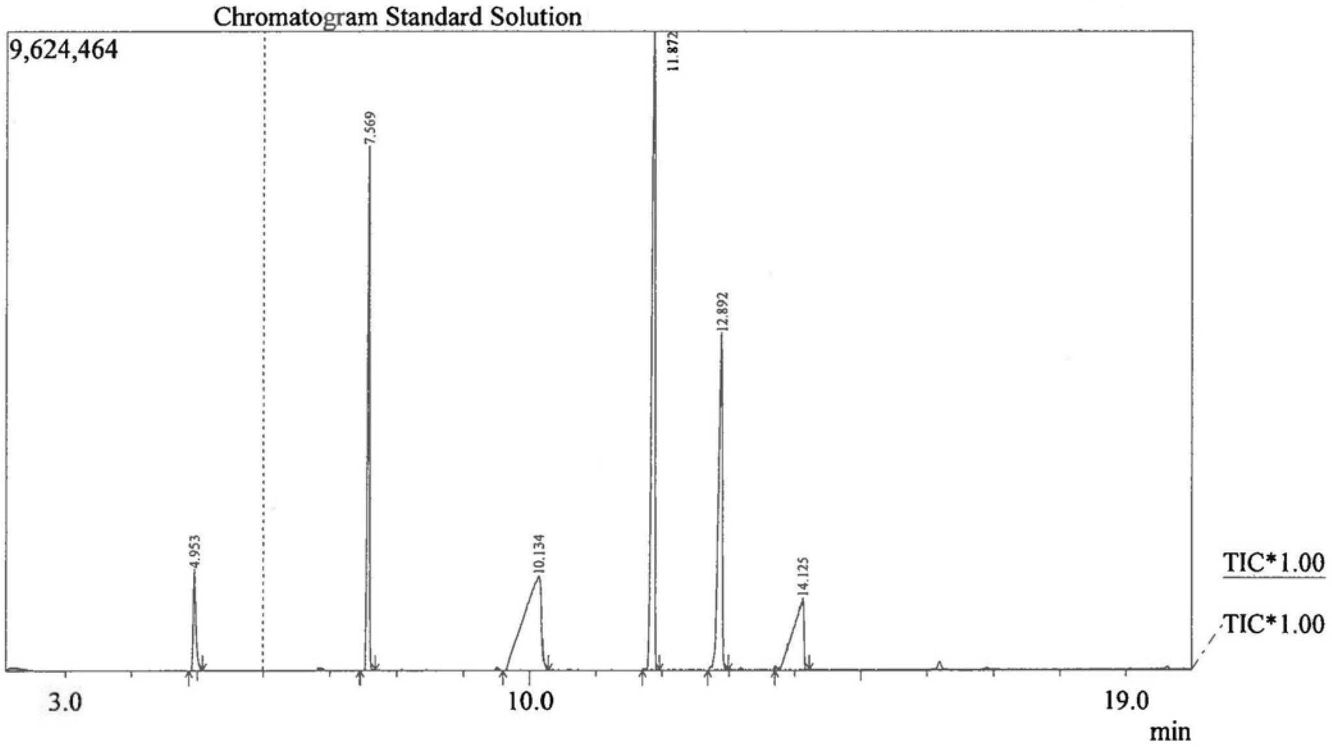
Fig. 5: Transferring blister liquid from syringe to a glass septum vial

the surface where some of the coating has been removed. This method is quick and easy, but it also is subjective and depends heavily on the sensitivity of the "sniffer." Confirmatory, more objective testing is available through sample collection and analysis of coating chips in the laboratory.

Sampling for the presence of solvents in coating films or blister liquids must be performed with care to avoid contamination, loss of solvent, or solvents extracting material from the (plastic) sample container.

Coating chips can be removed from the surfaces using a knife, chisel, scraper, or similar tool. The chips may be sniffed for solvent. However, the solvents can evaporate quickly, so the chips should be immediately placed into a septum vial (to avoid solvent loss) and the lid secured. In the absence of a glass vial or tight seal, the chips may be tightly wrapped in clean aluminum foil.

Liquids can be removed from intact blisters to determine if there are solvents in the solution. Frequently, salts are the first materials tested for. However, the ability of water-miscible solvents to create osmotic blisters should never be overlooked.



PEAK REPORT TIC

Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name
1	4.953	4.870	5.082	4296374	3.76	1536328	5.76	2.79	MI	Acetone
2	7.569	7.448	7.675	16701097	14.61	7912665	29.66	2.11	MI	t-butyl Acetate
3	10.134	9.589	10.275	26489033	23.17	1427967	5.35	18.55	MI	
4	11.872	11.696	11.957	33727265	29.51	9620901	36.06	3.50	MI	PCBTF
5	12.892	12.687	12.992	20679723	18.09	5094008	19.09	4.05	MI	Cyclohexanol
6	14.125	13.707	14.224	12413732	10.86	1088520	4.08	11.40	MI	
				114307224	100	26680389	100.00			

Fig. 6: The peaks shown above represent the individual solvents in the sample tested. They elute at different times, thus separating the different components. The table below identifies some of the solvents found in this sample. For example, the first peak is acetone and the fifth peak is cyclohexanol.

The blister surfaces should be cleaned of dirt and debris to avoid contamination. Once cleaned, the blister may be punctured using a knife, large pin, or finishing nail, each of which should also be clean. A syringe is placed through the hole after the plunger is depressed, and the plunger is then pulled back to suck blister liquid into the barrel.

Most syringes used in the field are plastic, so the fluid collected should be transferred to a glass septum vial as soon as possible (Fig. 5). It should be noted that multiple blisters may need to be sampled to obtain sufficient volume of blister liquid for testing.

The coating chips or blister liquid samples can be accomplished by gas chromatography (GC) or GC-mass spectroscopy (GC-MS). The sample is heated, causing the solvents present to evaporate or diffuse from the sample.

An inert carrier gas flowing through the system carries the compounds, leaving the sample into the column of the GC. The column, having various affinities to solvents, separates the solvent mixture (e.g. by boiling point) so that the individual solvent compounds are detected at different time intervals. An example of the chromatogram produced is provided in Fig. 6. Note that the table in Fig. 6 identifies some of the compounds found in the sample.

Conclusion

The next time you hear, "no one measures thinner addition" or "MEK is a universal solvent," you'll know the possible consequences of adding too much thinner or the incorrect type of thinner to a coating. It takes a few more minutes to do it right, and doing it right can save thousands of dollars in rework.

There are many circumstances that can create problems during industrial painting. Doesn't it make sense to minimize those that are self-inflicted?

JPCL

Richard Burgess, editor of the F-Files series and a senior coatings consultant with KTA-Tator, Inc. (Pittsburgh, PA), has over 20 years of experience in coating condition assessments; failure analysis; specification preparation; expert witness; and environmental, health, and safety consulting.

He is an SSPC-Certified Protective Coatings Specialist and a NACE-Certified Coatings Inspector Level 3.

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See the entire Business Meeting and
Awards Luncheon here:

Coatings Projects Honored at Structure Awards

By Charles Lange, *JPCL*

On Monday, Feb. 10, at the Annual Business Meeting and Awards Luncheon held during SSPC 2014 featuring GreenCOAT in Orlando, FL, SSPC President Ben Fultz and Executive Director Bill Shoup presented the Society's eighth annual Structure Awards, given for outstanding coatings projects completed on a variety of interesting and complicated structures.

This year's Structure Award winners conquered challenges that included working at extreme heights, recoating offshore wind farm structures, applying coatings to a copper roof in the extreme Florida heat, dry docking and rehabilitating large U.S. Navy ships, and repainting a mural on an elevated water storage tank.

The award winners are presented over the next several pages. The photo essay is based on nomination materials submitted to SSPC in 2013, and on information given at the awards ceremony.

GEORGE CAMPBELL AWARD

Named after the late George Campbell, founder of Campbell Painting Company in New York, this award honors a difficult or complex industrial or commercial coating project. Challenges may include extreme environmental conditions, time constraints, limited access or high traffic, complex industrial structures, or coordination with multiple trades or subcontractors.

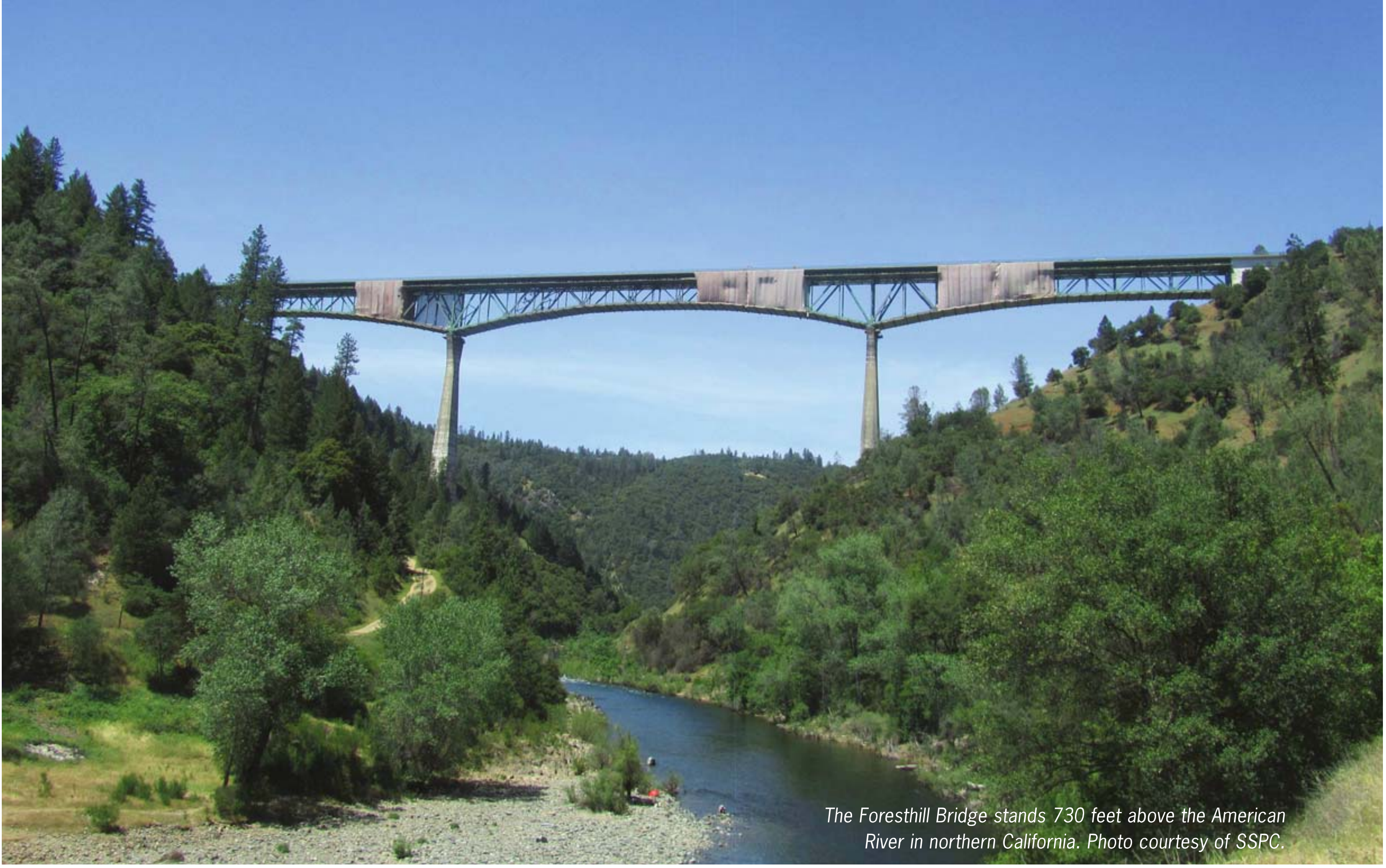
Foresthill Bridge

Location: Auburn, CA
Owner: County of Placer Department of Public Works
Contractor/Applicator: F.D. Thomas Inc. (SSPC-QP 1 and -QP 2)
Coating Supplier: Carboline Company
Start Date: February 2011
Completion Date: January 2014

The 730-foot-tall Foresthill Bridge (often called the Auburn-Foresthill Bridge) spans the American River in the western slopes of the Sierra Nevada mountains. Built in the early 1970s, it is the highest bridge in the state of California and the fourth-highest in the nation. The bridge had not been repainted since it was constructed, and it was also due for important construction improvements, including a seismic retrofit.

The $74 million project required removal and disposal of 194,000 pounds of original lead-based paint that had covered the bridge's one-million-square-foot surface. That same surface area was then abrasive blast cleaned to a Near-White (SSPC-SP 10) finish before receiving a three-coat organic zinc-epoxy-urethane system.

F.D. Thomas, Inc. also received the Golden Gate Partnership Award from the State of California Department of Industrial Relations Cal/OSHA Consultation Service for demonstrating a commitment to continuously improving the effectiveness of its workplace safety and health management system on this project.



The Foresthill Bridge stands 730 feet above the American River in northern California. Photo courtesy of SSPC.

SSPC President Ben Fultz (second from left) presents the George Campbell Award to (from left) Ray Tombaugh, KTA-Tator, Inc.; Grover Lee and Eric Anderson, F.D. Thomas, Inc.; Doug Moore and Tom Calzone, Carboline Company; Matt Randall, County of Placer Department of Public Works; and Debbie Simmons, Carboline Company. All SSPC Structure Awards ceremony photos courtesy of SSPC.

WILLIAM JOHNSON AWARD

This award recognizes outstanding achievement in aesthetic merit in industrial or commercial coatings work. Criteria include color, gloss, texture, and how the coatings complement the environment while enhancing the structure. The award is named after William Johnson, the late consultant with KTA-Tator, Inc., whose work in coatings formulation, failure analysis, and surface preparation was instrumental in advancing the industry.

Firgrove Mutual Zone 2 Reservoir

Location: Puyallup, WA

Owner: Firgrove Mutual Water Company

Applicators: J & L Co. Northeast (field) and CBI Services Inc. (shop)

Muralist: Rolf Goetzinger and Peter Goetzinger

Coatings Supplier: Tnemec Company, Inc.

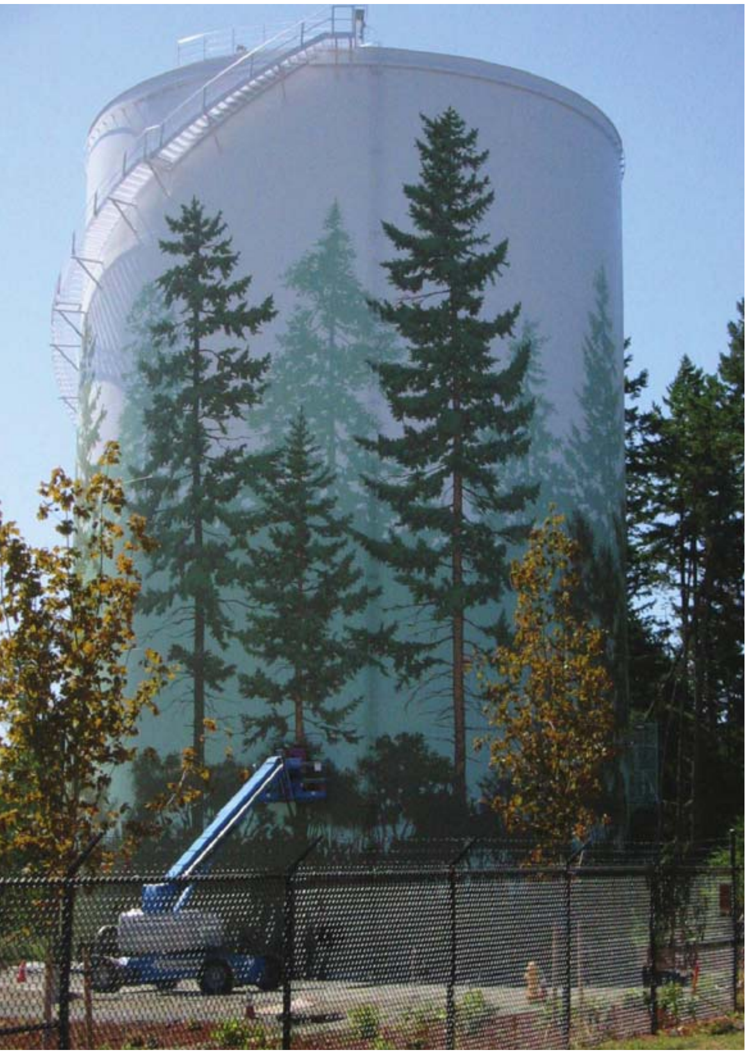
Start Date: April 17, 2012

Completion Date: August 17, 2012

This project involved constructing a new 105-foot-tall, 70-foot-diameter, field-welded steel standpipe (AWWA D100) water storage tank in the South Hill area of Puyallup, WA. Shop coating for the new tank consisted of a polyamidoamine epoxy applied to prepared steel. Polyamide epoxy primer and intermediate coats were applied in the field.

Mural artists and brothers Rolf and Peter Goetzinger worked from a single hydraulic lift to paint Douglas fir trees reaching 100 feet tall. They also painted a variety of other native plants that echo the trees and natural undergrowth surrounding the tank site.

Instead of using templates, stencils, or even a grid to guide the mural's layout, the artists used six-inch rollers to apply the acrylic polymer coatings freehand. Seven standard colors were used for the tank mural, with other custom colors



Applicators painted a mural displaying trees and other natural plants surrounding the Firgrove Mutual Zone 2 Reservoir site. Photos courtesy of Mike Nepple, Coldwater Project Services.

(From left) Larry Jones and Mitchell Hinds, Firgrove Mutual Water Company; and Vaughn O'Dea, Tnemec Company, Inc., are presented the William Johnson Award from SSPC President Ben Fultz (second from right).

mixed in the field, as well.

Located at a highly visible site at the intersection of a state highway and an arterial roadway, the tank now serves not only its water storage purposes, but it is also a local amenity and an attractive asset to its community.

