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The Voice of SSPC: The Society for Protective Coatings

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28 TELECOM MEETS WATER TOWER

*By Christopher Wolfgram and Daniel J. Zienty
Short Elliott Hendrickson Inc.*

More and more, telecommunications companies are using water towers as macro cell sites, mounting equipment onto handrail systems designed initially for access and maintenance. The authors present testing to determine the extent of potential heat damage to interior and exterior tank coating systems caused by welding additional bracing for telecom equipment.



34 PAINTING BOLTED BRIDGE CONNECTIONS

By Kenneth A. Trimmer, KTA-Tator, Inc.

This article explains painting faying surfaces, bolt holes and fasteners on bridges in an attempt to clear up existing confusion and provide points to consider when designing and painting bolted connections.



44 IMPROVING SURFACE PREP PRODUCTIVITY WITH RECTANGULAR BLASTING NOZZLES

*By Chang-Hun Lee, Byeong-Hun Do, Won-Jun Yun and Han-Jin Bae
Hyundai Heavy Industries, Co., Ltd.*

The authors share processes and results of tests for velocity, spray width and work efficiency (area) between standard round blasting nozzles and rectangular nozzles to determine advantages in productivity of one over the other.





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SSPC-SP 1: Basic, But Important

SSPC-SP 1, "Solvent Cleaning," is a simply written, relatively short industry standard that has been in effect since 1982, but it is an essential standard when it comes to ensuring a quality coating application. Its simplicity and brevity often overshadow its importance, as both contractors and inspectors are prone to take the requirements of SP 1 for granted to the point where they think they can recite its requirements without having to read the standard. Sometimes, this causes confusion at the shop or job site, and disputes can arise.

So, what does SP 1 actually say, and what is the intent of its requirements? And how can a contractor plan ahead to avoid disputes and ensure that these requirements are met?

SSPC-SP 1 is used to specify removal of visible deposits of oil, grease and other soluble contaminants from metal surfaces before additional mechanical means of surface preparation are employed. All of the SSPC surface preparation standards, including power tool-cleaning and dry and wet abrasive blast-cleaning standards, require solvent cleaning to SP 1 prior to performing the actual surface cleaning level called out in the project specification. SP 1 is also used during waterjet cleaning, although in some cases the project specification may waive SP 1 if the specifier believes that the waterjet process satisfies its requirements. Removing heavy deposits of oil and grease before power tool- and abrasive blast-cleaning is important, because mechanical cleaning processes can push these contaminants into the surface profile.

A solvent-cleaned surface is free of oil, grease, dust, dirt and other visible, soluble contaminants when viewed without magnification. In this case, "visible" means detectable with normal or corrected normal vision. SP 1 does not require the use of other verification methods aside from looking at the surface to determine whether the surface is "solvent cleaned." Typically, this visual confirmation is performed by applicators and inspectors to verify compliance.

In some cases, project specifications may call out additional methods of verification that are not requirements of SP 1. It is important to read the specification carefully to see if any additional methods of inspection are required. These include wiping the surface with a clean, dry white rag to see what comes off on the rag; performing an ultraviolet (UV) light test to detect hydrocarbon contamination; performing ASTM F22, "Standard Test Method for Hydrophobic Surface Films by the Water-Break Test," to detect hydrocarbon contamination; and performing a surface dust test using specified tape or examining the surface for dust in accordance with ISO 8502-3.

SSPC-SP 1 does not specify a particular method or material to be used for the solvent cleaning process. It does, however, list examples of solvents (such as water, emulsion or alkaline cleaners

and hydrocarbons) and methods for solvent cleaning (such as steam cleaning and solvent wiping).

It is important to note that SP 1 is required to be performed both prior to and following mechanical cleaning operations in the dry abrasive blast-cleaning standards such as SSPC-SP 10/NACE No. 2, "Near White Blast Cleaning," and the power tool-cleaning standards such as SSPC-SP 11, "Power Tool Cleaning to Bare Metal," and SSPC-SP 15, "Commercial Grade Power Tool Cleaning." Performing SP 1 prior to mechanical cleaning prevents the applicator from pushing contaminants into the surface during the cleaning process. Performing SP 1 after mechanical cleaning allows the applicator to remove any remaining visible contaminants before applying the prime coat.

This, unfortunately, is where disagreements may arise in the real world. In practice, performing SP 1 prior to mechanical cleaning is limited to removing oil and grease and possibly mud or bird droppings that can be pushed into the surface or contaminating recycled abrasives when they are being used. Surface preparation operations might take place in a shop or location where constant dirt or dust may be present. A solvent-cleaned surface might also be transported to another site for mechanical cleaning and/or paint application, where further "visible" contamination can accrue. Typically, these contaminants can be removed during mechanical cleaning without affecting surface profile and paint application. However, an overly aggressive or inexperienced inspector may perform a clean rag wipe test after solvent cleaning (prior to surface preparation) and find dust or dirt left on the surface, and the subsequent steps may be delayed further if the inspector insists on removal or the additional inspection methods described earlier. In many cases, blowing down the surface with clean, dry air effectively removes dirt and dust, but if that process is not included in the specification, it may not satisfy the inspector.

In addition to knowing the specific requirements of SSPC-SP 1, it is the contractor's responsibility to carefully review the specification documents and establish the exact criteria for visually inspecting a solvent-cleaned surface at the pre-project conference or before beginning work. This can save valuable time at the job site, ensure that the owner is getting his or her desired result, and avoid disputes between the contractor and the inspector about the job requirements.

For questions about this article or for more information regarding SSPC-SP 1 and other SSPC standards, contact Aimée Beggs, standards development specialist, or Joe Berish, corporate certification manager, SSPC. Beggs has been with SSPC for 36 years and has managed its standards development process since 1993. She can be reached at beggs@sspc.org or 412-281-2331, ext. 2223. Berish has been with SSPC since 2013 and can be reached at berish@sspc.org or 412-281-2331, ext. 2235.

Two Webinars Scheduled for June

The 2016 SSPC/JPCL Webinar Education Series continues in June with two free webinars from coating industry experts.

"The Confusion Surrounding the Painting of Bolted Connections — What Should and Shouldn't be Done," will be presented by Ken Trimber, president of KTA-Tator, Inc., on Wednesday, June 1, from 11:00 a.m. to noon, EST. There are a number of questions associated with painting the connections of structural steel joints. Should bolt holes be painted? How are galvanized or black fasteners prepared for painting in the field and what coatings should be applied? What restrictions are associated

with the use of coatings in slip-critical joints? This webinar will address these and other issues associated with the painting of bolted connections.

For more on this topic from Trimber, see his feature article on page 34.

"Surface Preparation by Wet Abrasive Blast Cleaning," will be presented by Thomas E. Enger of Clemco Industries Corp. on Wednesday, June 15, from 11:00 a.m. to noon, EST. Sponsored by Clemco Industries Corp., this webinar will cover industry standards, procedures, equipment, and materials used in a variety of air/water/abrasive, water/abrasive, and water-pressurized abrasive blast-cleaning systems.



Enger has over 30 years of academic and practical experience in heavy construction, construction equipment manufacturing and hazardous material management. He has extensive experience in applying federal, state and local regulatory requirements as well as in the use of industry standards for preparing surfaces for today's coatings. Enger has taught courses at Arizona State University and Maricopa Community College, and has instructed both safety professionals



Ken Trimber



Thomas E. Enger

and users of surface preparation equipment on complex regulatory requirements at SSPC and FABTECH over the last 15 years. Enger is certified by the Board of Certified Safety Professionals and the Institute of Hazardous Materials Management. His primary focus is product safety and practices for Clemco.

Registration, CEU Credits

These programs are 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 these online presentations at paintsquare.com/webinars.

SSPC Saudi Arabia Chapter Holds Technical Exchange Meeting

The SSPC Saudi Arabia Chapter, a three-time recipient of SSPC's Outstanding International Chapter Award, conducted one of its monthly technical exchange meetings on April 26 at the Le Méridien Al Khobar Hotel in Al Khobar, Saudi Arabia. The subject of the meeting was, "Recent Development in the Measurement and Assessment of Salt Contamination," and featured guest speaker Craig Woolhouse, business development manager for Elcometer. The meeting was



SSPC Saudi Arabia Chapter Chairman Mana Al-Mansour (left) and guest speaker Craig Woolhouse, business development manager for Elcometer. Photos courtesy of SSPC Saudi Arabia Chapter.



More than 100 attendees participated in the Saudi Arabia Chapter's technical exchange meeting.