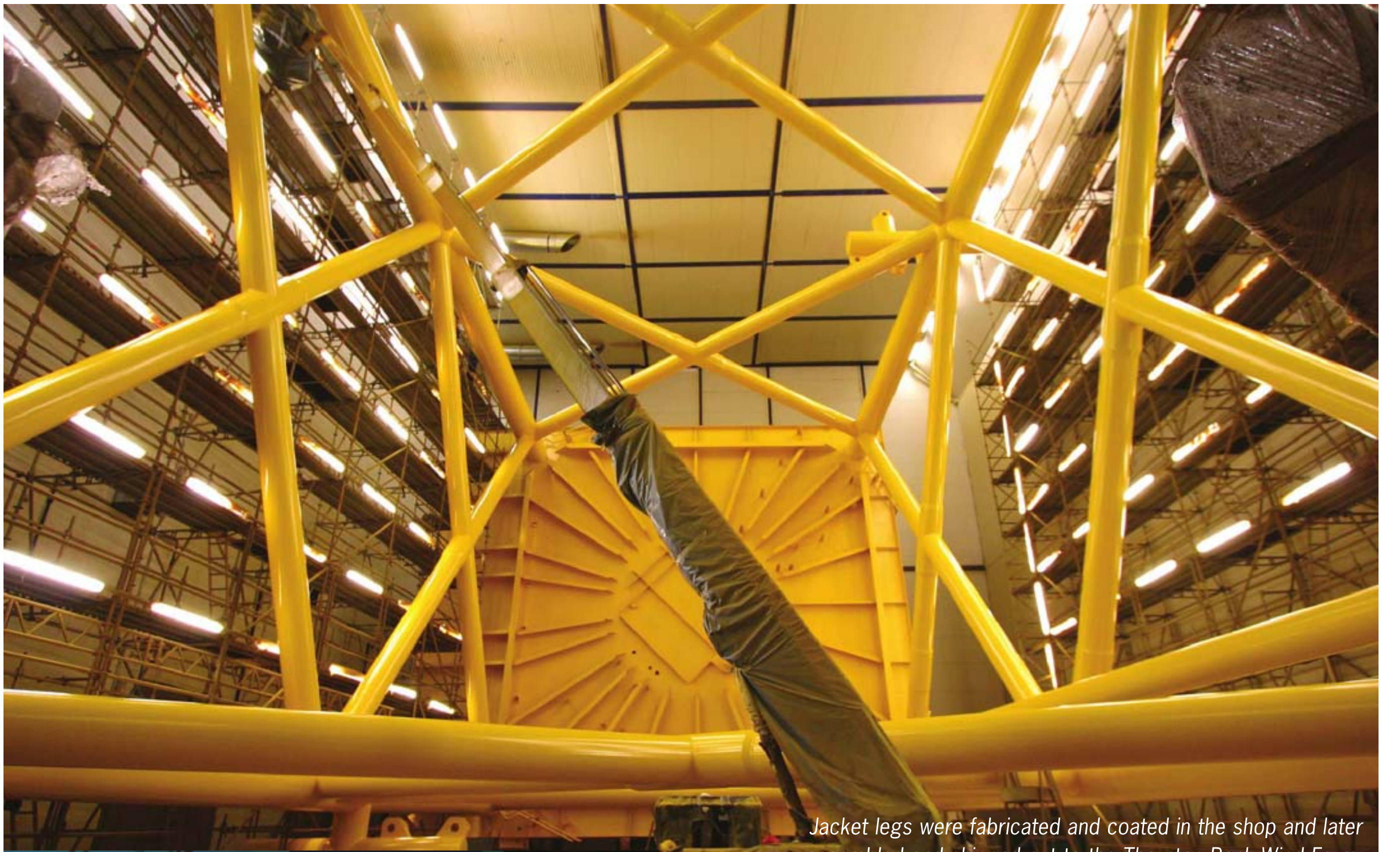
E. CRONE KNOY AWARD

This award, named after the late founder of Tank Industry Consultants, Inc., recognizes coatings work that demonstrates innovation, durability, or utility. It is given for outstanding achievement that may include excellence in craftsmanship, execution of work, or the use of state-of-the-art techniques and products to creatively solve a problem or provide long-term service.

Thornton Bank Wind Farm

Location: Coast of Belgium (North Sea)
Owner: C-Power N.V.
Contractor/Applicator: Smulders Group and THV Seawind (Dredging International)
Coating Supplier: Hempel Belgium
Start Date: Fall 2010
Completion Date: Fall 2012

Thornton Bank is an offshore wind farm located off the coast of Oostende, Belgium. This challenging project involved constructing 48 steel jacket foundations for wind turbine generators and one steel jacket foundation for an offshore transformer station.



Jacket legs were fabricated and coated in the shop and later assembled and shipped out to the Thornton Bank Wind Farm. Photo courtesy of Ronny Van Poppel/Smulders Group.

Ben Fultz, SSPC President (center), presents the E. Crone Knoy Award to Ronny Van Poppel (left) and James Massialas, Hempel.

The jackets' legs were fabricated at the Smulders Group Project Plant, where they were assembled into a jacket foundation and finished by adding resting platforms and boat landings. After the midsections were painted and metallized, they were connected to the jacket foundations and received a complete touch-up.

The building of all the structural parts for the jackets was executed at several different locations, and then the separate structures were transported to Belgium, where they were assembled and shipped out to Thornton Bank.

By the end of the two-year project, six different coating systems totaling 152,000 liters of paint had been used. The complexity of the project, along with challenges regarding production, worker safety, and meeting deadlines are among the reasons this project was chosen as an award recipient.

CHARLES G. MUNGER AWARD

This award honors an outstanding industrial or commercial coatings project that demonstrates the longevity of the original coating. The structure may have had spot repairs or overcoating with the original coating still intact.

Marco Island Prudential Realty Building

Location: Marco Island, FL

Owner: Gary Van Cleef

Contractor/Applicator: Spectrum Contracting

Coating Supplier: Tnemec Company, Inc.

Start Date: Spring 2005

Completion Date: April 2006

Coating a copper roof in Southern Florida can present many obstacles, such as extremely hot surface temperatures, daily rainstorms, and interference from salty ocean air. This roof in particular was also seamed, sloped, and multi-tiered, which can cause issues with a coating's wettability and edge retention.

The coating system applied to the copper roof of the Marco Island Prudential Realty Building has withstood exposure to the Florida sun for seven years. Photo courtesy of Tnemec Company, Inc.

(From left) Charles Stephens (on behalf of Gary Van Cleef); Vaughn O'Dea, Tnemec Company, Inc.; and Robert Valentine and Jeffrey Roberts, Spectrum Contracting, accept the Charles G. Munger Award from SSPC President Ben Fultz (second from left).

The roof was high-pressure washed and prepared according to SSPC-SP 2, Hand Tool Cleaning. The coating system included a polyamide epoxy prime coat designed for forgiving application and adhesion characteristics, spray applied at 2.5–3.5 mils, and a high-solids metallic fluoropolymer with a semi-gloss finish that provides color and gloss retention in severe exposure environments, spray applied at 2.0–3.0 mils.

The original coating system was applied in 2006.

MILITARY COATINGS PROJECT AWARD OF EXCELLENCE

This award recognizes exceptional coatings work performed on U.S. military ships, structures, or facilities. This year, two projects were presented this award.

USS Freedom

Location: San Diego, CA

Owner: U.S. Navy

Contractor/Applicator: YYK Enterprises Inc.

Coating Supplier: PPG Protective and Marine Coatings

Start Date: December 2012

Completion Date: January 2013

The *USS Freedom*, commissioned in 2008, went to dry dock in January 2013 to remove its existing failed coating system. It became the first U.S. Navy ship since the 1960s to receive a four-color camouflage pattern.

One coat of edge-retention epoxy was applied from the water line to the rail, and the four camouflage colors—black, haze gray, light gray, and ocean gray—were a semi-gloss

The four-color camoflauge pattern on the USS Freedom was applied with a color-stable, low solar-absorbing, low-VOC coating system. Photo courtesy of David Clapp.

SSPC President Ben Fultz (center) presents the Military Coatings Project Award of Excellence to (from left) Tom Morrissey, PPG Protective & Marine Coatings; Paul Ralph, YYK, Inc.; Dan Dunmire, DoD Corrosion Policy and Oversight; and Julio Mojica, PPG Protective & Marine Coatings.

Approximately 17.3 acres of steel onboard the USS Ronald Reagan *were prepared and repainted. Photo courtesy of IMIA.*

epoxy-polysiloxane system, applied as a finish coat from the waterline to the topside interface.

Because the *USS Freedom* is an active warship, the contractor and coating supplier had to meet accelerated deadlines. In only 72 hours, the coatings were manufactured in Arkansas and shipped to National City, CA. Priming and painting began immediately, and the ship was returned to service in less than six weeks.

The ship is also one of the first new ships painted with a color-stable, low solar-absorbing, low-VOC coating with unlimited recoatability for easier touch-up and maintenance.

(From left) Mark Schultz, The Sherwin-Williams Company; Dan Dunmire, DoD Corrosion Policy and Oversight; and Frank Griffeth and Joseph Rella, International Marine & Industrial Applicators, LLC, are presented the Military Coatings Project Award of Excellence from SSPC President Ben Fultz (second from left).

USS Ronald Reagan (CVN 76)

Location: Bremerton, WA

Owner: U.S. Navy

Contractor/Applicator: International Marine & Industrial Applicators, LLC (IMIA)

Coating Supplier: The Sherwin-Williams Company

Start Date: January 17, 2012

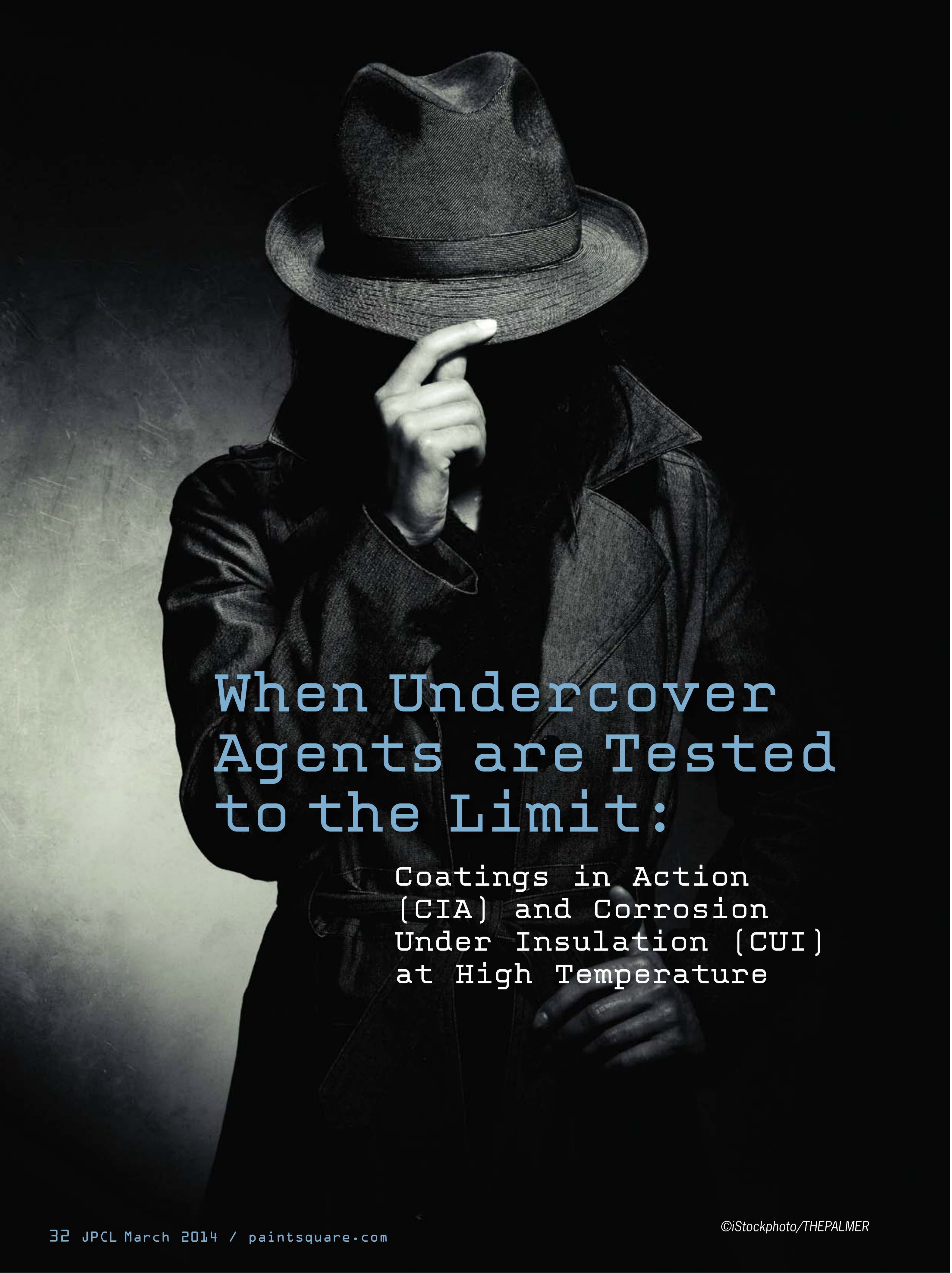
Completion Date: January 31, 2013

With a seven-month timeframe, an aggressive undocking schedule, strict environmental operating permits, and over 17 acres of steel requiring work, preserving the coating system on the *USS Ronald Reagan* at the Puget Sound Naval Shipyard in Bremerton, WA, required a lot of coordination.

Coatings preservation work was performed on the freeboard, underwater hull, sea chests, catwalks, various tanks, voids, and vent plenums. Approximately 17.3 acres of steel were staged, encapsulated, and preserved.

To prepare that much steel for coatings work, 48 blasting nozzles were in operation and eight 22-ton steel abrasive recycling units were mobilized and used at the same time, with some of the 50-foot units raised and placed on the carrier's flight deck. The freeboard was coated with a polysiloxane system, while elevators were prepared with aluminum abrasive and coated with polysiloxane system.

A total of 2,403 total government inspections were conducted over the course of the project, with a 99.9% pass rate. No re-work was required under the NAVSEA 009-32 coating specification. Working safely and efficiently, the contractors were able to complete work in time for the project deadline.



When Undercover Agents are Tested to the Limit:

Coatings in Action (CIA) and Corrosion Under Insulation (CUI) at High Temperature

©iStockphoto/THEPALMER

For industrial, marine, and offshore facility owners, the cost consequences of corrosion under insulation (CUI) can be intolerable in terms of lost production, chemical spills, environmental cleanup, and health and safety implications. Hence, it is very important to implement carefully designed CUI mitigation strategies.

Specialty coatings can be excellent tools for CUI mitigation strategies.[1] The authors showed in previous laboratory investigations using a CUI cyclic test, that coated carbon steel pipe insulated with Cal-Sil (calcium silicate) saturated with a 1% NaCl (sodium chloride) salt solution performed best with either thermal spray aluminum (TSA) or a spray-applied titanium modified inorganic copolymer (TMIC).[2,3] The raison d'etre for the use of calcium silicate as an insulation material was because it readily absorbs and wicks moisture and can hold about 20–40 times its weight in water,[4] thus representing a worst-case scenario.

The cyclic temperature range used in the earlier work was 95 C to 445 C.[2, 3] The temperature span was intended to ensure that the coated pipe test pieces were exposed to the NACE RP0198[5] critical corrosion temperature range (4 C to 175 C for carbon steel; 50 C to 175 C for stainless steel) and higher. Interestingly, an anomalous finding from the earlier work was that corrosion on wet and insulated bare steel pipe appeared to occur at temperatures higher than those known for the corrosion of dry carbon steel.[5, 6] This suggested that temperatures, measured by thermocouples on bare steel pipe encased in dry insulation, which were used to indicate temperatures of coated steel pipe encased in wet insulation, were incorrect and needed to be checked to provide greater accuracy. These new temperature measurements were carried out as part of this new CUI study.

The primary aim of the current investigation was to evaluate coating performance on both carbon steel and stainless steel pipes in the temperature range for CUI and at elevated temperatures approaching 600 C. Utilizing the Cyclic Pipe test, the cyclic temperature resistance of a new member of the TMIC class of coatings was compared and contrasted with one of the other specialty coatings studied in the previous work, an inorganic coating containing micaceous iron oxide (hereinafter Coating A and designated Coating #2 in the former study). Both the original TMIC coating tested and the new TMIC coating evaluated in this study were aluminum filled. They were formulated to provide similar flexibility, be unaffected by intra-film stresses during high temperature cycling in the typical CUI temperature range, and withstand cycling and continuous operation between ambient and elevated temperatures. In the present investigation, the new TMIC coating was touted to perform up to 600 C, much greater than the 450 C limit for the earlier version.

By Mike O'Donoghue, Ph.D., Vijay Datta, MS, Adrian Andrews, Ph.D., and Sean Adlem, International Paint LLC; Linda G. S. Gray, MSc, Coating Consultant; Tara Chahl and Nicole de Varennes, CET, RAE Engineering and Inspection Ltd.; and Bill Johnson, AScT, Acuren Group Inc.

Editor's Note: This article is the second part of a series on corrosion under insulation. The first part, "When Undercover Agents Can't Stand the Heat: Coatings in Action and the Netherworld of Corrosion Under Insulation," appeared in the February 2012 JPCL. This article is based on a presentation given at SSPC 2013, the annual conference of SSPC: The Society for Protective Coatings, held Jan. 14–17, 2013, in San Antonio, TX. It is available in the conference Proceedings (sspc.org).

Experimental

Part A: Temperature Profile Studies on Bare Steel Pipe

In the authors' previous work, the temperature profile of the steel pipe under wet insulation was assumed not to be dissimilar to the temperature profile measured by thermocouples under dry insulation. This study was undertaken to characterize the temperature profile under wet conditions and determine what, if any, differences occurred compared to the dry condition.

The materials and procedures were identical to those used in the previous CUI cyclic test,[2,3] except that under the dry condition, only the temperature was cycled. Two duplicate, insulated, bare steel test pipes were prepared. The dry condition was run first (over a two-week duration), followed by the wet condition (two weeks) using the same duplicate pipes.

The pipe was 60 cm long and 6 cm in outside diameter, with a 5-millimeter-thick wall.

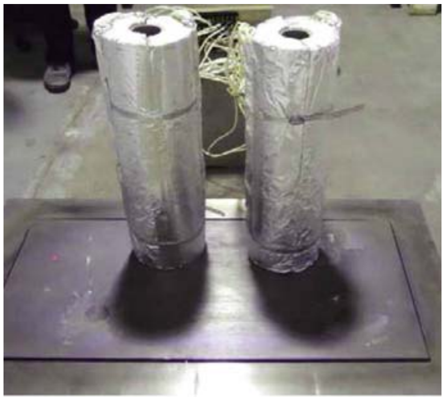


Fig. 1: Experimental set-up (left to right) Stainless steel pipe and carbon steel pipe

Thermocouples to measure the surface temperature of the pipe under the insulation were positioned at intervals varying from 20 mm to 50 mm, from the bottom (hot end) to the top (cold end) of the pipe, for a total of 18 thermocouples. Each pipe was encased in 5-centimeter-thick calcium silicate insulation sleeves.

In this study, an additional eight thermocouples were added to the pipe to measure the temperature within the insulation as a function of distance from the pipe surface. In this way, the temperature profile across the insulation was determined at 10, 20, 30 and 40 mm intervals from the pipe surface, at 150 mm and 450 mm from the bottom (hot end) of the pipe.

The CUI cyclic test procedure was as follows. At the beginning of the day, one liter of a 1% NaCl solution was poured slowly into the insulation surrounding the pipe at the top of the pipe. The pipe was then placed on a hot plate, which was immediately turned on. The hot end of the pipe reached approximately 600 C within two to three hours. After 8 hours on the hot plate, the insulated pipe was removed from the heat and placed in a shallow pan. One more liter of 1% NaCl solution was poured into the insulation, whereupon the insulated pipe was allowed to cool overnight. This procedure was repeated for five days a week (Monday through Friday), for two weeks. Almost all of the NaCl solution was absorbed by the insulation, with a minimal amount of solution flowing through the insulation, either to the pan or the hot plate.

Each morning, after the first day, the pipe was weighed when it was cool, prior to starting the next day's cycle.

The temperature profile, determined under dry conditions, was determined using the same procedure, except that the brine was omitted. A stable, reproducible profile was achieved within 2 to 3 hours, and the measurements were deemed complete after two days.

Part B: High Temperature CUI Studies on Coated Carbon and Stainless Steel Pipes
The CUI cyclic test previously employed by the authors was used again because it provided an accelerated and significantly more aggressive environment, which was favored by some facility owners.[2,3] A few modifications and changes were incorporated, such as the addition of stainless steel pipe, application of a coating to each half of the pipe, and increasing the testing temperature.

Sections of carbon steel and stainless steel pipe were abrasive blast cleaned to an SSPC-SP 10, Near-White Metal standard, using aluminum oxide grit. A 2–3 mil jagged profile was obtained. The TMIC coating was applied to one half of the pipe (1 coat @ ca 8 mils' DFT), and Coating A was applied to the other half (2 coats @ ca 6 mils' DFT/coat), along the length of the pipe, respectively. The liquid coatings were applied by air spray and cured at 25 C for seven days.

A pre-formed, 5-centimeter-thick calcium silicate pipe insulation was fastened around each pipe in a clam-shell fashion. Aluminum foil was wrapped around the insulated pipe and secured with zip ties, as shown in Figure 1. Both ends of the insulation were left open to facilitate the entry and drainage of the NaCl wetting solution. Figure 2 shows the pipe sample schematic.

The heat distribution on the hot plate was verified using temperature indicator crayons from 450 C to 750 C. The carbon steel and stainless steel temperature profiles were placed at the 650 C heat position.

The CUI cyclic test procedure of heating and adding 1% NaCl solution to the porous calcium silicate insulation is documented above and in the authors' previous work.[2,3]

The liquid was mostly absorbed by the insulation, with only a small amount of drainage from the bottom. The temperature profiles for the carbon and stainless steel pipes were slightly different. The procedure was repeated five days a week for six weeks, for a total of 30 cycles, whereupon the insulation was removed from the pipes and the coating performance was evaluated.

The surface temperature of the pipes under dry insulation was determined with two pipe samples that were identical to the coated pipe samples, except that the carbon steel and stainless steel pipes were uncoated and thermocouples were placed between the insulation and the steel at 5 cm intervals.

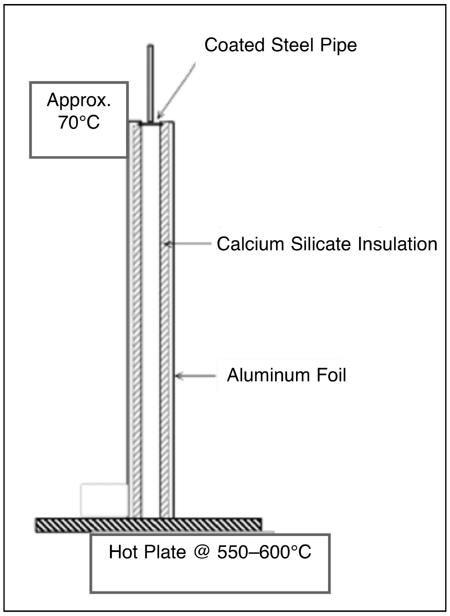


Fig. 2: Pipe sample schematic

The temperature of the hot plate was

adjusted such that the temperature gradient obtained along the pipe length with wet insulation was 72 C to 560 C for the carbon steel and 77 C to 600 C for the stainless steel pipe, as shown in Tables 1a and 1b. The hot plate settings were maintained for the duration of the testing with the coated and bare steel pipe samples.

To facilitate detailed analysis of the coatings' performance after CUI cyclic testing, each coated half of the pipe, as shown in Figure 3, was analyzed in 5 cm increments, moving from 0 mm (560 C) to 600 mm (72 C) for the carbon steel pipe and 0 mm (600 C) to 600 mm (77 C) for the stainless steel pipe. In the adhesion analysis, each area was divided into four test areas, with results reported based on the average temperature of that area.

Coating performance was evaluated based on visual examination and adhesion assessment (ASTM D6677). Visual examination included color change, degree of rusting, blistering, flaking, and cracking (ISO 4628, Sections 2 through 5).

Results

Temperature Profile Studies on Bare Steel Pipes—Wet Insulation

The results for days 1, 3, and 5 are shown in Figures 4a, 4b, and 4c (pp. 36–37). Complete results for days 1, 3, 5, 7 and 10 can be found in Appendix I, Figures 1a to 1e, available in full at paintsquare.com.

Each figure shows the temperature profile of the pipe as a function of distance from the hot end (on the hot plate) at various time intervals during the daily heating cycle. Zero hours refers to the start of the day where 1 liter of 1% NaCl solution was poured into the insulation and into the pipe (at ambient temperature), immediately before the pipe was placed on the cold hot plate (which was then turned on.) Temperature profile curves were obtained at various intervals for the following 8 hours, after which the pipe was removed from the hot plate, another liter of 1% NaCl was poured into the insulation, and the pipe left overnight.

Weight Change of the Pipe

The initial mass of the pipe with dry insulation was estimated to be 3.2 kg (7 lbs) made up of 2.7 kg (6 lbs) for the pipe and 0.45 kg (1 lb) for the insulation.

After the first 5 days of cyclic wetting and heating, the pipe plus insulation had a mass of 13.4 kg (29.4 lbs), an increase of 10.2 kg

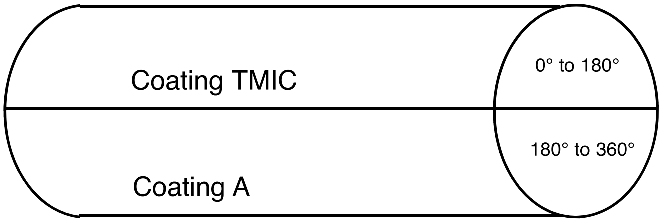


Fig. 3: Diagram of pipe

Table 1a: Distance along Carbon Steel Pipe and Corresponding Temperature

Distance from Bottom (mm)	0–50	50–100	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500	500–550	550–600
Approx. Wet Temp Range (°C)	560–515	515–400	400–375	375–285	285–265	265–207	207–190	190–160	160–118	188–99	99–87	87–72
Approx. Dry Temp Range (°C)	540–465	465–415	415–391	391–300	300–280	280–260	260–240	240–235	235–200	200–180	180–150	150–100

Table 1b: Distance along Stainless Steel Pipe and Corresponding Temperature

Distance from Bottom (mm)	0–50	50–100	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500	500–550	550–600
Approx. Wet Temp Range (°C)	600–536	536–460	460–365	365–305	305–250	250–120	120–112	112–102	102–98	98–95	95–92	92–77
Approx. Dry Temp Range (°C)	600–520	520–450	450–370	370–325	325–275	275–195	195–180	180–170	170–150	150–125	125–110	110–95

(22.4 lbs). Over the 5 days, 10 liters of 1% NaCl had been added to the insulation. Therefore, very little water evaporated from the insulation during the first five days.

After ten days, the pipe plus insulation had a mass of 14.0 kg (30.8 lbs), indicating that the pipe had reached a steady state. The insulation was presumably fully saturated, and the water loss by evaporative boiling was roughly equal to the amount of brine introduced.

The rate of evaporation was presumably matched with the rate at which brine was introduced into the insulation at 5 days. This was consistent with the observation of steaming (water vapor release) from the top of the pipe during the initial hours of heating.

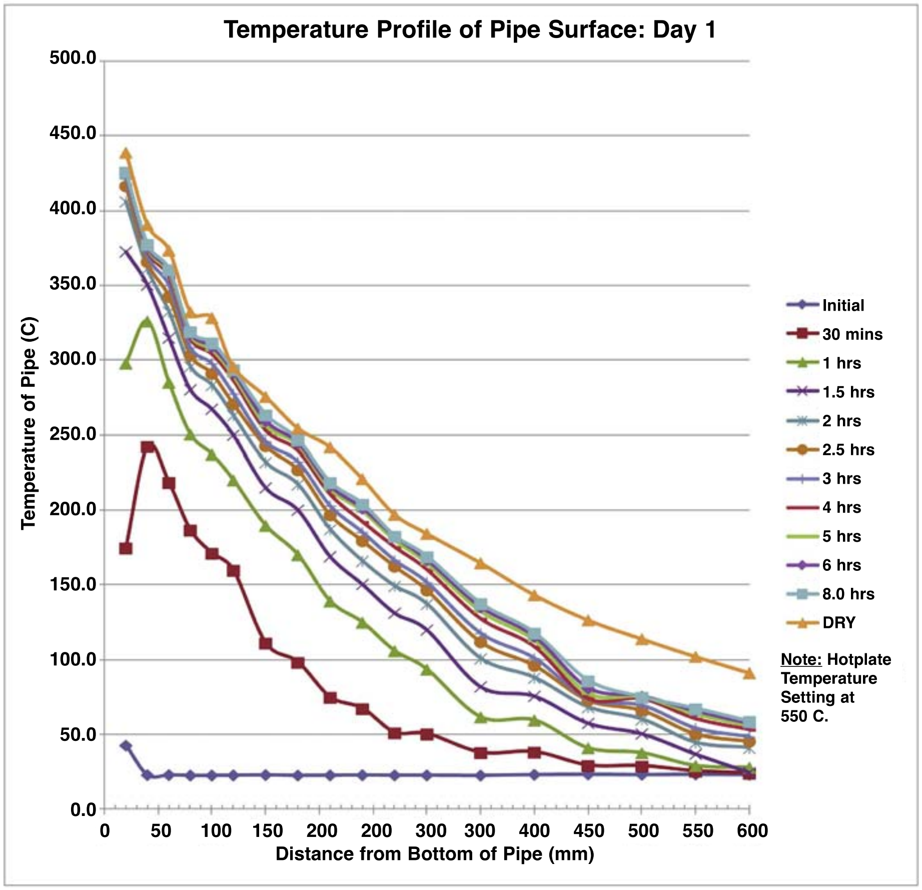


Fig. 4a: Day 1 of CUI cyclic testing with hydration

Temperature Profiles: Day 1

The pipe temperature increased rapidly as the heating cycle was applied. Over the 8-hour duration, the temperature profile curves tend toward the shape and values of that recorded for the dry pipe (Fig. 4a). The deviation from the dry curve is minimal at the high temperature end (bottom) of the pipe, presumably because the insulation is still dry, or has dried out from the heating. The deviation from the dry curve at the low temperature end (top) of the pipe is considerably larger, presumably due to the loss of heat into the moisture present in the insulation.

Temperature Profiles:
Days 2–5 and Days 6–10

The temperature profile progressively changed from days 1 through 5, after which little further change was observed.

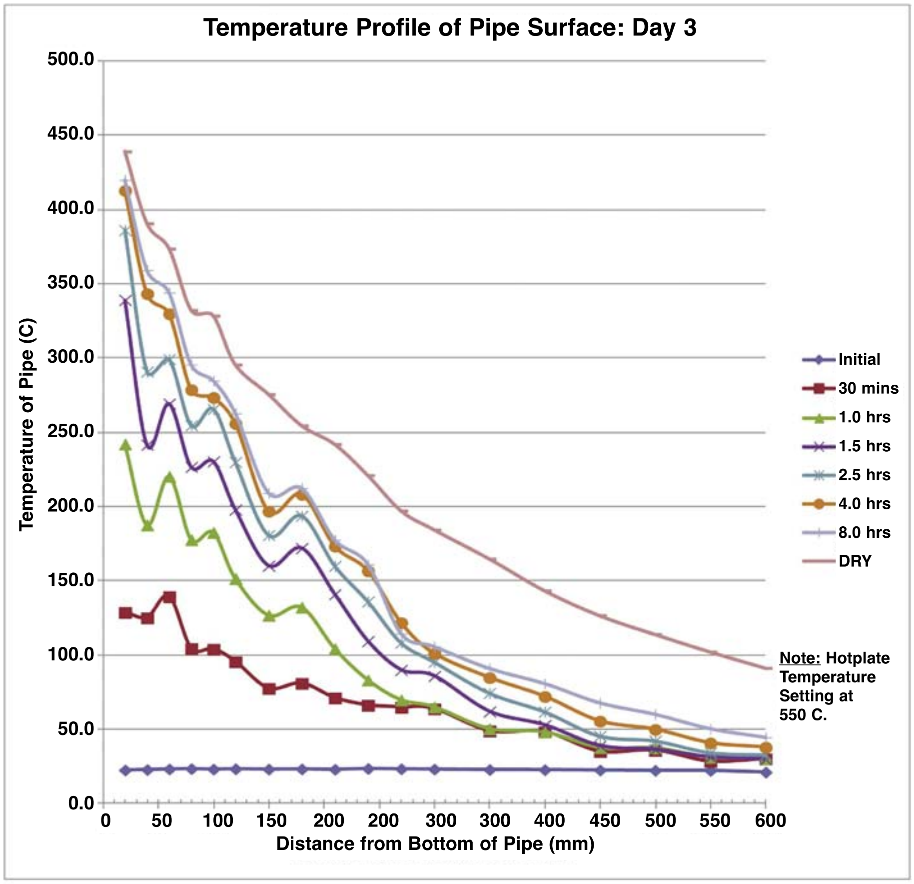
The temperature profile at the high temperature end of the pipe was rather erratic from days 2 to 4, especially at the beginning of the heating cycle (Figure 4b). The behavior, consisting of high and low temperature variations along the length of the pipe was attributed to random "dry" and "wet" spots in the insulation. The erratic behavior stopped at day 5, presumably because the insulation became fully saturated with brine (Fig. 4c).

The temperature of the pipe after 8 hours progressively decreased from days 2 to 5, particularly at the high temperature end of the pipe. After day 5, the portion of the pipe from 100 mm to 275 mm appeared to reach a limit of 100 C after 4 hours of heating. The heat supplied to the pipe resulted in evaporative boiling of the water saturated insulation, limiting the temperature to 100 C. The bottom (hot end) 50 mm of the pipe reached temperatures up to 350 C, suggesting that it quickly dried out due to heat input from the hot plate. Nevertheless, the temperature remained about 100 C less than the dry pipe. The top (cold end) of the pipe above 275 mm showed significantly less overall change in the 5 days, suggesting full saturation with brine had been achieved there first.

The difference between the dry pipe temperature profile and the 8-hour wet pipe profile progressively increased from day 1 to 5, after which little further change was observed. After 5 days, the brine that had been introduced into the insulation depressed the temperature at the low and high temperature ends of the pipe by about 75 C and up to 200 C, respectively.

In view of the water saturation, high rates of corrosion would be expected above 100 mm from the hot end. This was consistent visually with corrosion on the pipe, as previously documented.[2,3]

The temperature profiles showed little further change after day 5, indicating a steady state had been achieved where evaporation


Temperature Profile of Pipe Surface: Day 3

Note: Hotplate Temperature Setting at 550 C.

Fig. 4b: Day 3 of CUI cyclic testing with hydration

balanced the amount of brine poured into the insulation.

Temperature Profile Across the Insulation

The temperature profile results across the thickness of the insulation at 150 mm and 450 mm from the hot end of the pipe are shown in Appendix II, Figures 2a to 2e, available in full at paintsquare.com. In this article, Figures 5a, 5b, and 5c (p. 38) show results for days 1, 5, and 10, respectively.

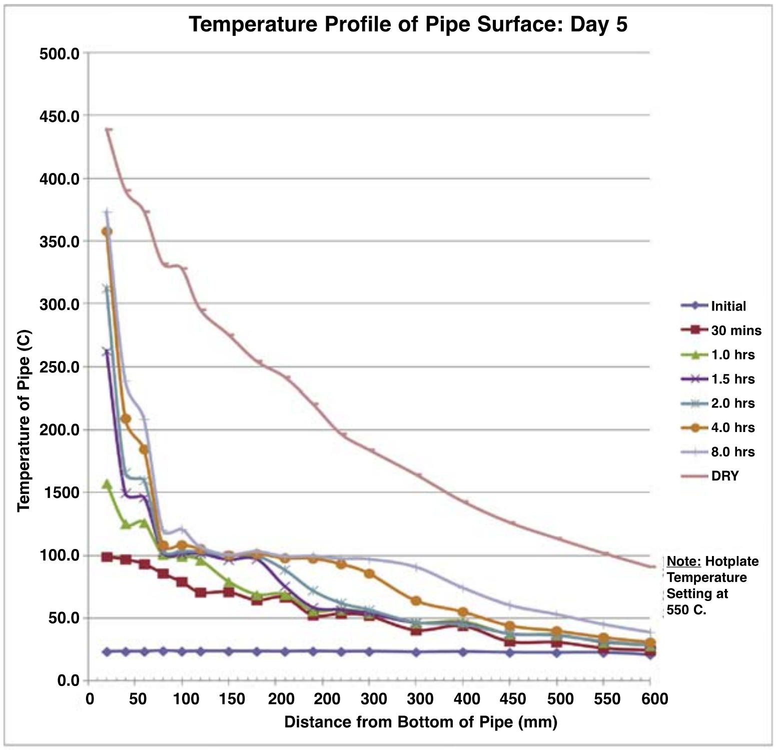
150 mm from the Hot End of the Pipe

On day 1, when the insulation was mostly dry, the temperature across the insulation gradually increased over the 8-hour heating cycle. The pipe surface temperature was 265 C, and the temperature within the insulation was 160 C and 90 C, respectively, at 10 mm and 40 mm from the pipe surface. From days 2 to 5, the insulation gradually became saturated with brine and lost its insulating characteristics. The temperature gradient across the insulation decreased significantly, and little further change was observed after 5 days. After 2 hours into the heating cycle for the water saturated condition, the pipe surface temperature was 100 C, and the temperature across the insulation was relatively constant at about 95 C. The brine facilitated heat transfer within the insulation, resulting in both rapid heating and the absence of a temperature gradient across the insulation.

450 mm from the Hot End of the Pipe

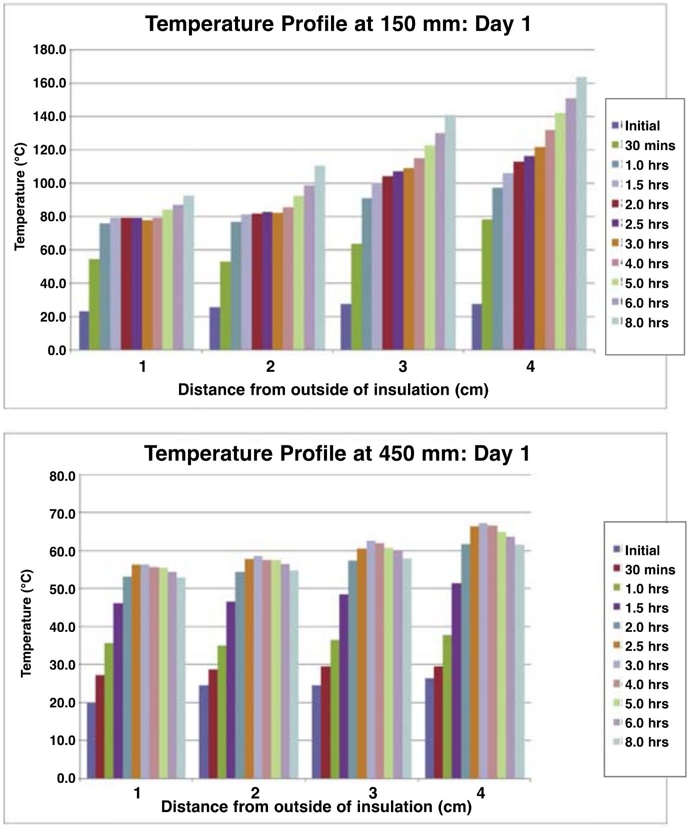
The temperature profile across the insulation at the cool end of the pipe was considerably different from the hot end.