ACA Elects Two Officers to Board

Two industry veterans with a combined 70 years of experience have been elected by American coatings manufacturers to serve on the American Coatings Association's board of directors.

The ACA has announced that Charles W. "Charlie" Shaver, chairman and CEO of Axalta Coating Systems, will serve



Charles W. Shaver

as ACA chairman, and Charles E. "Chuck" Bennett, chairman of Randolph Products Inc. and vice chairman of Dixie Chemical Company, will serve as ACA vice chairman and treasurer.

"We're delighted to have Charlie and Chuck as our new officers," said ACA President Andy Doyle. "Both gentlemen are extraordinary and experienced leaders committed to the

growth and well-being of the paint and coatings industry."

Shaver has spent over 35 years in the global petrochemical, oil and gas industry. He began his career with the Dow Chemical Company, serving in a series of operational, engineering and business positions from 1980 to 1996. Shaver moved on to hold various leadership roles with General Chemical and Arch Chemicals. Prior to leading Axalta, he was CEO and president of the TPC Group from 2004 to 2011.

Bennett's career in the industry began in 1979 with a position at Guardsman Products. He held various positions at Guardsman, and was CEO and president



Charles E. Bennett

upon his departure in 1996, when the company was sold to Lily Industries. At that time, he founded Polymer Products Inc., and two years later, he sold the company and served as Cook Composites and Polymers' CEO until 2008. He was Dixie Chemicals' CEO from 2009 to 2015, and he has been an equity partner involved in various management roles at Randolph Products since 2001.

Both Shaver and Bennett will serve two-year terms on ACA's Board, ending in April 2018. For more information, visit the ACA's official website, paint.org.

followed by a dinner sponsored by Elcometer and PAMATEC.

More than 100 participants attended the meeting, and the presentation was well-received and generated a lengthy and interesting discussions afterwards, according to Mana H. Al-Mansour, engineering specialist for Saudi Aramco and chapter chairman.

For more information on the Saudi Arabia Chapter and other SSPC Chapter activities, visit sspc.org/chapters.

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Whiskey Glasses Stir Coatings Research (April 4)

Inspired by a set of photographs showing whiskey residue left behind in glasses, a team of Princeton University surface engineers began studying whiskey evaporation to find the secret to improving uniformity in films and coatings. Specifically, the team measured the fluid motion within evaporating droplets of the liquor.

The engineers found that a combination of molecules — surfactants and polymers — help route the deposition process in whiskey, resulting in a spatially uniform deposition, according to a synopsis of the research.

Many solutions produce uneven stains when they dry on a surface, called the “coffee-ring effect,” because edges of the drops evaporate at a faster pace than those at the center. Previously, researchers discovered that mixing solvents, such as water and alcohol, reduces the coffee-ring effect but only for submillimeter drops. Large drops of whiskey, however, appear to produce uniform stains, as revealed by photographer Ernie Button of Phoenix. His photographs examine residues left behind by whiskey in a clear drinking glass when lit from below with various colors.

Button's images prompted the Princeton team to use fluorescent markers to track the motion of fluid in whiskey drops. They reportedly observed inward flow that partly countered the outward flow from differential evaporation. The team reasoned that the presence of fat-like molecules lowered the surface tension. Additionally, the team found that plant-derived polymers stick to the glass, helping to guide particles to the substrate where they adhere.

To confirm their findings, the researchers showed that whiskey-like liquids lacking either polymers or surfactants did not produce the same uniform stains. As for applications, the team says the research could lead to new coatings or 3-D printing technologies. Results of the study have recently been published in the journal *Physical Review Letters*.

PSN TOP 10 (as of April 30)

1. 45-Ton Beam Falls onto Crew of Four
2. Family Receives \$18M for Bridge Death
3. Lead Paint Complaint Halts Shipyard Job
4. Agreement Reached for Red Sea Bridge
5. Lost Navy Craft Found After 95 Years
6. Firm, Staff Charged in Kolkata Collapse
7. Highway Paint Spill Makes Massive Mess
8. Mexican Chemical Plant Blast Claims 24
9. Workers Win \$3.4M in Race Case
10. AkzoNobel Confronts Challenging Q1

WHAT'S GOT US TALKING

“Associations File Suit Over Silica Rule” (April 7)

A coalition of construction industry associations taking issue with the new Occupational Safety and Health Administration (OSHA) silica rule, made final March 25, are taking their concerns to a federal appeals court. The organizations argue that the federal agency did not fully address their concerns about the rule's impact on the construction industry.

Tony Rangus: “I wonder if this coalition made similar arguments years ago concerning asbestos, benzene, trichloroethylene, etc. In my opinion, the track records of many of the contractors here in the U.S. when it comes to putting employee safety first are dismal. All we hear is that it will cost a ton of money to comply, and they provide cost breakdowns to make their point. As always, in their view it is strictly a cost versus benefit comparison between profits and lives.”

John B: “It's interesting how the U.S. is one of the last countries in the world to do anything about silica sand. Most other countries have totally banned the use of silica sand for sandblasting, even third world countries ... Here, we are only talking about restricting it, not banning it. If our blasters actually knew the facts of what they were dealing with, they would never blast with it.”

M. Halliwell: “Perhaps if there were more companies and individuals being charged (rather than just individuals dying because of the shortcuts and non-compliance), then safety would be less likely to be viewed as a cost of business and one that's looked at by some as more expensive than worker's lives. It's too bad that safety gets lip-service in North America ... that needs to change.”

Kellie Allen: “Sadly, many facility owners live under the microscope of cost control and lack the personnel to police jobsites for this type of compliance. It is often true that OSHA compliance only happens after some poor souls lose their lives. Since disease onset can be decades after exposure, the only recourse the worker will have is some form of workers' comp claim — if the employer remains in business. The best approach is to educate the workers, a difficult task as many of them need their paycheck and will worry about 20 years from now when it happens.”

On Taking Action with Small-Diameter Blisters in Water Tanks

UNDER WHAT CONDITIONS SHOULD SMALL-DIAMETER BLISTERS (<1.5 INCHES) IN A WATER TANK LINING BE REPAIRED/REPAINTED? SHOULD THE BLISTERS BE BROKEN AND THE SUBSTRATE EXAMINED?

Warren Brand

Chicago Coatings Group

Short answer: leave them alone.

Assuming these are osmotic blisters, once equilibrium has been reached across the semipermeable membrane (the coating), osmosis and corrosion beneath the blister should stop. There will most likely be some corrosion directly under the blister; but again, if the

corrosion has stopped, and the corrosion is not a structural issue, they can be left alone. If it makes you feel better, sure, pop a few. Of course, there are many other variables to consider. First, if getting access to the tank is very costly, then remedial action may be prudent. But if you can inspect the tank easily and readily, then the blisters should be left alone.

Jim Johnson

CHLOR*RID International, Inc.

It would be usual to break a few of the blisters just to see and determine what is going on at the actual substrate. Assuming the blisters are caused by salt contamination, corrosion will be ongoing until the salts are removed. If the surface is not decontaminated and a new coating is applied, it will simply

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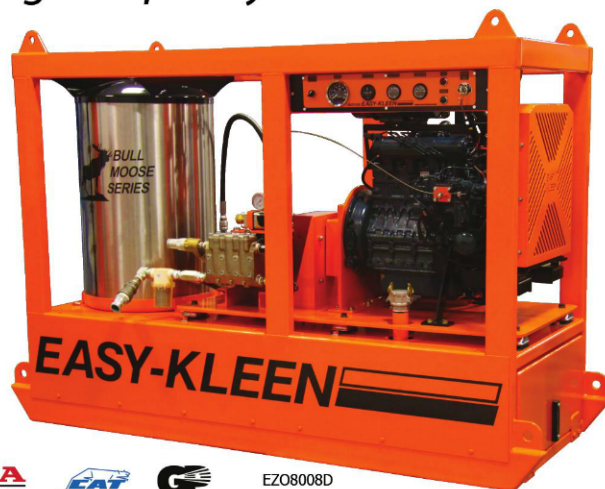
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blister again, and corrosion will continue. Determining when to repair or re-coat the surface requires far more information than is provided here.

B. Brown

Another source of blistering in a water tank could be a lining subjected to cathodic protection (CP) over-protection potential. CP is sometimes installed in municipal water storage. The problem is that the systems are rarely maintained, something that was not mentioned or defined in the question. Most coating manufacturers recommend a maximum potential of about -1 volt with reference to a copper/copper sulfate reference cell. When CP is the cause, the water inside the blister will be of high pH. One common cause is movement of the anodes where the anode ends up positioned too close to the coated surface. With rectified CP systems, failure of the CP controls is another common cause. With galvanic anode-applied CP, a magnesium anode placed too close to the surface to be protected can produce a potential more negative than -1 volt. Leaving the blisters alone is good advice if they are unbroken because the blister will be oxygen-deficient, and it is not uncommon to find the water inside clear and the substrate undamaged. You see, an oxygen molecule (O_2) is about half the size of a water molecule (H_2O). I tend to agree with both answers. Leave them alone but check one or two to figure out what's going on. If the substrate is black, contaminants may be present and careful collection of water inside the blister may give you the answer. Does water wick away from portions of the surface? Oil may be present. Examining the surface with a short wavelength black light (450 nm, to look for surface fluorescence) is not a foolproof check for oil contamination but is a positive indication if it does glow.



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Mark Lewis

East Bay Municipal Utility District

Another driver in this situation is whether or not the lining is under warranty.

Lydia Frenzel

Advisory Council

When I saw B. Brown's statement, "an oxygen molecule is about half the size of a water molecule," I thought that something was wrong. I did a little research. The molecular volume of an O₂ molecule is 1.56 times the molecular


volume of an H₂O water molecule.

Another site verified this; the oxygen molecular volume is 270 (cubic bohr)/mole; the water molecular volume is 159 (cubic bohr)/mole. Water migrates through a coating "easier" or "faster" than oxygen. As with B. Brown, I agree with both prior answers.

Peter Bock

Energy Designs Houston

Warren Brand, B. Brown and Ms. Lydia have technically correct answers, but they are looking at the question from a failure analysis point of view rather than a real-life operating point of view. They may be missing the forest while looking at the blisters on the trees. Taking a large tank in a refinery or chemical plant out of service, cleaning it and making it safe for entry is a million-dollar-plus project and is typically done on a seven- to ten-year cycle. If you remove a few blisters (as Warren suggests) and find any corrosion product or any steel loss on such a large tank, the cost of relining will probably be less than the potential cost of replacing steel seven years later (or a leak before then) if you did not properly identify and mitigate the root cause of the blisters. Right now, the tank is already out of service and clean, so a large part of the relining project cost (time and money) has been paid. Well-managed refineries where I have worked in the past actually had the in-house lining contractor on stand-by, so that after the owner's rep, the third-party inspector and the lining supplier's rep inspected a tank lining and found it lacking, the contractor could immediately jump in and start the relining project.



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HOW TO

KNOW THAT PAINT HAS DRIED

By Charles S. Brown, Greenman-Pedersen, Inc.

Painting a bridge or an industrial structure is an expensive operation. Now more than ever, state DOTs and facility owners are specifying warranties and application methods to ensure the longest possible life for their coatings. Determining what factors affect paint

cure can help to achieve the optimum performance and provide the owner and contractor with fewer headaches down the road. As always, for any coating to be successful, a good specification, quality contractor, proper equipment and of course an effective inspection program are all necessary components.

Once paint is applied we need to wait a specified period of time to let the paint pass from a liquid state to a solid state. This is commonly known as drying time.

Contractors, coating inspectors and owners speak of drying, hardening and curing of a coating, but it is important to clarify each of these coating states as they mean different things and occur at different times in the process.

Drying to the Touch for Solvent- and Water-Based Coatings

The paint-drying process corresponds to the evaporation of all solvents and diluents added to the paint in order to make it a liquid. Paint "dry" happens when the solvents evaporate from the coating, leaving the paint feeling dry to the touch even though it is not 100-percent cured. Drying time is sensitive to temperature and humidity. For most coatings, to be "dry to the touch" is not a sufficient state over which to apply another coat. Product data sheets must be consulted to ensure proper application.

Hardening (Dry to Recoat)

The hardening of a coating corresponds to the process by which the main polymer of the coating hardens with all the other pigments and additives that make up the paint, creating a solid and adherent coating. Hardening does not necessarily mean curing. Hardening is, however, most often the state at which recoat is acceptable.

Cure (Complete Cure)

The paint-curing process corresponds to both the drying and the hardening processes. For example, a coating can

be dry to the touch 30 minutes after application but not hardened enough to recoat until two hours after application. And still, the coating may not be finished curing until seven days after application.

Considering these definitions, it is important to understand that when using a two-component coating such as an epoxy polyamide or a polyurethane, and a hardener is not added, one can observe over time that the paint feels dry to the touch, meaning no smudges result, but has not hardened, still allowing easy removal of the applied coating. We can say then that the paint has dried (the solvent has evaporated), but it has not hardened, due to hardener not being added, and hence the paint has not cured.

Other issues that might cause drying or curing problems of a coating are:

- Problems with the coating material sent from the manufacturer.
- Use of the wrong thinner or contaminated thinner.
- Moisture in some generic thinners compromising paint cure.
- Coating film thickness.
- Problems related to the type of surface to which the coating is applied, for example, wood absorbs paint whereas paint lays on top of steel.
- Temperature considerations when mixing or storing coatings.
- Ambient conditions present during dry and cure times.

How to Check if Your Paint is Dry

To check if your paint is dry, touch an inconspicuous area with your finger. If the paint is not tacky and feels dry to the touch, it is dry, but as stated earlier, it is not necessarily cured.

How to Check if Your Paint is Cured

To check if your paint is cured, use the fingernail test. In an inconspicuous area, press your fingernail into the coating. If it leaves an indent, your paint is not fully cured. If no indent is visible and the surface is hard, your paint has most likely cured.

The most critical aspect of applying any coating is the review, understanding and familiarity of the information presented on the paint manufacturer's product data sheet prior to application. The product data sheet provides all the necessary information regarding surface preparation, application conditions, application equipment, mixing instructions, application procedures, spreading rate, drying schedule, clean up, performance tips and safety precautions.

The principal conditions that have the greatest effect on the cure of a coating are temperature and humidity.

Temperature

Air temperature and steel (surface) temperature affect solvent evaporation, brushing and spraying properties, drying and curing times and the pot life of two-pack and three-pack materials. If heating is required, this should be accomplished by indirect methods only.

Humidity

Paint should not be applied when there is condensation present on the steel surface or the relative humidity of the atmosphere is such that it will affect the application or drying of the coating. Regular practice involves measuring the steel temperature with a contact thermometer to ensure that it is maintained at at least 5 degrees (F) above the dew point.

Following are some conditions that can occur if a coating is not properly dried or cured.

Blushing (Amine Sweating)

If cured during cool ambient temperature conditions, dropping temperatures or high humidity, amine-cured epoxy resin coatings can develop a surface oiliness or exudates, commonly referred to as "amine blush" or "sweating." This is caused by the absorption of carbon dioxide and water into the coating film and its reaction with the amine curing agent. Some of the resulting problems can be surface tackiness or greasiness, incomplete cure, poor adhesion, poor adhesion on overcoating, coating discoloration over time and poor gloss retention.

Cratering

Cratering is the formation of small bowl-shaped depressions in the coating caused by air trapped in the film. The air forms a bubble that bursts, leaving a crater. Cratering is common in coatings that are roller- or brush-applied, often by an inexperienced applicator. Improper mixing procedures can also trap air in the coating causing cratering.

Orange Peel

Orange peel is the term for uneven film formation (with hills and valleys) that results in an appearance resembling the skin of an orange. This defect can be caused by improper application techniques where the spray gun is too close to the surface or the air pressure is too low to ensure proper atomization. Hot air temperatures may also cause this defect because paint droplets dry before they can flow out and fully level evenly together.

Wrinkling

This defect is the presence of a group of small furrows or ridges in the surface layer of paint, found mostly in alkyds and other oil-curing coatings. It is caused primarily by the action of solvents or reducers in the previous layers, which

either react with the substrate or are trapped and then try to escape to the surface, lifting and swelling the last layer of paint. A surface skin forms that prevents the underlying binder from curing any further. When the skin surface contracts, the film wrinkles.



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Blistering

Blistering can occur when there is a remainder of air, solvent or other contamination between the topcoat and the previous layers of paint causing the paint to lift and swell, thereby forming blisters. The primary difference between blisters and other types of defects is the characteristic circular shape and the absence of a puncture in the finish paint.

Thinning

Most coatings are made for application without the need to add thinner. However, when trying to apply coatings in lower temperatures it may be necessary to add thinner to reduce viscosity for an effective application. Adding thinner may cause the coating to take longer to cure or cause it to curdle. Always add the type and amount of thinner recommended by the paint manufacturer and remember to blend multi-component paints together thoroughly first before adding thinner.