On day 1, the temperature profile across the insulation stabilized within about two hours. After 8 hours, the pipe surface temperature was 80 C, and the temperature in


Temperature Profile of Pipe Surface: Day 5

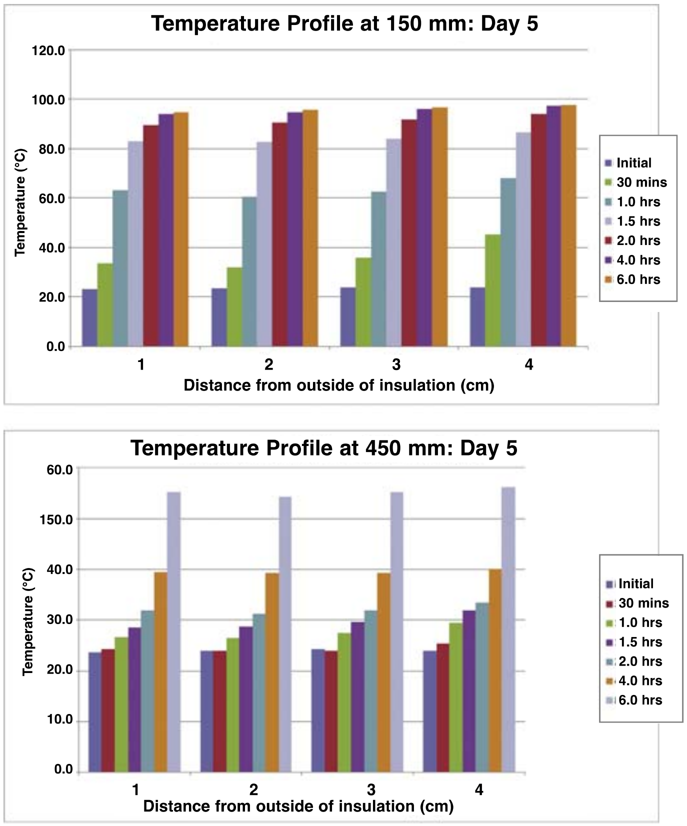
Note: Hotplate Temperature Setting at 550 C.

Fig. 4c: Day 5 of CUI cyclic testing with hydration


Temperature Profile at 150 mm: Day 1

Temperature Profile at 450 mm: Day 1

Fig. 5a: Day 1 of CUI cyclic testing with hydration (Top: 150 mm, Bottom: 450 mm)

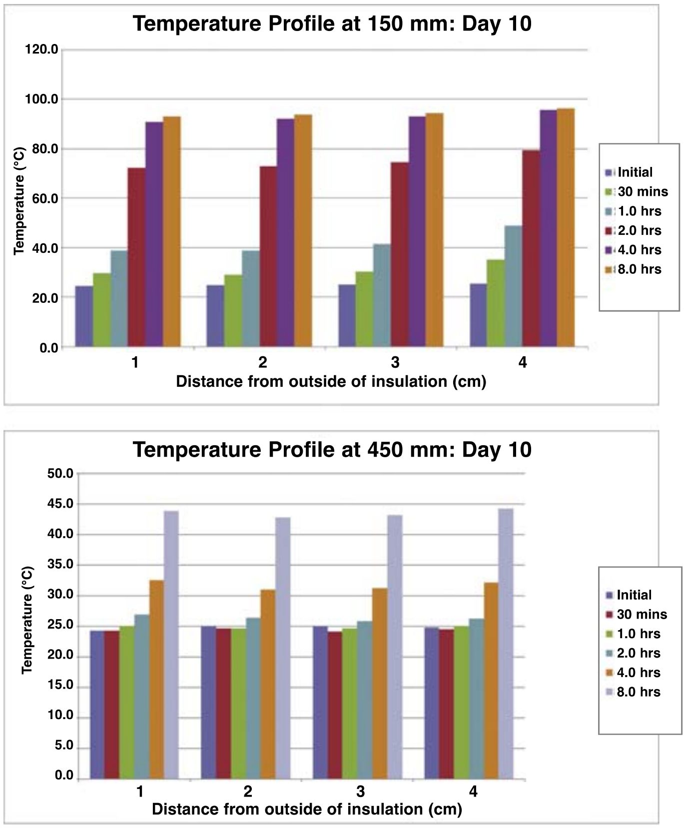

Temperature Profile at 150 mm: Day 5

Temperature Profile at 450 mm: Day 5

Fig. 5b: Day 5 of CUI cyclic testing with hydration (Top: 150 mm, Bottom: 450 mm)

the insulation ranged from 62 C (10 mm from pipe surface) to 53 C (40 mm from the pipe surface). Between 2 hours and 8 hours, the temperature within the insulation dropped slightly, possibly the result of the brine gradually diffusing throughout the insulation in this area of the pipe.

From day 2 to day 10, as the insulation became progressively more saturated with water, the temperature gradient across the insulation dropped and the overall temperature remained progressively closer to room temperature. After 4 to 8 hours of heating, the insulation temperature finally started to increase toward pipe temperature, but no significant temperature gradient developed, presumably due to the thermal conductivity of the brine. The pipe surface temperature dropped from 80 C on day 1, to 62 C on day 5, to 50 C on day 10. The difference between pipe surface temperature and insulation temperature gradually decreased over the 10-day interval from 20 C after 1 day to 6 C after 10 days (after 8 hours of heating).


Temperature Profile at 150 mm: Day 10

Temperature Profile at 450 mm: Day 10

Fig. 5c (Right): Day 10 of CUI cyclic testing with hydration (Top: 150 mm, Bottom: 450 mm)

Fig. 6: Overview of all samples after CUI cyclic testing

Results Part B

CUI Studies on Coated Carbon and Stainless Steel Pipes

The appearance of the coated pipe samples after CUI cyclic testing at high temperature is shown in Fig. 6 and the degree of rusting is shown graphically in Fig. 7 (p. 42). Blistering and flaking are not graphically presented, as they occurred under only specific conditions. The adhesion results are presented in Table 2.

Coating A In Action

Detailed pictures of Coating A after exposure to CUI cyclic test conditions are shown in Figs. 8 and 9 (p. 42).

Carbon Steel Pipe

Small rust pinpoints (ISO 4628-3 Rating 1) (Fig. 7, p. 42) occurred over the 100 C to 215 C temperature range. Also, a small amount of rust stains were evident on the pipe exposed to the 450 C to 560 C temperature range (0 mm to 100 mm). The rust stains from the 450 C to 560 C range were easily removed by lightly abrading the coating surface, indicating the rust did not originate from the steel substrate, but presumably came from corrosion at the end of the steel pipe.

The adhesion of Coating A to the steel substrate was excellent (Table 2). Virtually no coating could be removed by prying with a stout knife except for a few tiny coating chips (~1 mm in length), which disbonded cohesively at the region of the pipe exposed to 240 C. Coating A showed no visible signs of blistering, flaking, or cracking. Excluding rusting, Coating A had no other visible changes except for moderate dulling above 375 C.

Stainless Steel Pipe

There was no evidence of rusting (ISO 4628-3 Rating 0), (Fig. 7, p. 42) or blistering (ISO 4628-2) of Coating A along the entire length of the pipe. However, cracking (ISO 4628-4) and flaking of large coating chips (5 mm to 20 mm in length) occurred from the pipe's surface from 0 mm (600 C) to 100 mm (460 C). With the exception of the flaking, the adhesion of Coating A to the steel substrate was excellent (Table 2), and no coating could be removed by prying with a stout knife.

TMIC In Action

Detailed pictures of TMIC after exposure to CUI in cyclic test conditions are shown in Figs. 10 and 11 (p. 44).

Carbon Steel Pipe

No rusting occurred along the length of the pipe other than a small amount of rust stain over the 450 C to 560 C temperature range.

Table 2: Adhesion Analysis of Coatings after CUI Cyclic Testing (ASTM D6677)

CUI Cyclic Test	Coating A (Carbon Steel)		TMIC (Carbon Steel)	
Temperature (Hydrated)	Adhesion Rating	Coating Chip size	Adhesion Rating	Coating Chip Size
510°C	10	0 mm	10	0 mm
390°C	10	0 mm	10	0 mm
240°C	9.5	1 mm (CS and AS)	8	1–2 mm (CS and AS)
75°C	10	0 mm	8	1–2 mm (CS and AS)

CUI Cyclic Test	Coating A (Carbon Steel)		TMIC (Carbon Steel)	
Temperature (Hydrated)	Adhesion Rating	Coating Chip size	Adhesion Rating	Coating Chip Size
520°C	* Adhesion Test was not performed due to severe flaking of the coating.			
390°C	10	0 mm	10	0 mm
175°C	10	0 mm	8	1–2 mm (CS and AS)
75°C	10	0 mm	8	2–3 mm (CS and AS)

CS = cohesive separation; AS = adhesive separation

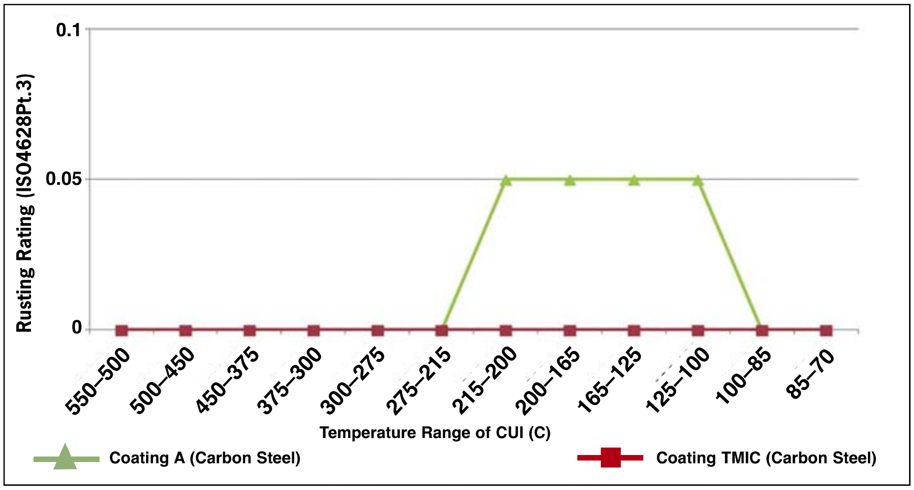


Fig. 7: Average rusting of coatings applied to carbon steel at changing CUI temperatures

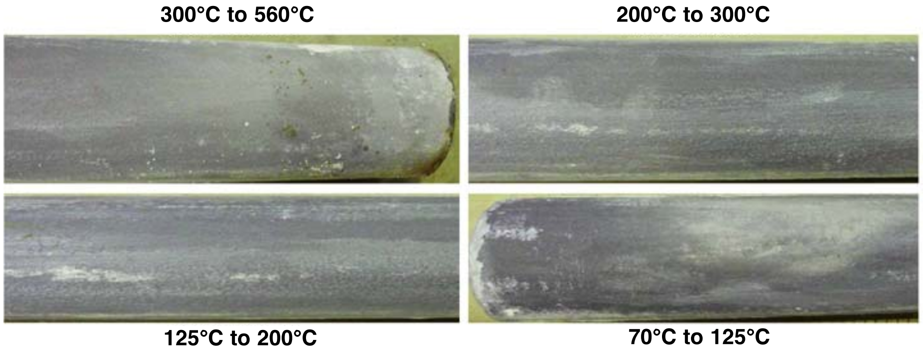


Fig. 8: Coating A applied to carbon steel after CUI cyclic testing

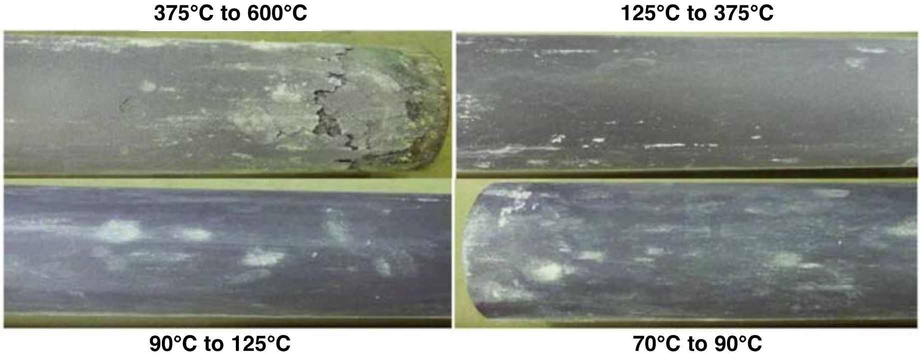


Fig. 9: Coating A applied to stainless steel after CUI cyclic testing

The rust stains were easily removed by lightly abrading the coating surface, indicating that the rust presumably came from corrosion at the end of the steel pipe.

The TMIC showed no evidence of any blistering, flaking, or cracking. The adhesion to the substrate of TMIC was very good (Table 2). A very small amount of coating chips (1–2 mm in length) disbonded cohesively and adhesively over the 75 C to 240 C temperature range when the coating was pried with a stout knife.

A slight loss of luster and moderate dulling of TMIC was most pronounced in the 450 C to 500 C temperature range.

Stainless Steel Pipe

There was no evidence of rusting (ISO 4628-3 Rating 0, Fig. 7), or blistering (ISO 4628-2) of TMIC along the entire length of the pipe. However, cracking (ISO 4628-4) and flaking of large coating chips (5 mm to 20 mm in length) occurred from the pipe's surface from 0 mm (600 C) to 100 mm (460 C). The TMIC disbonded adhesively and cohesively even though one coat was applied.

The adhesion to the substrate of the TMIC was very good (Table 2, p. 40). A very small amount of coating chips (1–3 mm in length) cohesively and adhesively disbonded over the 75 C to 175 C temperature range area when pried with a stout knife. A slight loss of luster and dulling of TMIC was most pronounced in the 320 C to 460 C temperature range.

General Discussion

Part A: Temperature Profile Studies on Bare Steel Pipes

When the insulation was dry, the temperature gradually decreased from the hot end of the

Table 3: Distance along Pipe Surface and Corresponding Temperature

Temperature Profile	0-50 mm	50-100 mm	100-150 mm	150-200 mm	200-250 mm	250-300 mm	300-350 mm	350-400 mm	400-450 mm	450-500 mm	500-550 mm	550-600 mm
DRY (°C)	445-390	390-335	325-285	285-245	245-210	210-190	190-160	160-145	145-135	135-115	115-110	110-95
WET (°C)	350-170	170-103	103-99	99-98	98-96	96-90	90-72	72-62	62-50	50-45	46-40	40-35

pipe to the cold end; when the insulation was water saturated, the temperature did not change gradually, but instead was arrested at 100 C between 100 mm and 300 mm from the hot end. The arrest was speculated to result from evaporative boiling of water from water saturated insulation, which did not dry out during the heat cycle in this area.

Measurements of temperature through the thickness of the insulation suggested that the insulation became water saturated at the top of the pipe after about 2 days, and towards the bottom of the pipe after 5 days. After water saturation, the temperature within the insulation was similar to the pipe surface temperature, and no significant temperature gradient occurred across the insulation.

High rates of corrosion of bare steel pipe would be expected over most of the pipe where the insulation remained wet and the temperature was ≤ 100 C.

The results indicated the temperatures to which the CUI coatings were subjected were considerably lower than predicted from the temperature measurement profile on the pipe with dry insulation.

In the authors' previous studies of the CUI cyclic testing performance of TSA, a TMIC coating, and two inorganic silicone polymer coatings, a temperature range of 95 C to 445 C was cited for the test pipes.

Differences of coating performance were generally observed at the reported ranges of 210–190 C, 245–210 C, 285–245 C, 335–285 C, 390–335 C, and 445–390 C. The best of the four coatings during the CUI cyclic test runs were TSA and TMIC. Furthermore, both were markedly superior in performance to Coating #1 and Coating #2 in that study. To reiterate, Coating #2 in the previous study is Coating A in the present study.

Also in the earlier work, corrosion was evidenced on bare steel pipe subjected to the same CUI conditions as coated pipes. In that case, a high density of small pits were seen at a reported temperature of 445–285 C, large pits at 285–190 C, and both small and large pits at 190–95 C.

First and foremost, this new work shows that the introduction of brine into the insulation significantly reduces the pipe surface temperature and insulating properties. In particular, if the saturation is sufficient that dry-out cannot occur, the steel pipe surface remains wetted by NaCl brine at elevated temperature, a condition producing high rates of corrosion. The earlier reported temperatures were lower in reality. This explains why corrosion on bare steel apparently

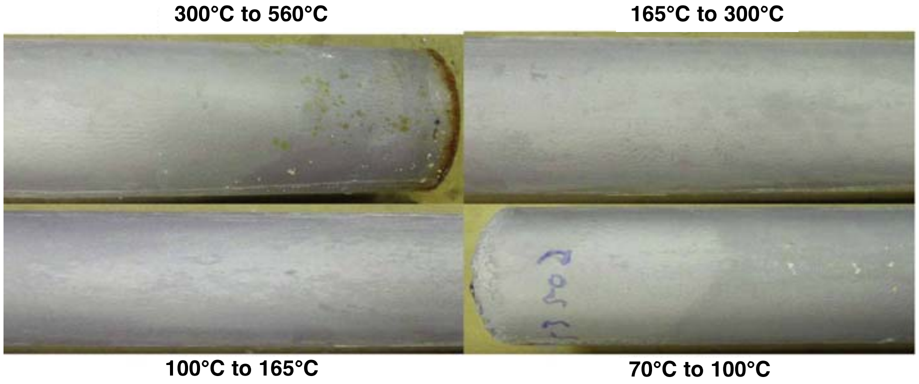


Fig. 10: TMIC applied to carbon steel after CUI cyclic testing

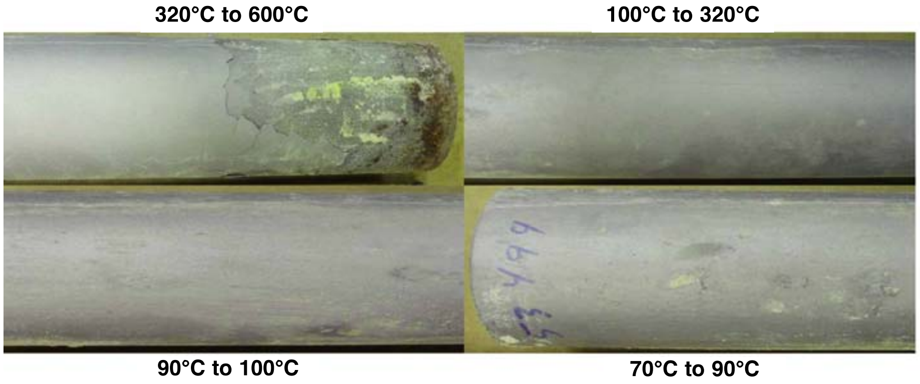


Fig. 11: TMIC applied to stainless steel after CUI cyclic testing

seemed to occur on carbon steel at temperatures higher than expected according to the received wisdom.[5, 6] Table 3 (p. 42) shows the temperature range corrections based on the current investigations. Notwithstanding the temperature corrections in Table 3, it is important to note that the ranking of coating performance of the four coatings remains unchanged. Applied to carbon steel pipes, and under repetitive cyclic thermal conditions, other than TSA, the TMIC coating rated to ca 400 C provided the best thermal resistance and corrosion resistance in the critical CUI temperature range of -4 C to 175 C.[2, 3]

Part B: CUI Studies On Coated Carbon Stainless Steel Pipes

It is interesting to note the compositional differences between carbon steel and stainless steel, the effect of temperature on these steels, and what influence, if any, might result from re-exposing coated carbon and steel pipes to the highest temperatures sustained in the present CUI studies.

Carbon Steel Substrate

The pipe material used for the CUI investigation was reported to be ASTM A513 (grade not reported), low carbon steel welded pipe. This pipe is generally produced in the hot or cold rolled condition. The microstructure of low carbon piping such as this generally consists of ferrite and pearlite.

The upper temperature of the CUI studies was 600 C (1,113 F), below the transformation temperature of 723 C (1,333 F) for steel. Below the transformation temperature, the phases present at room temperature will remain stable, and not transform to austenite. Some alteration of the microstructure in the form of grain growth and spheroidization of pearlite may occur over long-term exposure at high temperatures, but in general, the properties of the steel will remain relatively consistent.