About the Author

Charles Brown has over 25 years of experience in the coatings industry performing safety audits, air monitoring, paint inspections and teaching safety courses for contractors, state agencies and the federal government. He was the operations manager for an industrial painting contractor for over 14 years, taught courses nationally for SSPC and is past SSPC Chairman for the Painting Contractors Certification Program Advisory Committee. Brown is a NACE-certified Coating Inspector and an SSPC-certified Protective



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A HAIRY SITUATION: COATING FAILURE IN A 10,000-GALLON SHAMPOO TANK

Fig. 1: Opening one of the hatch doors provided the "smoking gun" as to the cause of the failure. Had the inspector been wearing gloves while opening the hatch, the mode of failure might still remain a mystery.

All figures are courtesy of the author and are representative of the coating failure described in this article.

**BY WARREN BRAND
CHICAGO CORROSION GROUP, LLC**

The phone rang at 3:30 in the morning while the inspector vacationed in Galena, Illinois, an angelic hideaway a few minutes east of the Mississippi, and former home to General Ulysses S. Grant. It was Christmas break and the temperature was -14 degrees F.

The voice on the other end of the line was panicked. "The coating is coming off into the shampoo. They're threatening to sue. They're talking about charging us for the bad batch of material and they need answers right away."

The amount of money resting on the next 12 hours was substantial. The entire batch, roughly 8,500 gallons of contaminated shampoo, now needed to be disposed of as hazardous waste. The contractor had mobilized crews to conduct repairs,

over Christmas break mind you, and the client was at risk of losing his lucrative toll contract if they could not meet demand. The owner insisted on a prompt response as the plant was in the process of a turnaround and these two tanks were the only ones operational.

The owner and the contractor both denied accountability, but time was of the essence and they agreed to abide by the conclusion of the inspector.

BACKGROUND

These were two, identical, 10,000-gallon-vertical process tanks referred to as Tank 1 and Tank 2. Each measured 10 feet in diameter, were 20 feet tall and made of carbon steel. They

were located inside a small toll manufacturing facility, had stainless steel agitators in the center and mixing carbon-steel baffles welded to the tank walls.

The contractor explained that part of the toll contract with the owner required that these tanks be lined in order to ensure the purity of the shampoo, as the client was concerned that rust could contaminate or discolor the product. Color was a critical issue to the brand.

The tanks were originally bare carbon steel, uninsulated (as they are inside the plant) and were used for other, proprietary processes in the past — but nothing that would reportedly cause unusual contamination of the steel.

Prior to being lined, the tanks were steam-cleaned, surface contaminant analysis-tested (SCAT) and were identified to have a chloride concentration of below 8 micrograms per-square-centimeter, which was acceptable according to the coating manufacturer.

The coating selected was a 100-percent-solids epoxy novolac that was to be applied at between 30-and-40 mils in one coat. The blast profile was to be 3-to-4 mils and SSPC-SP 5/NACE No. 1, "White Metal Blast Cleaned."

After the coating was installed, it was holiday tested as per ASTM D5162, "Standard Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coating on Metallic Substrates," thickness tested as per SSPC-PA 2, "Procedure for Determining Conformance to Dry Coating Thickness Requirements" and then hardness tested.

FAILURE ANALYSIS ON DEMAND

The failure analysis would need to be completed on the spot. As the inspector began the drive in the pre-dawn hours, information poured in over his cell phone.

It was reported that during routine testing of the shampoo, small filters, roughly the size, shape and functionality of coffee filters, identified particulates

of unknown origin. They were somewhat larger than talcum powder, but smaller than grains of salt. And they were green, which was, coincidentally, the color of the shampoo and the color of the coating which had been installed some six months earlier. The on-site lab concluded that the granules were organic in nature and most likely coming from the coating.

At first, the thought was that the coating was being worn away by the abrasive characteristics of one of the shampoo ingredients, which was a type of silicate. This would explain the fine particles found in the filters. The contractor, however, said that he had accounted for the abrasion when choosing the coating system and felt this was an unlikely mode of failure.

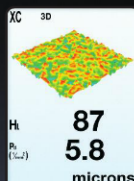
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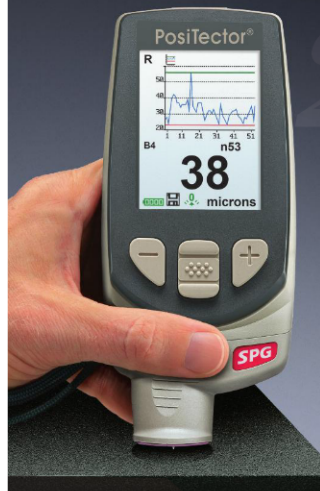


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Fig. 2: A view looking up from a 24-inch manhole in a similar tank, exhibiting side baffles and a center mixer. The coating on the side baffle near the top of the tank had softened and showed signs of wear.

His doubts were confirmed when an engineer at the facility opened up the tank top to look at the shampoo and coating and found that everything looked normal, until he went to close the lid to the top access plate and noticed green residue on his hand. The engineer then used his fingernail to scrape at the coating, which came off easily, like chalk.

While the tank was being slowly drained, the contractor shared with the inspector details about the materials used in the tank and the processes associated with the production of the shampoo.

The exact chemicals and processes were proprietary, but in broad strokes, the tank contained mostly water, to which was added bleach (at no more than 15-percent-total concentration), trisodium phosphate at less than 3 percent, silicates and other trace amounts of colorant, surfactants and fatty acids. All of the processing, it was reported, was carried out at ambient temperatures and agitation was constant.

The coating installed was apparently suitable for this application and could withstand up to twice the concentration of bleach and all of the other products with no degradation at all.

As the inspector had still not arrived at the facility, the contractor called

him after the tank had been completely emptied. "We got the manhole off and the coating at the bottom of the tank is rock-hard and glossy. But at the top of the tank, you can scrape it off with your fingernail."

It was confirmed that when the bleach is added by hand from the top, it is only added when the tank is being agitated and is added directly into the water (before the material is thickened by the other additives) to ensure that the concentration of bleach is at the correct ratio to the water and never higher than 15 percent.

At this point, three hypotheses could be considered: something was actively attacking the coating system, the coating system was not installed properly or there was a problem with the formulation of the coating constituents which was causing degradation and contamination of the product.

The contractor proposed that the tanks may have been put back into service before the coating system had properly cured. His belief was that the epoxy may not have had adequate time to cure, crosslink and develop sufficient chemical resistance to the bleach, which was the likely culprit of the overall degradation and attack of the coating system.



Fig. 3: It was determined primarily through visual inspection that the coating was overall properly installed and free of holidays. This photo shows an improperly applied 100-percent-solids epoxy system that required touch-up.

The owner assured the contractor that after the lining was installed the tank was not put back into service for over a week, even though it only needed 48 hours to cure, at 70 F. In fact, the work was done during an unusually hot summer and the ambient temperature inside the facility was substantially higher than 70 F.

Through conversation and research, it was determined that Tank 1 had been put back into service about two weeks earlier than Tank 2, seeming to support the contractor's contention that the tanks were put back into service too soon. However, the owner reasserted that Tank 1 was put back into service at least a week after the coating was installed, and even if the tanks were put back into service too soon, it would not explain the linear mode of failure, particularly since the materials in the tanks were under constant agitation.

But what would account for the gradual and systematic degradation of an apparently well-adhered, properly applied coating system up the vertical wall of the tank? To further investigate, the inspector instructed the contractor to scrape the coating as hard as he could with a

flat-head screwdriver in a straight line from the top of the tank to the bottom and call back with the results.

As suspected, the coating was soft at the top and then very gradually became harder and harder until roughly at the 4-foot interior level and below, the coating was rock hard, obtaining a Shore D hardness rating of approximately 78,

which was in line with the material product data sheet.

There have been many cases where coatings have failed in similar manners. Coating failures in the ullage area where vapors have condensed or become concentrated and damaged the coating are not uncommon — while below the liquid level, the coating remained untouched.

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Investigating Failure



Fig. 4: This is a 24-inch manway leading to sound, hard and well-preserved coating. Roughly 4 inches above the tank floor, the coating began to feel soft.


This is a frequent mode of failure when dealing with hydrogen sulfide and biogenic sulfide corrosion in wastewater. The author recalls one case where the coating was pristine below the liquid line and completely peeled above. The opposite can also happen, as in a case where the coating on the bottom of a tank and roughly 4 inches on the straight wall was completely dissolved and gone.

But this was different. In the other cases, the delineation had been clear, but in this case it was gradual.