In general, the coefficient of thermal expansion for carbon steel is 13.0 x 10^{-6} cm/cm C from 0 C (32 F) to 600 C (1,113 F). For a 25 cm length of pipe, the total linear expansion expected from room temperature to 600 C is 0.19 cm in length.

Stainless Steel Substrate

The stainless steel pipe used was reported to be a Type 304 austenitic stainless steel with a nominal composition of 8–12 weight percent nickel, 18–20 weight percent chromium, and 0.08 weight percent carbon maximum, with the balance iron. The microstructure of this material will be predominately austenite with some ferrite islands possibly present. The stainless property is achieved by the tenacious surface oxide layer that is formed due to the alloying of chromium and nickel. This layer may be damaged in the presence of chloride solutions, resulting in pitting attack.

Type 304 stainless steels may be susceptible to sensitization at temperatures from 550 C to 800 C. At this temperature range, chromium may migrate to austenite grain boundaries, resulting in a thin zone of chromium depletion adjacent to the grain boundaries. This chromium-depleted zone is susceptible to intergranular stress corrosion cracking in aggressive environments, including chloride solutions.

In general, the coefficient of thermal expansion for stainless steel is 17.3 x 10^{-6} cm/cm C from 0 C (32 F) to 600 C (1,113 F). For a 25 cm length of pipe, the total linear expansion expected from room temperature to 600 C is 0.26 cm in length. This will remain more linear from room temperature due to the austenitic matrix present.

Coatings on Carbon Steel

Testing showed that TMIC was virtually unaffected by the high-temperature heating and water saturation under insulation. There was no evidence of blistering, rusting, adhesion loss, or flaking of TMIC. TMIC contains aluminum flake pigmentation and is a very flexible coating. While Coating A also performed well and did not suffer any blistering or flaking, it did sustain a small amount adhesion loss at 240 C and some pin point rusting occurred where the coating was exposed to the 100 C to 215 C temperature range.

Coating A contains MIO pigmentation and is not as flexible as TMIC.[2, 3] As seen in the earlier studies, TMIC somewhat outperformed Coating A in the high temperature microenvironment of the CUI cyclic test.

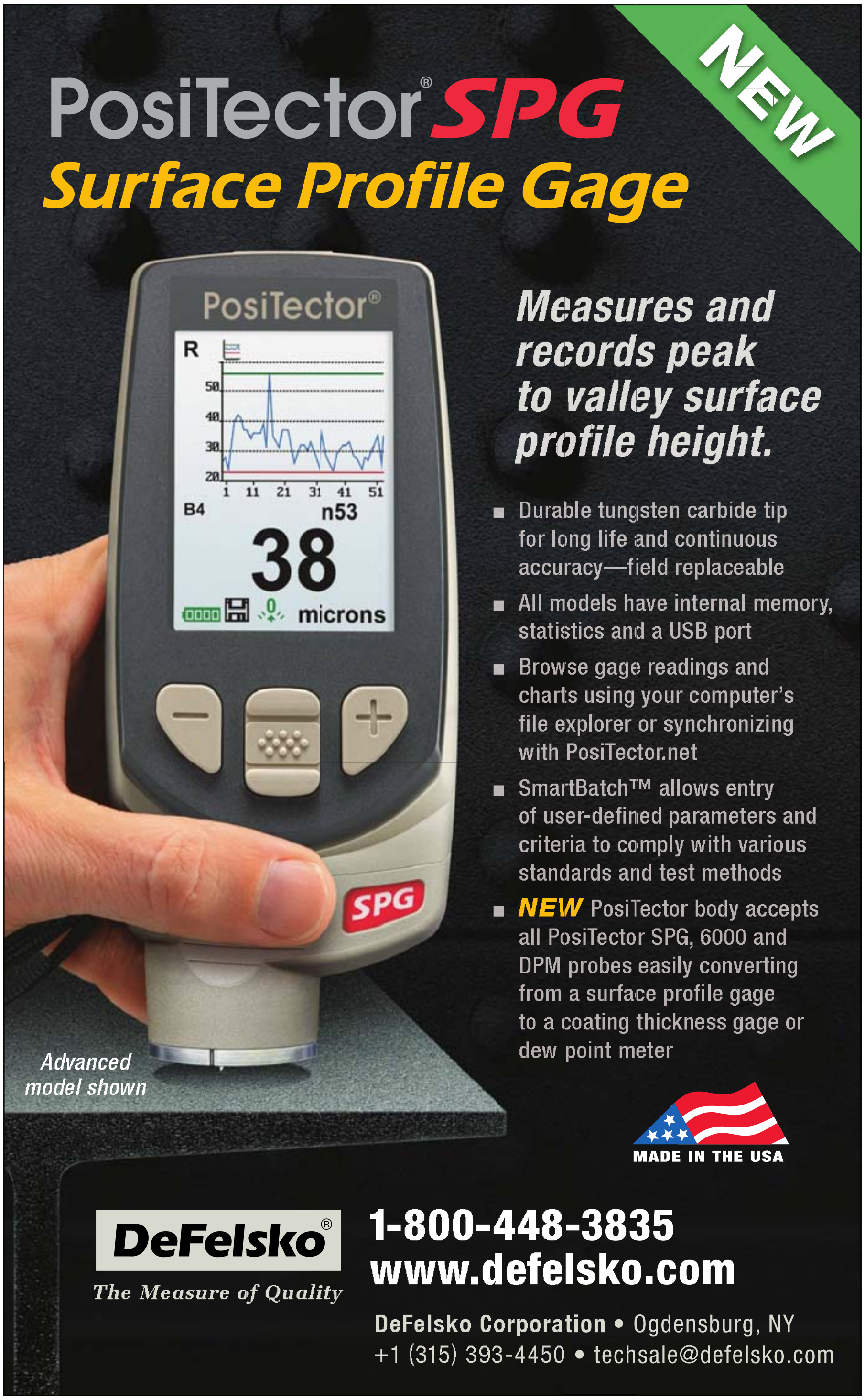
Coatings on Stainless Steel

Up to a temperature of 460 C, testing showed that TMIC and Coating A performed almost as well on stainless steel as they did on carbon steel pipes. Indeed, there were no observations of blistering, rusting, adhesion loss, or flaking in the temperature range of 70 C to 460 C for either coating. However, severe flaking occurred with both TMIC and Coating A due to exposure to the temperature range of 460 C to 600 C. An investigation of this phenomenon using metallographic and other analysis will be undertaken to fully understand the mechanism present. Some possible scenarios for the coating disbondment are significant sensitization and intergranular attack of the stainless steel during the cooler temperature cycles in the presence of the chloride solution. The higher thermal expansion coefficient may also contribute to the coating bond degradation at the elevated temperature.

TMIC also showed some separation in the coating at the temperature range of 460 C to 500 C.

Overall, TMIC performed as well as it did in previous studies at lower temperatures.[2, 3] Coating A performed better than it did in previous studies at lower temperatures.[2, 3]

At the time of writing, the authors' CUI research is continuing. Shorter carbon steel and stainless steel pipes have been coated with TMIC and Coating A and are being subjected to the same CUI test regimen as presented here. The dimensions of the pipes are 6 cm in diameter and 30 cm in length with a 5 mm thick wall. The results of that work will be presented at a later date together with any optical microscopy and SEM investigations.



Conclusions

One coat of TMIC and a two-coat system of Coating A showed similar performance under the applied CUI test conditions on both carbon and stainless steel pipes. On carbon steel pipes, TMIC was marginally better in that there was no evidence of blistering, rusting, cracking, flaking, or adhesion loss, whereas Coating A exhibited some pinhole rusting over the 100 C to 215 C temperature range.

When TMIC and Coating A were exposed to higher temperatures on carbon and stainless steel pipes, there appeared to be more compositional changes in stainless steel than in carbon steel at higher temperatures. This resulted in both coatings disbonding when applied to stainless steel.

The undercover agent TMIC performed as well as it did in previous studies at lower temperatures. The undercover agent Coating A performed better than it did in previous studies at lower temperatures.

The temperatures to which the CUI coatings were subjected were considerably lower than initially predicted from a temperature measurement profile on pipe with dry conditions. The introduction of water and or brine into the insulation material significantly reduces the pipe surface temperature and insulating characteristics.

The insulation type also plays a role in determining the corrosion resistance and performance of CUI coatings and therefore any prediction of coating lifetimes from short term aggressive testing methodologies is difficult. (Although accepted as true, this is not a conclusion of this study.)

The overall performance of a CUI coating is most likely insulation-type specific. Further work is underway to evaluate these coatings under a range of insulation types.

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By Robert Maley,
Corrosion Probe, Inc.

Preparing and Lining Concrete for Immersion Service: Steps and Procedures to Avoid Failures

The practice of lining concrete substrates has increased exponentially over the last 30 years, most notably in the wastewater treatment industry. Environmental regulations, coupled with changes to treatment processes, have resulted in far more severe environments in which concrete can and will corrode.

Other than the floor coating field, very few contractors specialize in preparing and lining concrete structures, as carbon steel lining opportunities far outweigh those of concrete substrates. Accordingly, the majority of craft workers, both young and old, have far more training and experience preparing and lining steel substrates. It has been the author's observation that many of the aforementioned craft workers, and in many cases, management personnel, do not fully comprehend the difficulty and distinctions inherent to a concrete lining project.

A lack of understanding and experience extends beyond the contracting level. Many engineers, consultants, and inspectors do not fully comprehend the idiosyncrasies of lining concrete. When all the aforementioned parties converge upon a complex lining project, the potential for a perfect storm exists.

This article examines many of the common errors that often occur when concrete substrates are rehabilitated and offers practical solutions for prevention of said errors.

Editor's Note: This article is based on a presentation given at SSPC 2013, the annual conference of SSPC: The Society for Protective Coatings, held January 14–17, 2013, in San Antonio, TX, and is available in the conference Proceedings *(sspc.org).*

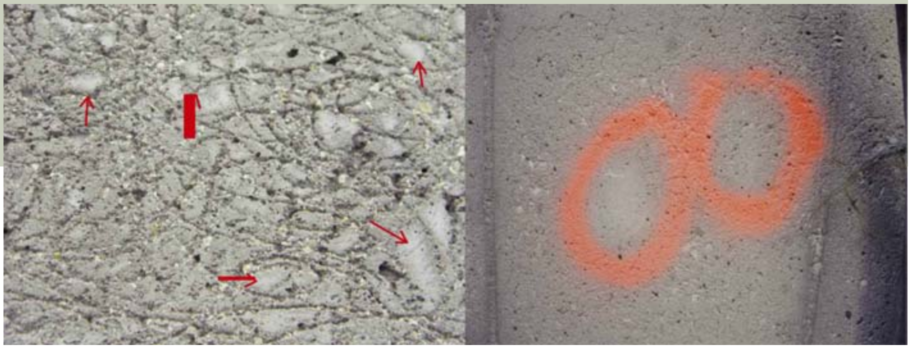


Fig. 1: Residual laitance on UHPWJ-prepared concrete (left) and abrasive blast cleaned concrete (right)
All figures and photos courtesy of the author.

Chronological Examination of Typical Missteps

Surface Preparation Phase

The majority of lining failures, regardless of the substrate (steel or concrete), are often attributed to inadequate surface preparation. Numerous written standards and visual standards for preparing steel substrates have been published by various industry organizations over the past 50 years. Steel substrate surface preparation standards, as well as many germane test standards, are fairly well understood and routinely cited in project specifications. Conversely, it is quite common for a specification or a lining material product data sheet to simply state for the contractor to "roughen or abrade concrete surfaces." Such ambiguous language does not suitably address the following often-overlooked critical aspects necessary to properly prepare concrete substrates.

- Laitance is not thoroughly removed from the surface. Laitance is a thin, weak, poorly adhered layer of aggregate fines, including unreacted concrete constituents (Fig. 1). Islands of laitance can be difficult to detect. If not removed, laitance will slowly disintegrate, disbonding the lining system from the substrate.
- The surface profile is not sufficient. Similar to linings applied to carbon steel, linings applied to concrete substrates require a sur-

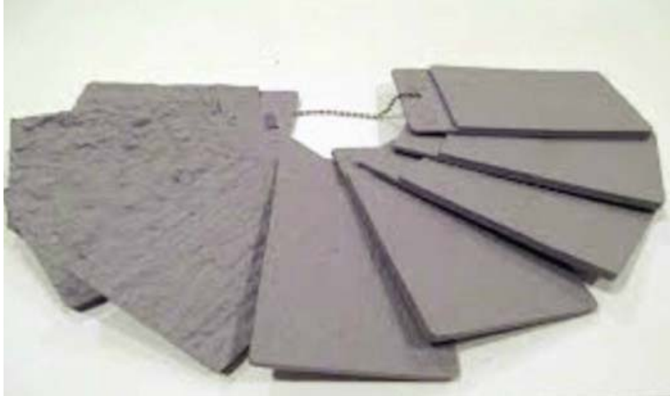


Fig. 2: ICRI CSP Coupons

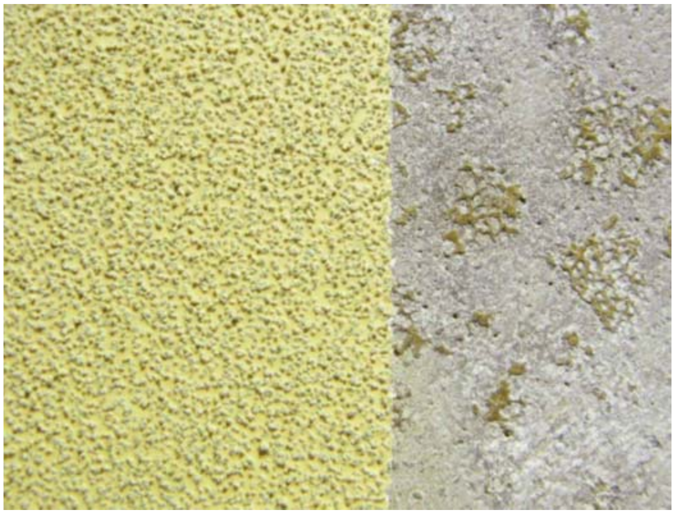


Fig. 3: Evaluation of surface profile using 60 grit sandpaper

Fig. 4: Cross section of bug holes

Fig. 5: Typical bug holes on formed concrete

Fig. 6: Residual lining material (substrate was prepared by UHPWJ followed by abrasive blasting)

face profile to promote mechanical bonding. Surface profiles on steel substrates typically range from 1.5 to 5.0 mils, depending on the film thickness of the lining. Surface profile can be objectively quantified in the field by using replica tape and a spring micrometer (per ASTM D4417, Method C).

Determining the surface profile of concrete substrates is performed by comparison method, and therefore can be somewhat subjective. Molded replica chips (coupons) are available from The International Concrete Repair Institute (ICRI). The ICRI coupons (Fig. 2) depict ten profiles identified as CSP 1 (least rough) through CSP 10 (most rough). ICRI Technical Guideline

310.2 provides additional information relative to the selection and methods of achieving the various CSPs.

ASTM Standard D7682, Standard Test Method for Replication of and Measurement of Concrete Surface Profiles Using Replica Putty, released in 2010, provides both visual means (Method A) and quantitative means (Method B) for determining the surface profile of concrete. The benefit of utilizing ASTM D7682 over a visually comparative method is that a permanent replica can be obtained.

Many industry standards, including SSPC-SP 13/NACE No. 6, Surface Preparation of Concrete, will describe a concrete surface profile by comparison to various grades of sandpaper, e.g. fine, medium, coarse, and extra-coarse. This method is also quite subjective because of the lack of uniformity typically found on a prepared concrete surface. Additionally, some lining manufacturers' product data sheets define the required surface profile as similar to coarse sandpaper without specifically defining coarse sandpaper (Fig. 3).

- Voids and bug holes are not opened or exposed. Formed concrete contains surface voids of varying dimensions, primarily as a result of air bubbles that are trapped during placement and compaction. Bug holes are small, regular or irregular cavities, usually not exceeding 15 mm (0.6 in.) in diameter, while voids can be significantly larger (Figs. 4 and 5).

The actual size of a bug hole is often obscured because the cavity extends beneath the surface. This condition is often referred to as "shelled over." Unless the bug hole is thoroughly opened or exposed, the resurfacer or liner will bridge over the void, resulting in air entrapment and pinhole formation due to outgassing.

- Protrusions are not removed from the concrete surface. Surface irregularities such as form lines, concrete spatter, fins, trowel licks, etc., are sometimes well-adhered to the substrate and are not conducive to achieving a monolithic lining with uniform film thick-

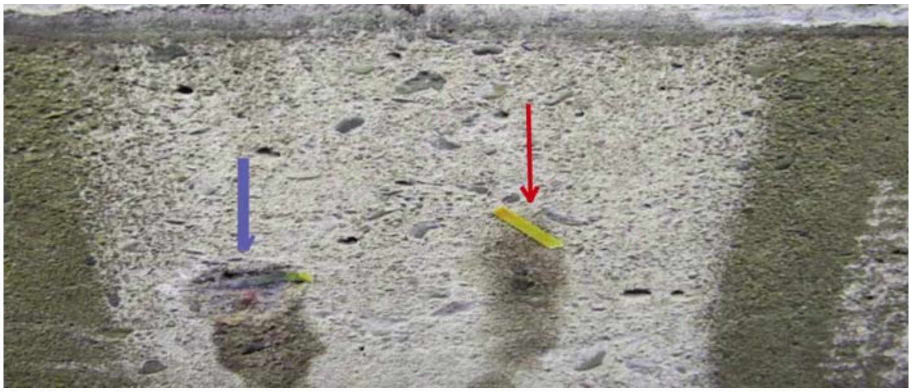


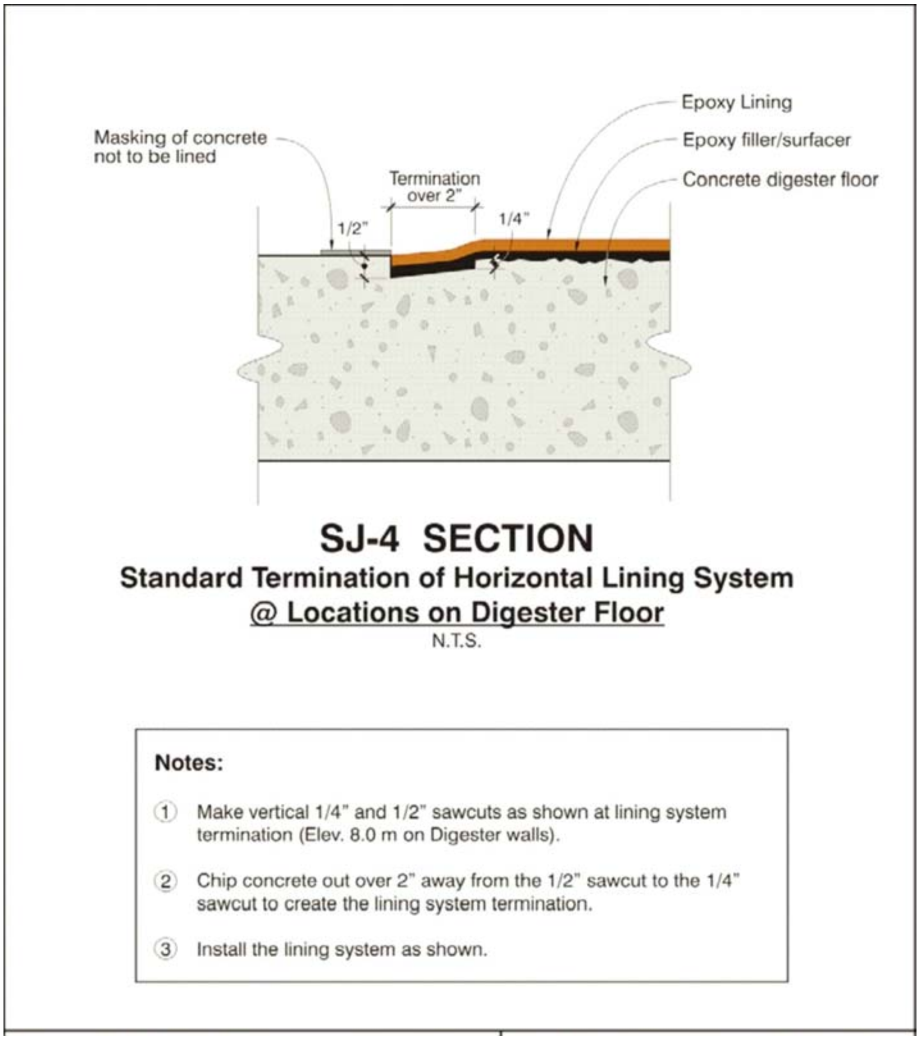
Fig. 7: pH gradient measurement of concrete prior to surface preparation. The red arrow depicts a surface pH of 7.0–8.0, while the blue arrow depicts a pH of 10.0–11.0 where concrete has been chipped back approximately ⅛ of an inch. Contaminated concrete should be removed to a depth where a minimum pH of 9.0 is attained.

ness. These irregularities must be removed mechanically by chipping or grinding.