Upon arrival at the facility the inspector was met by twelve angry men and was escorted to Tank 1. Entering the 24-inch manhole at the base, it was clear that the coating system below the 4-foot mark was glossy and intact. The line the contractor scraped into the coating was also clear and indicated that the coating was soft at the top and became harder farther down.

The wall mixing baffles had been coated and near the top of the tank showed slight wear patterns in the soft coating from mixing.


The inspector read documentation which provided more specifics about the constituents of the liquid in the tank. He read over the documentation and the



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Fig. 5: Holiday testing of a 100-percent-solids epoxy coating ensuring that the coating had covered all surfaces of the steel.

product data sheet of the installed material. On paper, there seemed to be no reason for this failure and certainly no explanation for its cause.

TANK 2: THE CONTROL SAMPLE

Focus was now placed on Tank 2, which had reportedly been working flawlessly. After a thorough question-and-answer

period, it appeared that both tanks operated in exactly the same fashion and in fact, on occasion, a tie-in line between the tanks was opened and the tanks operated as one.

Metal stairs wrapped their way around each tank with a deck at the top. Each tank top had a mixing motor in the center and a large plate that opened to allow for sampling, inspection and addition of ingredients.

The shampoo swirled near the top of the tank, leaving about 2 feet of coating exposed. Upon inspection of Tank 2 the coating looked sound, yet, when scrapped with a fingernail, it too was soft — not as soft as that in Tank 1, but certainly not as designed. The handle on the hatch of Tank 2 was warm to the touch.

If both tanks were to operate at ambient temperatures, why was the handle on the hatch of Tank 2 warm to the touch?

Things became instantly clear. The product data sheet of the coating system clearly indicated that the material was compatible with bleach, and a variety of other chemicals, *at ambient temperatures*. It also stated that post-curing is not necessary for most applications, but the material "...may be post-cured to expedite curing or to increase chemical

resistance." It then provided a post-curing schedule.

The coating system was designed to be compatible with 15-percent bleach at ambient temperature, but as the temperature rose, the bleach began to chemically attack the coating, thus explaining why the coating was still performing properly at the lower portions of the tank, which were actually operating at ambient temperatures.

There is a well-established axiom that for every 10-degree-centigrade change in temperature, the rate of reaction will double, and here was proof.

Evidentially, while the shampoo in the tank was mixed, the agitation was not sufficiently turbulent to distribute the heat, which was used to make the material less viscous to allow for easier pumping.

The contractor provided his documentation, which the owner had signed-off on, clearly indicating that the system was purported to operate at ambient temperatures.

Unfortunately, the coating systems in both Tank 1 and Tank 2 were too badly compromised to be saved by post-curing and therefore, it was decided to completely remove the existing coatings, install exactly the same coating system, and simply post cure, at just six hours at 150 F.

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**BY CHRISTOPHER WOLFGRAM
AND DANIEL J. ZIENTY
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Figures courtesy of the authors unless otherwise noted.

MEETS WATER TOWER

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It is safe to say that water towers have become a predominant location for the placement of cellular telecommunication equipment. Their height and design style make them a natural consideration for what the industry calls macro cell sites. And when one carrier locates cellular telecommunication equipment on a tower, you can be sure that others will soon follow.

Water towers are not just hosting antennas but also associated equipment such as remote radio units (RRUs). This equipment can add thousands of pounds of additional weight, and on many water towers its placement is on the handrail system. Because many handrail system designs were constructed to meet OSHA guidelines limited in purpose to access and changing out light bulbs, there is a need by the carriers and their engineers to “beef them up.”

The question that arises is, at what point has the facility reached its maximum capacity?

One method of providing structural support has been the addition of bracing that is welded to the existing handrail system and to the roof of the tower. However, this method creates heat, which damages the coating system on adjacent areas both on the interior and exterior of the tank. In the following case study, the issue was amplified because the water tower was recently constructed and the coating system was new.

After initially receiving plans that incorporated the bracing method identified above, the carrier's engineer submitted plans that generally provided additional stiffeners to the vertical support posts of the handrails in the form of welded channels. The 3-inch channels would be welded to two sides of the vertical support pipes and to the 3/8-inch-thick base plate already in place. The engineer determined that only a 1/8-inch weld was required at the base plate but the question remained: would a



Fig. 1 (top left): The base material of the test plate used in all testing consisted of a ¼-inch-thick A36 steel plate with a ¼-inch-thick A36 steel reinforcing pad welded in place resulting in a total test plate thickness of a one-half-inch.

Fig. 2 (top right): Prior to beginning the testing, the coating was removed from the reinforcing pad to meet SSPC SP 11 Power Tool Cleaning to Bare Metal.

Fig. 3 (bottom left): Phase One testing involved completing a ½-inch (reinforcing) surface weld to the reinforcing pad in separate passes beginning at 1 inch in length followed by subsequent passes increasing in length by 1 inch each up to 8 inches overall.

Fig. 4 (bottom right): Though the dry heat resistance rating for the polyurethane was exceeded in the final two samples, there was no visual damage to the coating system.

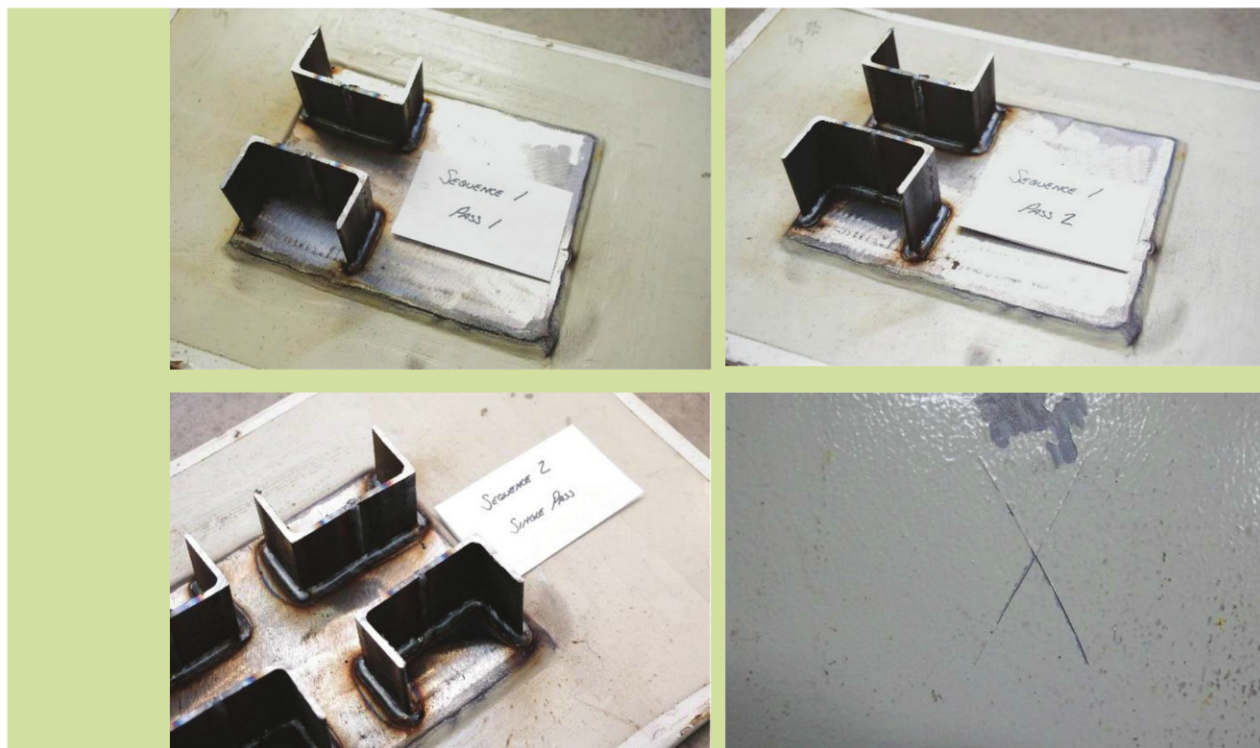
½-inch weld damage the interior coating system?

In order to determine the amount of heat generated during operations to modify water towers to effectively support telecommunications equipment, a two-phase test was conducted to simulate the heat generated through welding and

the subsequent heat absorption by the storage tower's shell/roof plates. Phase One testing was completed utilizing test plate surface welds in 1-inch increments increasing from 1-to-8 inches in length. Phase Two testing utilized channels welded to the test plate surface with pre-selected weld sequences.

TABLE 1: TEST RESULTS FOR PHASE ONE

Weld Length (Inches)	Pre-Weld Base Metal Temp (F)	Weld Face Temp (F)	Back Side Temp (F)	Visual Coating Damage
1	81.5	130.5	118.5	None
2	79.5	198.5	155	None
3	79	238	155	None
4	81	279	191.5	None
5	78.5	301	186.5	None
6	81.5	313	198	None
7	82.5	329	205.5	None
8	82.5	462	219.5	None



The welding was completed using a MIG welding machine and a 0.30-inch diameter, ER70S-6 electrode with a wire feed speed of approximately 350 inches per minute and a 75-percent CO₂/25-percent Ar shielding gas. The voltage was approximately 22 volts and the amperage approximately 180 amps. These parameters were used for all welds in this case study.

The base material of the test plate used in all testing consisted of a 1/4-inch thick A36 steel plate with a 1/4-inch thick A36 steel reinforcing pad welded in place resulting in a total test plate thickness of one-half-inch (Fig. 1). The test plate was prepared to meet SSPC-SP 10/NACE No. 2, "Near White Blast Cleaning," and coated with two coats of a polyamide epoxy with an acrylic polyurethane topcoat. The total coating system thickness was measured at an average of 10.2 mils DFT meeting

SSPC-PA 2 standards. Prior to beginning the testing, the coating was removed from the reinforcing pad to meet SSPC-SP 11, "Power Tool Cleaning to Bare Metal" (Fig. 2).

PHASE ONE TESTING

Phase One testing involved completing a 1/8-inch (reinforcing) surface weld to the reinforcing pad in separate passes beginning at 1 inch in length followed by subsequent passes increasing in length by 1 inch each up to 8 inches overall (Fig. 3). The test plate was heated to approximately 80 F prior to initial welding and permitted to cool to approximately 80 F between weld passes, allowing for a consistent beginning temperature for each test in Phase One. The test plate was elevated during welding operations to eliminate backing and simulate the interior of a tank roof.

Fig. 5 and 6 (top left and right): The first test of Phase Two consisted of dividing the required welding of the channel to the test panel into two separate passes: a back pass along the outer edge of the channel and a front pass along the inner edge of the channel, allowing time for cooling between passes.

Fig. 7 (bottom left): This single, 12-inch pass was reasonably believed to produce enough heat to cause failure of the coating system by exceeding its dry heat resistance.

Fig. 8 (bottom right): A cross-cut adhesion test was completed as per ASTM D3359 and results met a 2A rating (jagged removal along most of incisions up to 3.2 mm [1/8 inch] on either side).

TABLE 2: TEST RESULTS FOR PHASE TWO

Sequence	Pre-Weld Base Metal Temp (F)	Weld Face Temp (F)	Back Side Temp (F)	Visual Coating Damage
Back/Front Pass 1	81	320	236	None
Back/Front Pass 2	83	497	251	None
Full Perimeter	83	885	346	None



Fig. 9: The mechanically enhanced (non-welded) handrail bracing uses stiffening diagonals in lieu of the proposed 3-inch channel supports to provide the required loading capacity for equipment.

Upon completion of each weld test, the temperature was measured using an infrared thermometer to determine the maximum weld temperature. Readings were taken on the weld surface and on the back side of the test plate. Temperature readings were followed by visual examination for coating damage (Table 1, p. 30).

Per the manufacturer's product data sheets, the dry heat resistance for the polyamide epoxy was rated at 250 F and

the dry heat resistance for the acrylic polyurethane was rated at 200 F. Though the dry heat resistance rating for the polyurethane was exceeded in the final two samples, there was no visual damage to the coating system (Fig. 4, p. 30).

PHASE TWO TESTING

Phase Two testing involved completing a $\frac{1}{8}$ -inch fillet weld around the base of a 3-inch channel fabricated from two 1 $\frac{1}{2}$ -by-1 $\frac{1}{2}$ -by- $\frac{1}{8}$ -inch angles, 2 inches in

height and made of A36 steel. This phase simulated the use of proposed handrail post reinforcement as the support structure for telecommunications equipment. Similar to Phase One, the test plate was heated to approximately 80 F prior to initial welding and permitted to cool to approximately 80 F between weld passes. The test plate was also elevated during welding operations to eliminate backing and simulate the interior of a tank roof.

The first test of Phase Two consisted of dividing the required welding of the channel to the test panel into two separate passes: a back pass along the outer edge of the channel and a front pass along the inner edge of the channel, allowing time for cooling between passes (Figs. 5 and 6, p. 31). Based on results from Phase One, the 6-inch weld required to complete a single pass along one side of the channel was believed to pass without exceeding the dry heat resistance for the coating system.

The resulting maximum temperatures of the back side of the test plate in the first test of Phase Two exceeded the dry heat resistance for the acrylic polyurethane in pass one (236 F) and exceeded the dry heat resistance for both the polyamide epoxy and the acrylic polyurethane in pass two (251 F). The increased maximum temperatures reached in the 6-inch-long passes resulted from localizing the heat from a straight line pass on flat steel to a C-shaped pass within the fillet at the junction of the metals. Similar to the results in Phase One, no damage to the coating system was visible.

The second test of Phase Two was completed with the intent to demonstrate failure of the coating system due to exposure to excessive heat. This test consisted of welding the channel to the test panel in one pass around the full perimeter. This single, 12-inch pass was

reasonably believed to produce enough heat to cause failure of the coating system by exceeding its dry heat resistance (Fig. 7, p. 31).

As expected, the resulting maximum temperature of the back side of the test plate exceeded the dry heat resistance for both the polyamide epoxy and the acrylic polyurethane reaching a maximum of 346 F. Unexpectedly, however, no visual damage to the coating was observed.

RESULTS

Phase One testing was executed to identify a baseline for temperatures occurring in field use of 1/8-inch reinforcing surface welds. Prior to this testing, sufficient data was not available to determine, and thereby prevent, damage to the water storage tank interior wet surface.

Phase Two testing was designed to create a field-use situation as proposed by a telecommunication carrier's engineer where the fabrication of multiple pieces was anticipated to create areas of increased heat due to larger surface area and constricted areas such as the corners of a fillet weld. This was substantiated through the data collected. The use of intermittent welds similar to the sequencing phase, and timing to allow for cooling, reduced heat exposure, and in this circumstance, allowed for welding to be completed without exceeding the coating manufacturer's specified dry heat resistance recommendations.

Though no visible coating damage was noted, the coating system was checked for brittleness post-welding where temperatures did exceed the manufacturer's specified dry heat resistance recommendations for two back-to-front passes followed by the full perimeter as shown in Table 2. Gently tapping on the coating, however, revealed evidence that damage

had indeed been done to the coating system, resulting in a loss of adhesion to the substrate and hardening of the coating system to the point of becoming very brittle. A cross-cut adhesion test was completed as per ASTM D3359 and results met a 2A rating (jagged removal along most of incisions up to 3.2 mm [1/8 inch] on either side) (Fig. 8, p. 31). Instrumentation to complete a pull-off adhesion test was not available.

Excessive heat will damage coating systems. However, due to the results of this test, the use of sequencing may minimize or even eliminate the damage if properly monitored with incorporation of a predetermined proper weld sequence followed by the welder.

CONCLUSION

The conducted test and observations show that based on a 1/8-inch weld employed on a 1/4-inch steel plate with a 1/4-inch reinforcing pad similar to typical water storage tank roof construction, a developed sequencing and temperature-monitoring process allows for the installation of appurtenances without damaging the water storage tank interior coating system.

CASE FOLLOW-UP

For this particular water storage tank, the telecommunication carrier's engineer revised the handrail plan to include the use of stiffening diagonals in lieu of the proposed 3-inch channel supports to provide the required loading capacity for equipment (Fig. 9). This revision in design omitted the need for welding to the water storage tank roof to prevent damage to the interior wet coating system.

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of others including NACE Coating Inspector – Level 3 and AWS Welding Inspector certifications. Wolfgram has been a member of SSPC for over 10 years and is

the current vice-chair of the North Central Region Chapter. He was featured in the August 2015 *JPCL* bonus issue, *Coatings Professionals: The Next Generation*.

Dan Zienty is a principal at Short Elliott Hendrickson Inc. and has been a manager for protective coatings related projects there for more than 20 years. He has



a Bachelor's degree in construction technology from Purdue University, is an SSPC Protective Coatings Specialist and a NACE-certified Coating Inspector. Zienty

has received numerous Engineering Excellence Awards from the Consulting Engineers Council of Minnesota for his work on water tower restorations and has authored and presented related articles on protective coatings maintenance. He is an active member of SSPC and was recently appointed to the AWWA D102 Subcommittee for Steel Elevated Tanks, Standpipes/Reservoirs. *JPCL*

BY KENNETH A. TRIMBER, KTA-TATOR, INC.