- Residual coating/lining materials are not thoroughly removed from the surface. It is common to find residual coating material embedded in the concrete surface (Fig. 6). A thorough visual examination is required to identify embedded materials.
- Surface contamination is not thoroughly removed. Generally speaking, contamination, which can exist on the concrete surface following surface preparation, cannot be visually identified. Therefore, various testing is required subject to the type of contaminants anticipated. Typical contaminates include chlorides and sulfates. Laboratory analysis of concrete powder samples obtained at various gradient depths should be performed if contamination is suspected.
- The surface pH is below 9.0. A pH of less than 9.0 would suggest the presence of acid salts, indicative of active corrosion reactions. The alkaline constituents of the hydrated cement paste binder readily react with acidic solutions, resulting in a depletion of calcium hydroxide (pH < 10.0) and depletion of calcium silicate hydrate (pH < 8.0). Conversely, a pH greater than 12.5 would suggest that the concrete is too green and may not be fully hydrated. ASTM D4262, Standard Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces, provides guidance for testing the pH of concrete surfaces. Gradient pH measurements should be performed to determine the depth of contamination (Fig. 7).

Restoration/Resurfacing Phase

Prepared concrete substrates, particularly those previously subjected to harsh exposures, quite often require restoration or repair prior to application of a chemical resistant lining system. Additionally, a resurfacing material is recommended to fill bug holes and surface porosity on all concrete substrates to provide a monolithic surface for lining application. Deficiencies that commonly occur during the restora-



SJ-4 SECTION

Standard Termination of Horizontal Lining System

@ Locations on Digester Floor

N.T.S.

Notes:

① Make vertical 1/4" and 1/2" sawcuts as shown at lining system termination (Elev. 8.0 m on Digester walls).

② Chip concrete out over 2" away from the 1/2" sawcut to the 1/4" sawcut to create the lining system termination.

③ Install the lining system as shown.

Fig. 8: Example of termination detail where the wall lining was carried onto the floor to prevent edge lifting/undercutting. In this example, the floor was not subjected to the same corrosion mechanisms as the walls and therefore did not warrant lining application.

Table 1: Commonly Used Industry Methods and Standards for Testing Adhesion

METHOD	INDUSTRY STANDARD	LIMITATIONS
Anhydrous Calcium Chloride	ASTM F 1869	• only for horizontal surfaces • requires a minimum of 60 hours
Plastic Sheet	ASTM D 4263	• requires 16 hours
RH Probes	ASTM F 2170	• hole must be cored (destructive)
Electronic Meters	None	• measures at or just below surface

tion/resurfacing phase include the following.

- The substrate is not thoroughly cleaned of dust and debris. Due to its inherent porosity, as well as the abundance of bug holes and larger surface voids, prepared concrete surfaces cannot be effectively cleaned by blowing them down with compressed air or sweeping. Vacuuming the entire surface followed by pressure washing with clean water (when feasible) are far more effective methods to ensure that residual dust has been thoroughly removed.
- The substrate is too wet or too dry. Excessive moisture within the concrete substrate can be problematic for many reasons, most notably related to adhesion. Several test methods and industry standards can be used to determine substrate acceptability. The method or standard selected should be consistent with the recommendations provided by the manufacturer of the restoration/resurfacing material. Table 1 lists some of the most commonly used industry methods and standards.

Many restoration/repair mortars require that the substrate be surface saturated dry (SSD), meaning that the concrete substrate must be dampened to insure that water within the applied mortar is not absorbed into the substrate. An SSD condition is typically achieved by lightly misting the concrete substrate with clean water. Ponding, pooling, glistening, dripping, or running water is detrimental and therefore should be avoided. The objective is to slightly darken the surface so as to preserve the water needed for hydration purposes. Insufficient water for hydration of the restoration/repair mortar may result in cracking or poor adhesion, which can be exacerbated by the curing stresses associated with the application of a chemical resistant liner.

- Application conditions are not suitable. As is true for any substrate, application parameters for material temperature, surface temperature, air temperature, relative humidity, and dew points must be strictly monitored. There are two additional application parameters which are unique to concrete substrates and are quite often overlooked.

1) Materials should not be applied in direct sunlight.

2) Materials should not be applied if the surface temperature is ascending.

Under both of these conditions, air entrained within the concrete substrate expands as temperatures rise. The air vapor is released at the surface (known as outgassing) and results in the formation of pinholes and craters as the air is expelled through the mortar or lining. Alternatively, if the mortar or lining is capable of resisting the vapor pressure, then blisters will form beneath the mortar or lining.

- Post-application curing is not performed. Many cementitious materials require post-application curing efforts, which typically consist of periodically misting or spraying the material with clean water, or maintaining a wet cure with fabric or burlap, to insure that sufficient water is available for proper hydration. Curing efforts may extend several days depending on the ambient conditions.
- Cracks and joints are not properly treated.

Treatment of cracks is dependent on the mechanism that induced the crack, as well as the anticipated crack movement. If not properly treated cracks can and will reflect through many lining systems. Construction joints, expansion joints, contraction, and isolation joints all serve different purposes and may require different treatment methods. A detailed discussion of crack and joint treatment is beyond the scope of this article and is quite often overlooked during lining applications.

Lining Application Phase

The lining application phase introduces several typical or common challenges, as well as several challenges unique to concrete substrates and lining concrete in immersion service, such as the following.

- Lining terminations are inadequate or nonexistent. In many circumstances it is not necessary or cost effective to apply a lining system to an entire structure as the corrosion severity may vary from liquid to vapor phase, or as a result of erosion/abrasion. Whenever partial lining is performed a leading edge exists which is susceptible to lifting and undercutting. Wherever possible, it is desirable to terminate the lining system above the highest liquid operating level rather than in the immersed area. The lining system should always be terminated within a chase or saw cut. Similarly, all penetrations and metal embedments require detailed lining terminations typically requiring a chase or saw-cut (Fig. 8).
- Substrate moisture content is unsuitable. As previously discussed, excessive moisture is detrimental and must be constantly controlled and monitored as conditions change.
- Application conditions are not suitable. The discussion contained within the restoration/resurfacing phase holds true for the lining application phase.
- Repair/restoration material is not abraded. The presence of laitance is highly probable when Portland cement-based repair mor-

Fig. 9: Pull-off adhesion testing. 90% of the failure occurred cohesively within the substrate, whereas 10% of the failure occurred cohesively within the filler/surfacer.

tars are used for repair/restoration. Any laitance must be removed before application of the chemical-resistant lining.

- Materials are improperly stored or mixed. Although not previously discussed, many failures emanate as a result of inadequate storage and mixing practices. Most repair and lining materials consist of multiple components requiring specific storage and application temperatures where heat replaces solvent to reduce the materials' viscosity. Mixing these materials properly can be quite laborious, after which a short (5–30 minute) pot life exists for application.

Testing and Repair Phase

The final phase of a lining project often involves performing various tests to verify that the work was properly performed and the materials will ultimately provide the desired long-term protection. Testing requirements can vary widely depending on the specification, as well as the manufacturers' requirements, particularly when extended warranties come into play. This article will only address the tests that are common to most projects: dry film thickness, adhesion, and holiday detection.

Dry Film Thickness Testing

Two primary options are available: destructive and non-destructive. Arguably, destructive testing is the most reliable, albeit often statistically questionable test method because of the limited number of areas tested. A wide range of film thicknesses should be anticipated, as certain application methods by nature (i.e., troweling, plural component spray, hopper/gravity fed spray) and many reinforced thick film lining materials are not conducive to achieving uniform film thickness. Although unfortunately not often cited, Table 1 in section 5.4 of SSPC Paint Application Specification No. 9, Measurement of Dry Coating Thickness on Cementitious Substrates Using Ultrasonic Gages, provides guidance relative to restriction levels of coating thickness on concrete. The table contains four levels for minimum and maximum film thicknesses for spot readings, which recognize the wide percentage variations typically observed. More importantly, however, the manufacturer should provide guidance relative to absolute minimum and maximum film thickness tolerances.

Another somewhat reliable method of determining dry film thickness is to calculate the material quantities based on the actual surface area. The reliability of this method is dependent on accurately measuring the surface area, determining a realistic loss factor for overspray, and carefully monitoring the quantity of material actually applied to the substrate, as quantities mixed rarely equate to what is actually applied.

Adhesion Testing

The applicable industry standard for determining pull-off adhesion strength on concrete is ASTM D7234, Standard Test Method for Pull-Off Adhesion Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers, although the older and far more familiar standard for metal, ASTM D4541, Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers, is often inadvertently cited. Rather than offering a detailed comparison of the standards, suffice it to say that the two standards are quite different, most notably in the diameter of the loading fixtures (larger for concrete) and the requirement to score around the loading fixture when film thickness exceeds 20 mils (concrete).

Adhesion of a lining to the concrete substrate as well the intra coat adhesion in multi coat systems can be quantified via the ASTM D7234 test procedure. Adhesion values cannot always be accurately determined whenever cohesive failure of the concrete occurs during testing. For example, if the loading fixture is removed from the concrete substrate at 350 psi and the failure plane is within the concrete (cohesive failure), one can only conclude that the adhesion of the lining to the substrate is a minimum of 350 psi. Should the project specification require a minimum adhesion value of 375 psi, the 350 psi test result does not necessarily satisfy the specification requirements.

Many specifications rely on the lining manufacturers' published data for acceptable adhesion values regardless of; the tensile strength of the concrete; the concrete surface profile, or the type of instrument utilized. The often-utilized requirement of "concrete failure" as a benchmark for acceptable adhesion is far too ambiguous, and not always attainable. As demonstrated in Figure 9, multiple failure planes can and will occur on a single test.

Heated discussions are commonplace on job sites when adhesion testing data does not meet the requirements of the specifications. The basis of these discussions is often attributed to one or a combination of the following:

- utilizing ASTM D4541 as opposed to ASTM D7234 (often because D4541 data was provided by the manufacturer);
- varying interpretations of the requirements within ASTM D7234; and
- insufficient test data available from the lining system manufacturer.

If not clearly stated in the project specifications, the test methods, test procedures, test equipment, and acceptance criteria should be clearly established and mutually agreed on before the project commences.

Fig. 10: Repairing holidays. Most specifications do not set a limit for the maximum number of holidays allowed, either for the entire structure or expressed as a holiday to substrate area ratio.

Holiday Detection

Holiday Detection can often be the most contentious member of the testing triumvirate based upon the following common scenarios.

- No industry standard is referenced in the project specification (NACE SPO 188 or ASTM D 4787). Suggested voltage settings vary between the two standards.
- No voltage setting is established either in the project specification or indicated on the manufacturers' published technical data.
- The measured dry film thickness exceeds the specification requirements, therefore a higher voltage setting must be utilized.

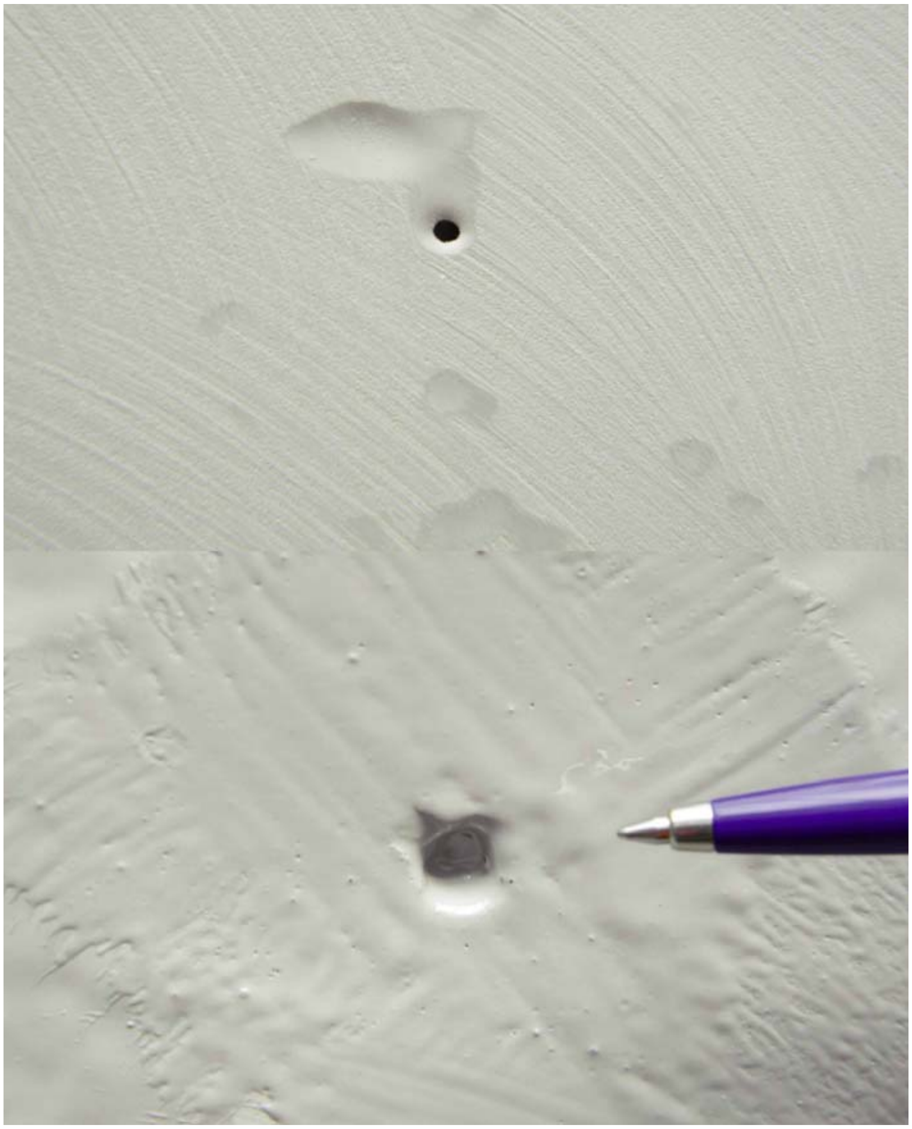


Fig. 11: Before (top) and after (bottom) of an improperly repaired holiday

Fig. 12: Off-ratio repair material found during anniversary inspection

- An appropriate voltage setting cannot be determined due to a wide range of dry film thickness variations that are within acceptable parameters established by the project specifications, e.g. 100–125 mils.
- The test is improperly performed—a slow, methodical holiday hunting expedition as opposed to a 1-foot-per-second sweeping method cited in the industry standards.
- An acceptable amount of holidays is not indicated in the project specifications.
- A specific quantity/density of holidays, which constitutes rejection of the entire lining system, is not indicated in the project specifications. Figure 10 depicts a relatively small structure where an excessive quantity of holidays were identified and repaired.

Repairs

Many problems can arise surrounding repairs, particularly when the identified repair areas are minimal. The project dynamics are typically such that the contractor has done a good job, a few minor repairs (holidays and damage from adhesion testing) are required, and all parties are anxious to wrap things up. Strict attention to detail is often lost at this juncture, including the following.

- Holidays are not thoroughly exposed back to the substrate, but are merely covered with a dab of lining material, which essentially masks the holiday or results in reoccurrence of the same holiday (Fig. 11).
- The specified dry film thickness is not achieved over the repaired areas. Many linings are systems comprised of multiple applications of differing materials, or the linings require spray application to achieve the specified dry film thickness. Once again, the common practice is simply to dab a small amount of the finish coat over the repaired area. For example, if the specified liner thickness was 125 mils, then it is quite likely that numerous areas would end up with about 10–20 mils of protection, considerably less than the thickness required to achieve the desired protection and/or durability of the lining system.
- The repair material extends beyond the area that was prepared. Most lining materials have very short recoat windows, and therefore, require scarification as well as solvent cleaning to ensure that the repair material will adhere to the existing liner. Repair materials that extend beyond the prepared area will likely disbond, thereby jeopardizing the entire repair, as edge lifting and undercutting may occur.
- Repair materials are often improperly mixed (off-ratio) (Fig. 12). Most contractors shudder at the thought of mixing up a five-gallon unit when only a few ounces of material are needed. Regardless of the techniques that are employed, the potential for poorly mixed or off-ratio material is immense. A paint stick and a plastic quart container are no match for a mixing drill and an appropriately sized metal pail.

Finger Pointing or Avoidance

Now that we have established where, when, and how problems can occur, what are the best ways to avoid them? Should the burden of quality control be placed on the application contractor? Possibly, but I don't recommend it. Nonconformities that may be dismissed as minor or inconsequential can often result in catastrophic failures.

Some owners have the mindset that sureties and extended warranties protect their interests, but owners might also fail to consider the negative consequences associated with lining failures.

The ideal solution for avoiding lining failures, albeit not a panacea, is to anticipate potential pitfalls by developing succinct written instructions for the work processes, specific remedies relative to deficiencies, and quality control measures to be incorporated throughout all work phases—a.k.a., a Technical Specification, and competent third party inspection.

Design Phase Considerations

A comprehensive technical specification with explicit inspection hold points and

well defined acceptance criteria is the foundation for achieving a successful lining project. Unfortunately, many specifications are recycled from purportedly similar projects, and therefore, they fail to address many critical items. When critical items are overlooked, one of two consequences can occur. Either the lining project continues, resulting in a high likelihood of premature lining failure, or costly change orders to rectify specification related deficiencies are issued.

Many common missteps have been discussed above, and they merit further exploration for inclusion within technical specifications. Additional items for consideration include the following.

- The potential for hydraulic pressure exists when structures are fully or partially below grade. Quite often it is advisable to waterproof the exterior of the structure to minimize or eliminate vapor pressure.
- Concise surface preparation methods should be given (i.e., abrasive blasting, ultra-high-pressure water jetting, or other mechanical means). Many product data sheets and application guides simply reference SSPC-SP 13/NACE No. 6 as a surface preparation standard, but they fail to identify a specific method as required by the standard. In many cases, it is mistakenly assumed that abrasive blasting will be performed.
- Methods as well as requirements for controlling environmental conditions suitable for lining application should be identified (e.g., heating, cooling, dehumidification, and shading).
- It is important that a distinction be made between concrete restoration (repair) and resurfacing. Restoration should be used where large voids exist, erosion/chemical damage has occurred, and cement paste loss has exceeded a depth of ½-inch. Properly finished new concrete should not require restoration or repair. Restoration/repair materials are generally Portland cement-based mortars and require post-application curing efforts.

Resurfacing is typically used to fill bug holes, seal pores and capillaries, and provide a smooth surface for coating and lining application. Resurfacing materials can be Portland cement-based, polymer/epoxy-modified cementitious, or pure epoxy-based materials.

As previously stated, additional surface preparation requirements may be necessary dependent on the restoration, repair, or resurfacing materials that are specified. Recoat windows may also need to be addressed.

A primer/sealer can be used to minimize outgassing. A compatible primer/sealer should be applied whenever a full skim or sparge coat of resurfacing material is not specified, or in addition to the restoration/resurfacing materials.

Visual acceptance criteria should be given. Many high-performance, thick-film lining systems are difficult to apply and are susceptible to running, sagging, and orange peeling. Restrictive language relative to aesthetic qualities should be limited to defects that jeopardize the film quality and integrity.

Define the acceptance values, locations, and quantities of tests to be performed. Avoid relying solely on an industry standard or manufacturers' product data sheets because both can be subject to interpretation, or if used together, may be contradictory.

Regardless of whether or not the lining manufacturer requires specific training/certification of its applicators, onsite training by the manufacturer should be encouraged. Manufacturer involvement should be additionally extended to include participation in hold-point inspections, including testing and final inspection.

Conclusion

Lining failures on concrete substrates can be attributed to a plethora of causes—some obvious, such as inadequate surface preparation, and some obscure, such as moisture vapor transmission. In many regards, the surface preparation and subsequent application of high-performance linings on concrete substrates is a relatively adolescent industry. Tools, equipment, methods, and practices are continually being developed to increase the efficiency and productivity of surface preparation and lining application. Restoration materials, resurfacers, and chemical-resistant linings require manufacturer training, specialized skills, and application equipment, which might not be common knowledge to the average painter. Quality assurance processes and quality control measures for concrete substrates must be developed and implemented in greater detail as compared to other substrates.

Finally, as is often stated, a comprehensive specification, which delineates appropriate materials, proper surface preparation, precise application requirements, and rigorous quality control practices are critical.

About the Author

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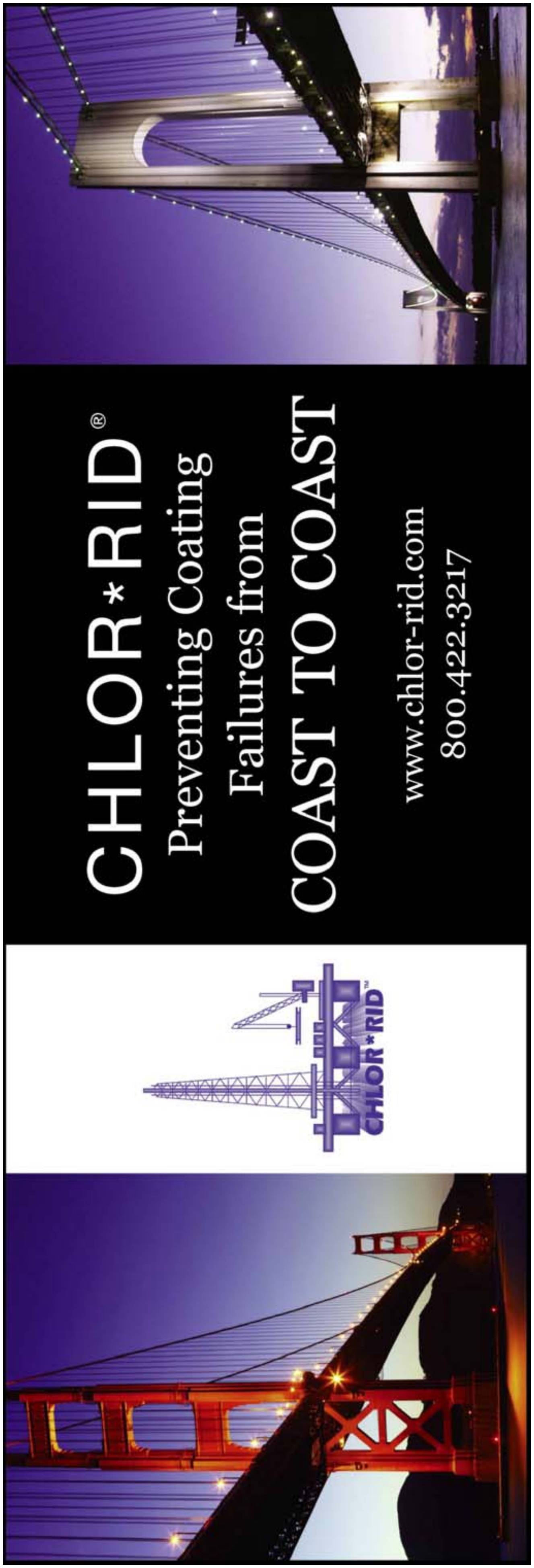

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Shipyard Regulatory Update

WHAT'S HAPPENING WITH ENFORCEMENT, REGULATION, AND NEW OSHA GUIDANCE DOCUMENTS

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This article reviews OSHA enforcement on shipyard activities and recent guidance on illumination and ventilation related to ship repairing, shipbuilding, and shipbreaking that fall under OSHA's Standards for Shipyard Employment (29 CFR 1915). It also discusses new OSHA information on abrasive blasting hazards and potential Cal/OSHA Lead Standard changes that are applicable to shipyard and many other industrial painting sectors.

Shipyards are fixed facilities with dry docks and fabrication equipment capable of building a ship, defined as watercraft typically suitable or intended for uses other than personal or recreational. Activities of shipyards include the construction of ships, their repair, conversion and alteration, and the production of prefabricated ship and barge sections.

OSHA ENFORCEMENT SUMMARY

Review of the most frequent OSHA citations for NAICS Code 336611–Ship Building and Repairing from October 2012 through September 2013, and OSHA's enforcement data for NAICS 336611 and 29 CFR 1915, indicates the following areas of non-compliance resulting in citations. Areas are ordered from highest to lowest, and some similar areas were grouped by the author.

- Respiratory protection
- Wiring design, protection, methods, components, and equipment for general use
- Guarding of deck openings and edges
- Welding and cutting (arc, gas, and oxygen-fuel)
- Hazard communications
- Toxic metals
- Painting
- Abrasive wheel machinery
- Occupational noise
- Hand and portable powered tools and equipment
- Confined space
- Lighting
- Lockout/tagout

OSHA SHIPYARD FACT SHEETS

Illumination

In November 2013, OSHA issued a Fact Sheet on Safe Lighting Practices in the

Table 1: Minimum Lighting Requirements

According to OSHA Fact Sheet on Safe Lighting Practices in the Shipyard Industry

Lumens (Foot-Candles)	3	5	10	30
Areas of Operation	General areas on vessels and vessel sections such as: • Accessways • Exits • Stairs • Gangways • Walkways	General landside areas such as: • Corridors • Exits • Stairs • Walkways	Landside work areas such as: • Machine shops • Electrical equipment rooms • Carpenter shops • Lofts • Tool rooms • Warehouses • Outdoor work areas	First-aid stations
		Landside tunnels, shafts, vaults, pumping stations, and underground work areas	Health and sanitation facilities such as: • Changing rooms • Showers • Sewered toilets • Eating or drinking areas • Break areas	Infirmaries
		All assigned work areas on any vessel or vessel section		Offices

Shipyard Industry. It elaborated upon 29 CFR 1915.82, Subpart F, General Working Conditions: Lighting, and provided the minimum lighting requirements (Table 1).

Note that the values in Table 1 differ from SSPC-Guide 12, Guide for Illumination of Industrial Painting Projects, which suggests that a higher level of lighting is required for work, surface preparation, and inspection activities. SSPC-Guide 12 recommendations are shown in Table 2.

Use of a portable light meter can help assess the adequacy of lighting. Be sure to use it frequently to re-verify that lighting levels remain constant. Make sure your light meter is capable of taking measurements in the range of your lights and that it meets your accuracy needs. Most light meters have an accuracy range from 5% up to 18% and even higher.

Table 2: Minimum Lighting Requirements

According to SSPC-Guide 12

SSPC-Guide 12	Minimum Foot-Candles	Recommended Foot-Candles
General Work	10	20
Task specific — surface preparation and coating application	20	50
Task specific — inspection	50	200

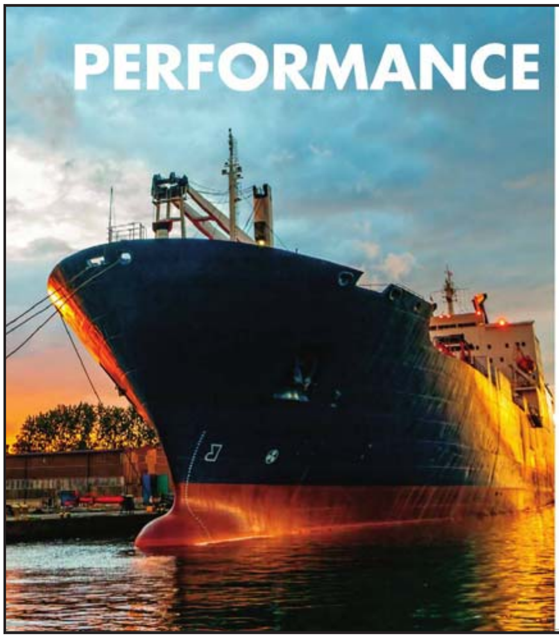
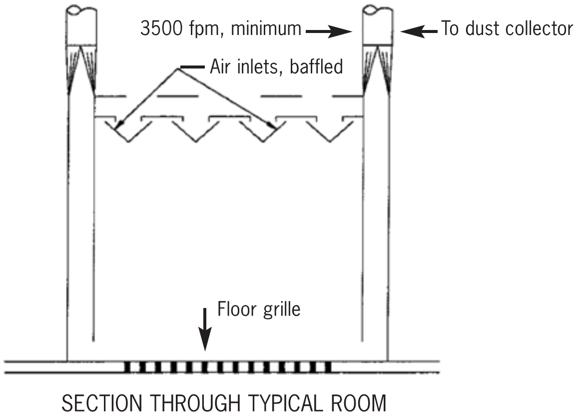


Fig. 1: Typical blast booth design

Source: Reference 10.80.3 and 10.80.4; American Conference of Governmental Industrial Hygienists, Abrasive Blasting Room, 02-91, VS-80-01



Q = 60–100 cfm/ft^2 of floor for downdraft with typical choice 80 cfm/ft^2
Q = 100 cfm/ft^2 of wall for cross draft
Lower control velocities may be used depending on toxicity of the contaiminant, object and blasting media, and the size of the blasting room.
Notes:
1. The above ventilation is for operator visibility and to control escape of contaminants into adjacent work areas.
2. Operator in an abrasive blasting room is required to wear appropriate NIOSH-certified respiratory protection.
3. For rotary tables, use 200 cfm/ft^2 of total opening (taken without curtains).
4. For blasting cabinets, see VS–80–02.

OSHA VENTILATION IN SHIPYARD EMPLOYMENT GUIDE—A SHIFT IN APPROACH?

OSHA 3639-04 2013: Ventilation in Shipyard Employment provides a review of basic principles of ventilation and provides methods for selection, installation, and use of ventilation systems to reduce contaminants during shipyard operations. While it primarily focuses on confined and enclosed spaces, it provides guidance applicable to any industry. Unlike General Industry (1910) and Construction (1926), Maritime (1915) does not have specific ventilation requirements.

OSHA General Industry Standard Ventilation standard (1910.94, Ventilation), published in the 1970s, established the first requirements for abrasive blast booths as (1) exhaust-ventilated to provide continuous air flow at all openings during blasting operations, (2) capable of preventing escape of abrasives into adjacent work areas, and (3) able to provide prompt clearance of dust when abrasive blasting ceases.

The *Industrial Ventilation: Manual of Recommended Practices*, published by the American Conference of Governmental Industrial Hygienists, provided the basis for the design of blast booths for the stated purpose of “operator visibility and to control escape of contaminants into adjacent work areas.” It established the minimum air flows (60–100 feet per minute), transport velocities in ductwork (3,500 feet per minute), and design criteria with inward air flow exhausting to a remotely located dust collection system, as shown in Figure 1.

SSPC-Guide 6, Guide for Containing Surface Preparation Debris Generated During Paint Removal Operations, relies on the *Industrial Ventilation Manual* criteria as the basis of its ventilation requirements

for abrasive blasting containments. In industrial field painting, it generally involves bringing duct work to the face of the containment system or just inside the containment wall and having air inlets generally across from them, mimicking the design of a blast booth (Fig. 2).

This type of ventilation is considered dilution ventilation (general exhaust ventilation), which is "a form of exposure control that involves providing enough air in the workplace to dilute the concentration of airborne contaminants to acceptable levels."[1]

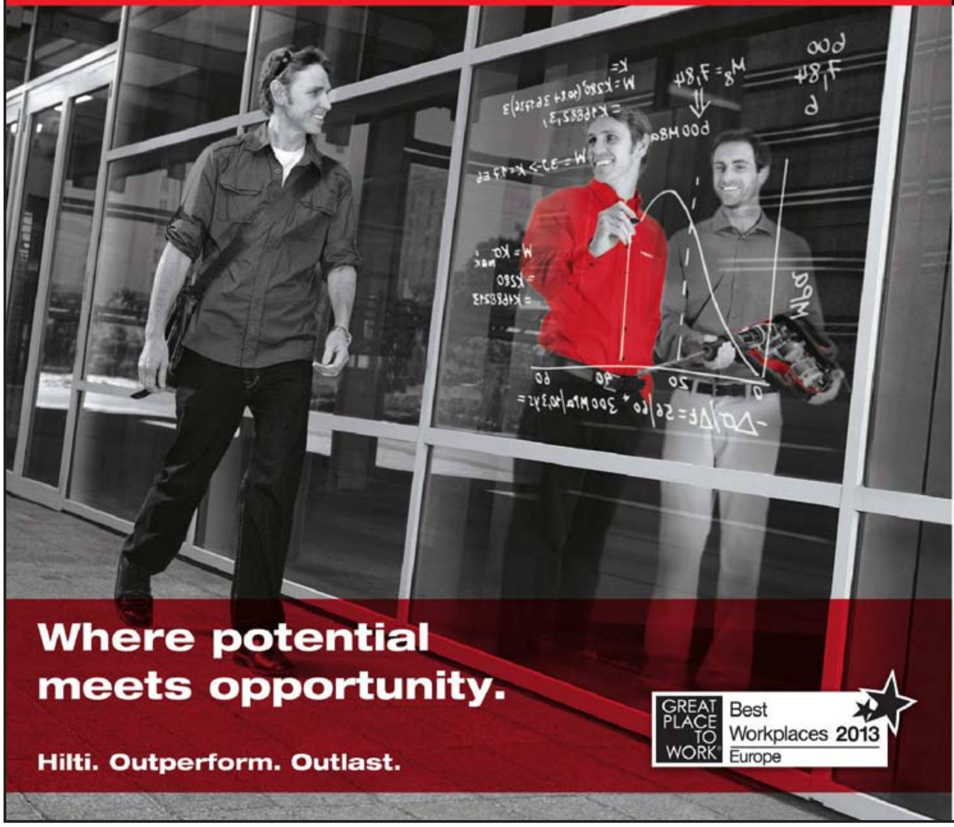
The Shipyard Guide states that both general dilution ventilation and local exhaust ventilation (LEV) at the source are suitable for controlling exposures. However, it states that local exhaust ventilation is typically preferred and more effective.

The Shipyard Guide also states that dilution ventilation involves the reduction of contaminants being generated in the space through the introduction of clean outdoor air (through air inlets) and removal of the contaminants through a dust collector. It notes that sometimes, this can cause a supply and exhaust imbalance that positively or negatively pressurizes the space or results in short circuiting (when only a small portion of the space is ventilated). The Shipyard Guide depicts dilution ventilation as inefficient, requiring a lot of air and air movement to reduce the level of hazardous contaminants.

The Shipyard Guide also suggests that four factors should be considered before using dilution ventilation for protecting worker health.

(1) The quantity of contaminant released should be relatively low and uniform.
(2) Workers should be located far away from the contaminant source.
(3) The toxicity of the contaminant must be low.
(4) There is no need to collect the air contaminant.

If we apply the four factors to industrial painting and abrasive blast cleaning in the construction, marine, or shipyard industries, where the quantity of contaminants are high and non-uniform and many of which are toxic, it would suggest that LEV may be more appropriate than dilution ventilation.



LEV is “an industrial ventilation system that captures and removes emitted contaminants before dilution into the ambient air of the workplace.”[1] While we typically associate LEV with vacuum shrouds and vacuum attachments, LEV can include placement of one or more exhaust air ducts in the immediate vicinity of where the exposure is occurring. LEV is frequently used in the shipbuilding industry and is the recommended method when workers are exposed to hazardous chemicals, when a large amount of dust or welding fumes are generated, or during cold weather when increased heating costs from the use of dilution ventilation is a concern.

The Shipyard Guide suggests that using ventilation in an exhaust mode and placing the ductwork where contaminants are released in the air by the operation is an effective method in capturing the generated contaminants and greatly reduces exposure to workers in a space (Fig. 2).

Table 3 (excerpted from Ventilation in Shipyard Employment), suggests that LEV may be more appropriate for abrasive blast cleaning.

While the preference for LEV may be specific to shipyards, all industries should evaluate the hazards and unique characteristics of the work area to which their employees are exposed and consider all methods for reducing exposures. When working with materials covered by comprehensive health standards (such as lead) which require the use of engineering controls for the purpose of reducing worker exposures to as low as feasible, LEV may be more in line with the definition of an engineering control, which focuses on elimination or reduction of the hazard at the source.

Duct Work

Whether you use dilution or local exhaust ventilation, an integral part of the system is the ductwork. The Shipyard Guide is consistent with the guidance provided in SSPC’s C3 Course, and SSPC-Guide 16, Guide to Selecting Dust Collectors, and states that consideration should be given to the type and length of the hose and layout of duct work to ensure the greatest amount of air flow.

As the length of hose or ductwork increases, the amount of air moved decreases due to frictional losses. Therefore, the shortest length of hose or ductwork should be used.

Equally important is the amount of bends or turns in the ductwork. A greater number of bends or turns greatly decreases the volume of air moved. Try to keep the hose as straight as possible. To put this in perspective, one sharp 90-degree bend in a 20-inch-diameter duct is equivalent to adding 46 additional feet to the length of the ductwork.

When we install ductwork through manways, small openings, and other limited egress areas, it may impede entry/exit. The Shipyard confined space standard requires that if ventilation ductwork blocks access to a confined space, then all workers must be provided with airline respirators, and a person must be stationed outside the space to maintain communication and to aid in the event of an emergency. The Guide suggests a saddle be used in these cases. A saddle is a piece of equipment that allows entry/exit without removing the duct work.