High-strength bolts have been used to assemble steel structures for over 60 years, supported by research conducted by the Research Council on Riveted and Bolted Structural Joints (RCRBSJ). RCRBSJ was founded in 1947 but is now known as the Research Council on Structural Connections (RCSC). Despite the long history of use, there is still confusion when it comes to painting faying surfaces, bolt holes and fasteners. This article will attempt to clear up some of the confusion and provide items to consider when designing and painting bolted connections.

TESTING OF COATINGS FOR SLIP-CRITICAL JOINTS

Before discussing the interpretation of test results for coatings used in slip-critical joints, it is helpful to understand the testing procedures. Testing and certification of the coatings is addressed in RCSC's "Specification for Structural Joints Using High-Strength Bolts." The revision in effect at the time of this writing is August 1, 2014 (with April 2015 errata), although proposed changes are currently under discussion. Certification requires that criteria be met for both slip coefficient testing and tension creep testing, as outlined in Appendix A of the specification.

The specimens must first pass the slip coefficient testing before being subjected to tension creep. A minimum slip coefficient of 0.30 is required for Class A certification and a minimum slip coefficient of 0.50 is required for Class B certification. Although not discussed in this article, there is also a Class C certification, which requires a minimum slip coefficient of 0.35. Class C is for roughened hot-dip galvanized surfaces.

COEFFICIENT OF FRICTION (COF) TESTING

The slip coefficient test is used to determine the mean slip coefficient of a coating under short-term static loading. The test plates for slip coefficient testing are fabricated from $\frac{5}{8}$ -inch-thick, flat carbon steel (no raised edges, protruding defects or warp) with a minimum yield strength of between 36-and-50 ksi. The plates measure $\frac{5}{8}$ -inches-by-4-inches-by-4 inches with a 1-inch hole drilled 1 $\frac{1}{2}$ -inches from one edge and one of the sides ($\frac{5}{8}$ -inches-by-4 inches) is machined smooth. While the specification does not explicitly indicate whether hot-rolled or cold-rolled steel is to be used, the surfaces must be as flat as possible. The surfaces of cold-rolled steel are typically flatter than those of hot-rolled steel and offer greater planarity, so cold-rolled steel is typically used.

The plates are abrasive blast-cleaned and coated with the material being evaluated — for example, inorganic zinc, organic zinc or thermal spray coatings (TSC). The standard requires the test coating to be applied to both sides of each plate at a thickness 2

Painting Bolted Bridge Connections

Figures courtesy of the author.

mils greater than the maximum that will be applied to the structure (typically 2 mils greater than the manufacturer's recommended maximum thickness), but the thickness reported on the certification does not include the extra 2 mils.

Each test specimen is composed of three coated plates.

Figure 1 shows two of the plates used for slip coefficient testing.

The mean slip coefficient of the coating is determined by testing five replicate specimens (three test plates per specimen). The test setup has two major loading components, one to apply a clamping force to the specimen plates and another to apply a compressive load to the center plate so that the load is transferred across the faying surfaces by friction (Fig. 2). A threaded rod is inserted through the holes of the three plates, rather than a bolt. A nut on the end of the rod secures the plates and a clamping force is applied and maintained throughout the test using a hydraulic cylinder at 49 ± 0.5 kips to represent the minimum clamping force of an A490 bolt. A vertical load is subsequently applied to the center plate at a rate not exceeding 25 kips/min until slip occurs between the plates. Testing of each replicate specimen requires approximately seven minutes to complete.

TENSION CREEP TESTING

Tension creep is the tendency of a coating to undergo deformation under sustained service loading and includes the effect of a loss in clamping force due to significant compression or creep deformation of the coating. The test plates for tension creep are composed of $\frac{5}{8}$ -inch-thick, flat carbon steel (again with no raised edges, protruding defects or warp) measuring 4-by-7 inches with two 1-inch holes drilled 1 $\frac{1}{2}$ inches from each end. Surface preparation and application of the test materials is identical to the plates prepared for slip coefficient testing. Each test specimen consists of three plates with the test coating applied to the top halves. Figure 3 (p. 36) shows two of the plates used for tension creep testing.

Three replicate specimens (of three plates each) are linked together in a single chain-like arrangement (Figs. 4 and 5, p. 38). The

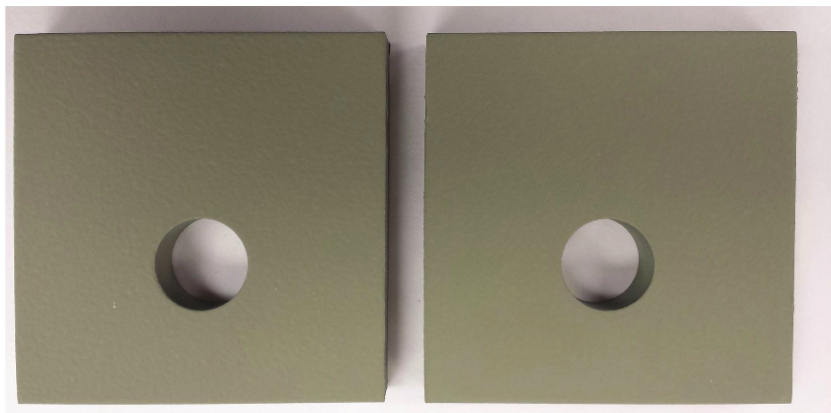


Fig. 1: Test plates for slip coefficient testing with test coating already applied.

clamping force is achieved by connecting the painted portions of the plates with $\frac{7}{8}$ -inch diameter A490 bolts that are secured with corresponding nuts. The unpainted portions are only connected using loose pin bolts and are not part of the test. A load is applied to the chain in tension and held for 1,000 hours (approximately 42 days). At the end of 1,000 hours, the tension is increased over the course of a few minutes to a final load. Both the locked tension for 1,000 hours and the final tension to be placed on the specimens are derived from a formula that is based on the slip coefficient classification of the samples and the average clamping force. While the actual clamping force depends on the bolt type or installation method, for Class B it is a minimum of 32.7 kips for the locked tension and a minimum of 49 kips for the final tension. Because bolts are used to secure the samples, the results could be impacted if there is significant compression of any material—for example, the paint, TSC or galvanizing on the faying surfaces or beneath the bolt head or washer/nut and the steel plates, which could affect the clamping force.

INTERPRETATION OF SLIP COEFFICIENT AND TENSION CREEP RESULTS

According to the RCSC specification, the mean slip coefficient of coatings can be categorized as Class A or B, and as indicated previously, a Class A slip coefficient

rating is a minimum of 0.30 and Class B is a minimum of 0.50.

Bare abrasive blast-cleaned steel and most inorganic zinc primers meet Class B. Some organic zinc primers meet Class B, but others only meet Class A. Clean mill scale meets Class A. For TSC, an FHWA study (Slip and Creep of Thermal Spray Coatings, Publication No. FHWA-HRT-14-083) tested both sealed and unsealed 100-percent zinc and 85/15 (zinc/aluminum). The slip coefficient of both unsealed systems was > 0.75 , easily exceeding the Class B requirement. The slip coefficient for the sealed systems was 0.414 for 100-percent zinc and 0.439 for 85/15, which only meet the Class A requirement. For tension creep, both of the unsealed

systems met the Class B criteria. When sealed, both systems failed, even though the tension creep parameters were based on the less rigorous Class A requirements. When used in joints, TSC should not be sealed.

There are a few factors to be cautious of when applying the slip coefficient and tension creep test results to shop and field work.

Recognize that the tests are performed with the same material on the mating faces. For example, the same Brand X primer is applied to all faces of the test plates and the certification is then issued for the specific product that was tested. Though applying Brand X inorganic zinc to one face of a joint and Brand Y inorganic zinc to the other face may perform, the certification does not address the use of two different brands in a single joint unless it is specifically tested that way. Likewise, the certification does not address the use of Brand X inorganic zinc on one face and Brand Z organic zinc on the other, even if both products are produced by the same manufacturer, unless it is specifically tested that way.

The minimum primer curing time used during the qualifying tests before assembling the joints must be strictly adhered to; otherwise, the uncured paint in the joint could behave as a lubricant. The RCSC



Fig. 2: Slip coefficient test apparatus with testing underway. A vertical load is applied to the center of the three plates to induce slip.