Table 3: Comparison of Ventilation Systems

DILUTION VENTILATION		LOCAL EXHAUST VENTILATION	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Requires less maintenance	Does not completely remove contaminants	Captures contaminant at source and removes it from the workplace	Requires regular cleaning, inspection and maintenance
Effective control for small amounts of low toxicity chemicals	Cannot be used for highly toxic chemicals	Only choice for highly toxic airborne chemicals	Ducting style may make it difficult to access the space
Effective control for flammable or combustible gases or vapors	Ineffective for dusts or metal fumes or large amounts of gases or vapors	Can handle all sorts of contaminants including dusts and metal fumes	
Best ventilation for small dispersed contaminant sources or mobile sources	Requires large amounts of heated or cooled makeup air	Requires smaller amount of makeup air since smaller amounts of air are being exhausted	
	Ineffective for handling surges of gases or vapors or irregular emissions	Less makeup air is needed to heat or cool	

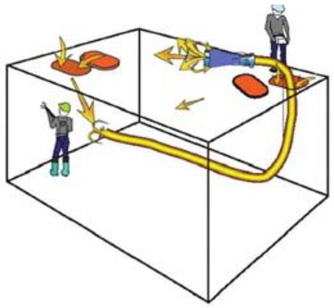


Fig. 2: Efficient method of supplied ventilation (forced air) with system away from tank opening.
Source: Edward J. Willwerth, Atlantic Environmental & Marine Services

ABRASIVE BLASTING HAZARDS

OSHA released a new fact sheet in November 2013, titled, Protecting Workers from the Hazards of Abrasive Blasting Materials. It outlines the following abrasives and likely health effects.

- Silica sand (crystalline) can cause silicosis, lung cancer, and breathing problems in exposed workers.
- Coal slag and garnet sand may cause lung damage similar to silica sand (based on preliminary animal testing).
- Copper slag, nickel slag, and glass (crushed or beads) also have the potential to cause lung damage.
- Steel grit and shot have less potential to cause lung damage.
- Slags can contain trace amounts of toxic metals such as arsenic, beryllium, and cadmium.

The fact sheet also suggests that when performing abrasive blasting to reduce worker hazards from materials, one needs to use nearly identical controls as one would for lead or other toxic metals, including engineering controls (e.g. containment and ventilation), work practices (hand and body PPE and hygiene), and respiratory protection. Some other observations made in the fact sheet include:

- recommending the use of alternative, less toxic blasting materials such as sponge, baking soda, or dry ice;
- keeping coworkers away from the blaster;
- cleaning and decontaminating tarps and other equipment at the worksite; and
- scheduling blasting when the least number of workers are at the site.

Take a look at your abrasive blast cleaning operations and materials and consider what equipment, processes, materials, or worker changes may be necessary to reduce worker exposures to abrasive blasting material hazards.

ARE WE CLOSER TO REVISING THE CAL/OSHA LEAD STANDARD?

In April 2011, the California Department of Health/Occupational Lead Poisoning Prevention Program (OLPPP) began providing information to support revisions to the 30-year-old Cal/OSHA Construction Lead Standard based on more recent health-based scientific evidence. OLPPP suggests that the following changes are necessary.

- Provide medical surveillance, blood lead level (BLL) testing, annual blood pressure measurements, and questionnaires to all employees likely to be exposed to lead.
- Increase frequency of medical surveillance of BLLs and further increases if above 10 µg/dL.
- Remove employee from lead exposure at or above 30 µg/dL or if two successive blood lead concentrations measured over a four-week interval are at or above 20 µg/dL.
- Return employee to work when two blood lead tests taken four weeks apart are less than 15 µg/dL.
- Lower Permissible Exposure Limit (PEL)/Action Level (AL) which reflect new medical/toxicological information on chronic and low-level health effects.
- Conduct regular testing of surfaces in eating areas and change areas and clean more frequently when lead is found. Establish a quantitative limit for lead on surfaces and specify sample collection and analysis methods.
- Provide quarterly employee training. Training should maximize the use of participatory and hands-on methods.
- Post warning signs in areas where lead is present.
- Define and require minimum engineering and work practice controls unless the employer can demonstrate that such controls are not feasible.

- Do not allow certain high-risk work practices.

In October 2013, the California Department of Public Health (CDPH) made a recommendation to Cal/OSHA for a new PEL based on the low level health effects literature and new modeling of the relationship between air lead levels and blood lead levels.

CDPH used an updated version of the original model used by OSHA to develop the General Industry Standard for lead and challenged the model using actual BLL and mortality data obtained over the last 20 years. The modeling and the conclusions support the overwhelming body of recent scientific evidence indicating the health impacts of very low BLL exposures ranging from 5–10 µg/dL. The modeling focused on two issues.

- Estimate the amount of lead in workplace air inhaled by workers without respirators that would result in BLLs of 5, 10, 15, 20, and 30 µg/dL over a 40-year working lifetime.
- Estimate the time it would take for a worker's BLL to come down to 15 µg/dL from a higher level once the worker is removed from workplace lead exposure.

The modeling arrived at the following conclusions.

To keep almost all workers' (95%) BLLs below 5 µg/dL over their working lifetime, the amount of lead in the air the worker is exposed to must not be above 0.5 µg/m^3 averaged over an 8-hour workday.

The model also shows that the amount of lead in a worker's blood climbs very fast in the first few years of workplace exposure and then climbs much more slowly in the remaining years. Even though a worker's BLL does not climb much during the remaining years, lead levels in the bones continue to increase. The lead in the bones is slowly released into the blood throughout a worker's lifetime.

The model also estimates the time it may take for a worker's BLL to come down to a BLL of 15 µg/dL, after removal from workplace exposure.

The CDPH concluded that based on available scientific evidence adverse health effects begin to emerge at BLLs of 10 µg/dL and likely lower.

Modeling suggests that in order to maintain BLLs of 10 µg/dL over a working lifetime in 95% of workers, the air concentration of lead must not exceed 2.1 µg/m^3 as an 8-hour TWA average or to maintain a BLL of 5 µg/dL a PEL of 0.5 µg/m^3 as an 8-hour TWA average.

Cal/OSHA is expected to introduce a final rule by the end of this year. Industry professionals expect medical removal levels to be established at 15–20 µg/dL and a PEL of approximately 20 µg/m^3 as an 8-hour TWA average.

REFERENCES

1. OSHA Technical Manual.

ABOUT THE AUTHOR

Alison B. Kaelin, CQA, has more than 25 years of public health, environmental, transportation, and construction management experience in the coatings industry. She is the owner of ABKaelin, LLC, a provider of OSHA training, quality assurance, auditing, consulting, and related services to the protective coatings, construction, fabrication, and nuclear industries.

Kaelin is a certified quality auditor and NACE-certified coating inspector. She was a 2012 *JPCL* Top Thinker, a 2012 *JPCL* Editor's Award Winner, and an SSPC Technical Achievement Award winner in 2005. At SSPC 2014, she was presented the inaugural Women in Coatings Impact Award. She is a *JPCL* contributing editor.

JPCL

Photo courtesy of Georgia World Congress Center

Atlanta Welcomes the American Coatings Show

From April 7–10, the Georgia World Congress Center in Atlanta, GA, will play host to the 2014 American Coatings Conference and Show.

The Conference, which will be comprised of tutorials and information sessions pertaining to coatings, inks, adhesives, sealants, and construction chemicals, kicks off on Monday, April 7, and runs through Wednesday, April 9. The Show will be open Tuesday, April 8, through Thursday, April 10, and will feature over 400 exhibitors from the protective coatings field and other related industries.

The following preview provides information that may be of interest to industrial coatings professionals. All information is current as of press time. For more information, please visit american-coatings-show.com.

Schedule At A Glance

Monday, April 7

Pre-Conference Tutorials

- Tutorial 1: Antimicrobial Surfaces
- Tutorial 2: Easy-to-Clean Coatings
- Tutorial 4: Waterborne High-Performance Coatings
- Tutorial 5: Functional Films
- Tutorial 6: Polyurethanes
- Tutorial 8: Antifouling Coatings
- Tutorial 9: Anticorrosive Coatings
- Tutorial 10: Fundamentals of Catalysis for Modern Coatings
- Tutorial 11: Sustainable Coatings and Processes

Plenary Session

- Welcome Address and Conference Introduction
- Keynote Presentation: Energy as a Driver for Coatings Innovation in the 21st Century
- Awards Ceremonies

Session 2: Bio-Based Coatings

- 2.1 Bio-Based Waterborne Floor Coatings with Enhanced Flow and Appearance
- 2.2 Novel Alkyd-Type Coating Resins Produced Using Cationic Polymerization
- 2.3 Bio-Succinic Acid: Enabling Performance in Polyurethane Coatings
- 2.4 Curing Kinetics of Bio-Based Epoxy-Anhydride Thermosets
- 2.5 Lactide-Modified Polyester Resins with Enhanced Coatings Performance
- 2.6 Cost Reduction in Alkyd Enamels, Primers, and Stains

Session 3: Measuring & Testing

- 3.1 Formulating High-Performance Coatings with Novel Adhesion Methods
- 3.2 A Critical Study of Scratch Resistance Test Methods
- 3.3 Non-Contact, Substrate-Independent, Multi-Layer Paint Thickness Sensor
- 3.4 Statistical Modeling of Coating Lifetime in Disparate Environments
- 3.5 Application of High Throughput Screening for a Clear Concrete Sealer Formula
- 3.6 Correlation Between UV-A and Long-Term Florida Weathering: Formulation and Structure/Property Relationships in Polyurethane Coatings

Poster Sessions

- p.3 High-Performance Silicone Defoamers
- p.4 Formulating Low-VOC, Flexible Coatings
- p.6 Self-Coalescing Latex Particles with Good Coatings Properties
- p.7 Test Method for Leveling and Applied Hiding of Paints Applied by Roller
- p.8 Development of Water Soluble Catalysts for Polyurethane Coatings Application
- p.9 Creative Routes to High-Solid, Low-Viscosity Acrylic and Polyester Polyols
- p.10 High-Output Automated Workflows in the Paint & Coatings Industry
- p.11 Modeling a Bio-Based Polyol Pigmented 1K Polyurethane Formulation
- p.13 PU-PDMS Fouling-Release Coatings: Effect of Surface Damage

- p.14 Biocide Resistant Bacilli in Paint: The Nanotechnology Option
- p.15 Influence of Monomers and Cure Conditions on the Shrinkage
- p.16 Fouling-Release Performance of Silicone Oil-Modified Siloxane-Polyurethane Coatings
- p.17 Synthesis, Characterization, and Applications of Sulfonate-Based CUPs

Tuesday, April 8

Session 6: Polyurethanes I

- 6.1 The Unique Chemistry of Waterborne UV Curable Resins on Flexible Substrates
- 6.2 Aliphatic Hardcoats from CO$_2$-Based Polycarbonate Polyols
- 6.3 Low-VOC High-Performance 1K Waterborne Polyurethanes
- 6.4 Development of Water Soluble Catalysts for Polyurethane Coatings Application
- 6.6 Tailoring Cross-Link Density and Index in 2K Waterborne PVDF Coatings

Session 7: Protective Coatings I

- 7.1 Alkyd Latex Polymer Design and Coating Formulations for Low-VOC Metal Primers
- 7.2 Novel Low-VOC Waterborne Technology for Direct-to-Metal Application (DTM)
- 7.3 New Developments in Direct-to-Metal Coatings
- 7.4 Innovative Two-Coat, Single-Cure Powder Coating System
- 7.5 Improving Corrosion Resistance of Powder Coating Systems for ACE Applications
- 7.6 Novel Flake Glass Designed for Bridge Protective Coatings

Session 8: Novel Materials

- 8.1 Novel Rheology Control Agents for Industrial and Automotive Coatings
- 8.2 Lower Temperature Cure of Melamine Cross-linked Coil Coatings
- 8.3 HEUR Technology for Improved Coating Properties & pH-Responsive Thickening
- 8.4 New Additives—Better Surface Effects with Fewer and Shorter Fluoro-Chains
- 8.5 Nonionic Synthetic-Associative Thickeners: Resolving Thickening Efficiency
- 8.6 New Superwetting Surfactants for Coatings Application

Session 10: Polyurethanes II

- 10.1 New Reactive Diluents for 2K Solvent-Borne Polyurethane Coatings
- 10.3 DTM Acrylic Polyol for 2K Polyurethane Coatings
- 10.4 Improved Polycarbonate Diol-Based Coatings for Oil & Mining Pipelines
- 10.5 High-Solids Polyurethane Dispersions as an Environmentally Friendly Alternative for Textile Coatings
- 10.6 Latent Polyisocyanate Crosslinkers for Aqueous Functional Resins

Session 11: Protective Coatings II

- 11.1 Waterborne and Solvent-Free Inorganic Silane Binders for Zinc-Rich Paints
- 11.2 “In Zinc We Trust”—New Environmentally Friendly Inhibitors
- 11.3 New Advances in Rheological Performance in High-Solids Marine and Protective Coatings
- 11.4 Innovative Polyamine Rheology Modifiers for High-Solids Industrial Coatings
- 11.5 Use of Organometallis Ester Corrosion Inhibitor in Alkyd Emulsion Paints
- 11.6 Towards a Bright Future with New Anti-Corrosion Pigments

Session 13: Waterborne Coatings

- 13.1 Low-VOC Waterborne Alkyd Emulsion: New “Green” NPE-Free Emulsifying Agents
- 13.2 New Reactive Emulsifiers for Waterborne Alkyd Coatings
- 13.3 New High-Performing Polymeric Grinding Resins for Decorative and Industrial Coatings
- 13.4 Breakthrough Waterborne Technology Brings Alkyd Back to the Road
- 13.5 Innovation in Benzoate Technology for Coatings Applications
- 13.6 Stir-In Carbon Blacks for Waterborne Coatings

Session 14: Epoxy Coatings

- 14.1 Renewable Ultra LITE Epoxy Diluents—Non-Toxic Alternatives to Substances
- 14.2 Global Environmental Regulations Drive New Technologies in Epoxy Coatings
- 14.3 Improving Performance of Epoxy-Polysiloxane
- 14.4 Is Your WB 2K Epoxy Formulation Giving You a Headache? Here’s the Cure!
- 14.5 Waterborne Epoxy Dispersions and Curing Agents for Garage Floor Coatings
- 14.6 Epoxy Systems with Markedly Enhanced Properties

Session 15: Nanotechnology

- 15.1 High-Solids Hard Nano-Latexes for Improved Waterborne Coatings Performance
- 15.2 Stress Development and Film Formation in Multiphase Composite Latexes
- 15.3 Quantifying Nanomaterial Release from Nanocoatings Exposed to UV Radiation
- 15.4 Accelerating Drying of Tinted Waterborne Coatings

Exhibitors

The following is a list of American Coatings Show exhibitors that may be of interest to industrial protective coatings professionals. All information is current as of press time.

3M Energy + Advanced Material	635
ACT Test Panels	1856
Advanced Composite Materials	2539
AGC Chemicals America	856
Air Products	1115
AkzoNobel	1931
Allnex	1907
Amazon Paint	464
American Coatings Association	1259
Arizona Instruments LLC	759
Arkema Inc.	2204
Ashland Specialty Ingredients	1541
BASF–The Chemical Company	1505
Bayer Material Science LLC	2305
BYK Gardner / BYK Additives	1007
Cabot Corporation	821
Cardolite	2233
Cathay Coating Mfg. Co. Ltd.	1565
CFCM Magazine (*Canadian Finishing & Coatings Mfg*)	224

Chemtura Baxenden	1049
Chicago Society for Coatings Technology	2066
Chitec Technology Co. Ltd.	2244
CI Coatings	530
CINIC Chemicals America, LLC	1035
Clariant	1939
Coatex	2204
The Coatings Group	2740
Coatings Research Group	722
Coatings World Magazine	2630
Croda	1335
DeFelsko Corporation	2141
Dow	807
Dow Corning Corporation	2547, 1935
Dupont	929
Eastern Coatings Federation	2167
Eastman Chemical Company	1341
Evonik	1707
Excalibar Minerals LLC	1948
Fischer Technology Inc.	1940
Heucotech Ltd. / Heubach	1751
Huber Engineered Materials	1133
Huntsman	2504
Hybrid Coating Technologies	2642
Lonza	1033
Lubrizol	2214
Mallard Creek Polymers, Inc.	2359
Michelman	2321
Missouri Univ. of Science & Technology Coatings Institute	1863
Momentive Specialty Chemicals	1105
North Dakota State Univ. Coatings & Polymeric Materials	1867
Nubiola USA	1741
Nuplex Resins	1641
NürnbergMesse GmbH	465
Pacific NW Society for Coatings Technology	2062
Paint & Coatings Industry	242
Paint & Pintura / Construchemical Magazines	352
Paint PAC	2520
PaintCare	2521
Palmer Holland, Inc.	2615
Paul N. Gardner Co., Inc.	1022
Philadelphia Mixing Solutions, Ltd.	2640
Piedmont Society for Coatings Technology	2063
Powder Coatings Institute	1967
Reichold Inc.	1305
Southern Society for Coatings Technology	2067
Specialty Polymers	1139
TQC bv	1322
Troy Corporation	1523
U.S. Polymers-Accurez, LLC	846
U.S. Silica	2532
Univar	1935
Vincentz Network	1459
Wacker Chemical Corporation	1313
Wacker Chemie AG	1323
Waterborne Symposium Univ. of Southern Miss.	1966
Wenzhou Lypont Powder Coatings Co., Ltd.	453
Worlee-Chemie GmbH	1849

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COMING UP

Courses

All SSPC course information can be found at sspc.org

April 1–2 SSPC CAS Refresher/CAS Level 1, Pittsburgh, PA

April 1–3 SSPC Plural Comp App, Rowlett, TX

April 5–6 SSPC C7 Abrasive Blast, Chesapeake, VA

April 5 NACE CIP One-Day Bridge, Virginia Beach, VA, nace.org

April 7–8 SSPC CCI Conc Ctg Insp Level 1/2, Phoenix, AZ

April 7–8 SSPC CCB Conc Ctg Basics, Phoenix, AZ

April 7–10 SSPC C3 Lead Pt Removal, Sulphur, LA

Apri 7–11 SSPC C2 Planning & Spec, Kent, WA

April 8–11 KTA-Tator Basic Ctgs Insp, Pittsburgh, PA, kta.com

April 9–10 SSPC Weathering, Pittsburgh, PA

April 10-11 SSPC C13 Water Jetting, Seattle, WA

April 11 SSPC C5 Lead Pt Refresher, Sulphur, LA

April 12 SSPC PCS Prot Ctgs Spclst, Kent, WA

April 12–13 SSPC C14 Marine Plural Comp App, Norfolk, VA

April 12–13 SSPC QCS Qual Cntrl Spvsr, Norfolk, VA

April 13 SSPC CCI Supplement, Phoenix, AZ

April 13–17 NACE Basic Corrosion, Houston, TX, nace.org

April 14 SSPC CAS Refresher, Portland, OR

April 14 SSPC Using PA 2, Norfolk, VA

April 14–15 SSPC C7 Abrasive Blast, Honolulu, HI

April 15 SSPC CAS Level 1, Portland, OR

April 15 SSPC PCI Workshop, Norfolk, VA

April 15–16 SSPC CAS Level 2, Portland, OR

April 16–17 SSPC C14 Marine Plural Comp App, Honolulu, HI

April 21–26 NACE Ctgs w/ Cath Prot, Houston, TX, nace.org

April 23–24 SSPC Bridge Ctg Assessments, Rowlett, TX

April 24–25 SSPC ATT Train-the-Trainer, Zephyrhills, FL

April 25 SSPC Nav Std Item 009-32, Norfolk, VA

April 26–27 SSPC C12 Airless Spray, Norfolk, VA

April 28–May 2 SSPC C1 Fundamentals, Tucker, GA

April 28–May 2 SSPC NBPI, Norfolk, VA

April 28–May 3 SSPC PCI Levels 1/2, St. Petersburg, FL

Meetings & Conferences

April 1–3 Electric Power Conf/Expo, New Orleans, LA, electricpowerexpo.com

April 3–5 IBTTA Board & Committee Mtgs, Jersey City, NJ, ibtta.org

April 7–10 ACA American Ctgs Conf/Show, Atlanta, GA, american-coatings-show.com

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