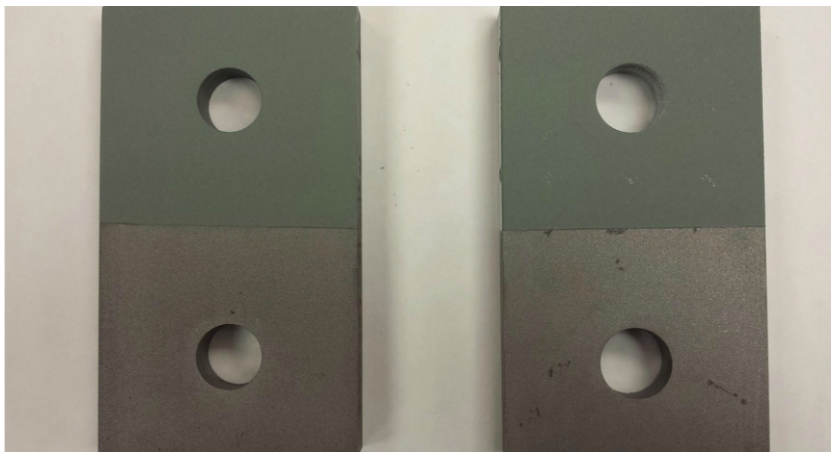


Fig. 3: Test plates for tension creep testing with the test coating applied to the top halves. The blast-cleaned and uncoated bottom halves are for assembling the plates into a chain. The uncoated portions are only connected using loose pin bolts and are not part of the test.

specification states that research indicated "that all curing effectively ceased at the time the joint was assembled and paint that was not fully cured at that time acted as a lubricant. The slip resistance of a joint that was assembled after a time less than the curing time used in the qualifying tests was severely reduced. Thus, the curing time prior to mating the faying surfaces is an essential parameter to be specified and controlled during construction." The qualification tests establish the minimum time required to achieve adequate curing of the product so that the slip resistance is not

impacted.

The maximum thickness and thinner type shown on the certification must not be violated for the certification to be valid. This is why the thickness of the primer specified for connections is often different (lower) than the thickness specified for the rest of the steel.

The test plates are typically coated with the same material at the same thickness on the backsides (beneath the bolt, washer and nut) and the faying surfaces. That is, if a single coat of inorganic zinc primer is applied to the faying surfaces at 7 mils,

the same inorganic zinc primer is applied to the backside of the plates at 7 mils. The presence of paint on the backsides of the specimens has no effect on the slip coefficient test results since the clamping force is maintained continuously throughout the test. However, paint on the backsides of the samples for the tension creep test could influence the results because the clamping force is accomplished using $\frac{7}{8}$ -inch A490 bolts, and a loss of clamping force could result from compression of the coating (Fig. 6, p. 40).

Since the primer is applied to the backsides as part of the normal test protocol, any compression of the coating is incorporated into the test results. However, the effect on bolt pretension of any additional coats applied to the backsides of the plates is not incorporated into the normal test regimen. Accordingly, for a given project, if a decision is made to paint the backsides of the splice plates with the full coating system rather than just the primer, the effect of the full paint system on the tension creep performance is not clearly addressed by the certification. It should be noted, however, that professionals closely involved with the RCSC specification have indicated that specimens with 10 mils of coating on the backsides of the plates had been successfully tested in the past;



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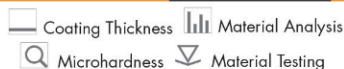


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and therefore, it was assumed that up to 15 mils of combined coating thickness/ galvanizing thickness (in the case of galvanized fasteners) would not likely affect the results. While this assumption may be valid, because many different coating types and brands are used in the field, it is the author's opinion that if multiple coats will be applied to the backside of splice plates prior to bolting, consideration should be given to testing the system, at least in those cases where a Class B certification is required.

PAINTING OF BOLT HOLES

Painting of bolt holes does not affect the life of the steel because once the bolts and plates are in place, the weather is sealed out, preventing corrosion. When bolt holes are specified to be painted, it is typically done to prevent the formation of rust stain from the holes between the time of painting and assembly.

A good source of information regarding the painting of bolt holes is found in AASHTO/NSBA "Steel Bridge Collaboration S 8.1-2014," which is also published as SSPC-PA Guide 13, "Guide Specification for Application of Coating Systems with Zinc-Rich Primers to Steel Bridges."

SSPC-PA Guide 13 states the following in paragraph 3.4:

"Miscellaneous Surfaces to be painted and the coating system to be used shall be as indicated on plans and/or contract documents. Unless otherwise noted, paint is not required on flange surfaces that will be embedded in concrete, or inside bolt holes, although overspray is permitted on flange surfaces and inside bolt holes."

Another document, SSPC-PA 1, "Shop, Field, and Maintenance Painting of Steel," has been revised and is undergoing final review. While the following has not been officially approved by SSPC at the time of this writing, it establishes the position of the committee responsible for drafting the revisions. Note the last sentence.

"7.8.1 Contact surfaces of members to be joined by high strength bolts in a friction connection (faying surfaces) shall provide the required slip coefficient based on

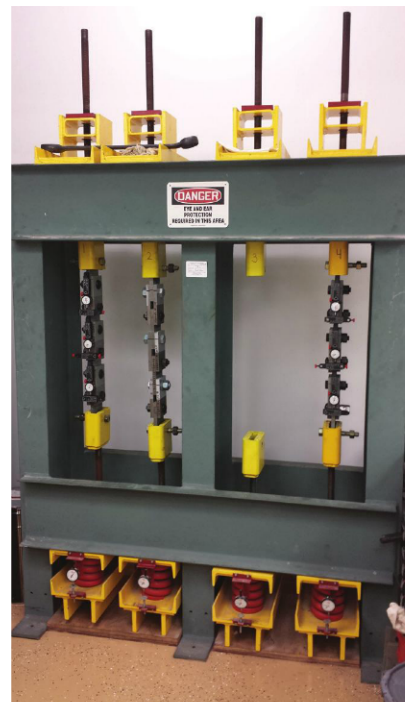


Fig. 4: Tension creep testing apparatus with three test chains in place.



Fig. 5: Close up of a single tension creep chain. The plates are installed with coated surfaces in contact with coated surfaces and bare surfaces in contact with bare surfaces.

the specified class of slip resistance based on the design criteria. Uncoated faying surfaces shall meet the surface preparation and cleanliness requirements for the specified class and shall be free of oil and grease. If coated faying surfaces are required or permitted, the coating used shall be tested and certified to the required class (see Note 15.13) and shall not exceed the thickness tested. The application to, or removal of, coating from bolt hole interiors is not required unless specified in procurement documents, although overspray coating is frequently present."

It is common to see holes only incidentally coated with overspray, rather than purposely painted (Fig. 7).

CLEANING AND PAINTING OF FASTENERS

A number of fastener types are used in bolted connections, but the following discussion is limited to black bolts and



Fig. 6: Samples are assembled for tension creep to determine the effect of the full coating system applied to the backside. Note the visible compression of the coating after pretensioning the bolt.

galvanized bolts (hot dip galvanized and mechanically galvanized). SSPC-PA Guide 13 also addresses the painting of fasteners in Sections 5.4 and 5.5.

Black Bolts

According to SSPC-PA Guide 13, when black bolts are installed prior to cleaning

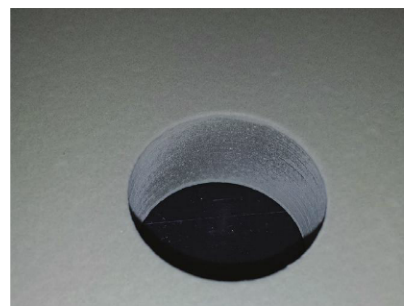


Fig. 7: Interior of a bolt hole coated only with overspray.

and painting, the fasteners are blast-cleaned together with the steel to achieve the specified surface cleanliness and profile and primed with the same inorganic or organic zinc specified for the structure. (Note that this Guide is specifically for the use of zinc primers. If a non-zinc primer is being applied to the structure, the same primer would be applied to the fasteners.)

When black bolts are installed after painting has been completed, the Guide recommends that the fasteners be blast-cleaned prior to painting. While blast-cleaning the bolts installed after painting results in an excellent surface for the application of the coatings, there are significant drawbacks to this approach during implementation. In order to properly prepare the fasteners, the blast nozzle must be held at many different angles to the surface and pointed in many directions. The result is the potential for extensive overblast damage to sound, intact coating located in proximity to the fasteners.

If the shop coating involves zinc primer without the intermediate and finish coats, the entire area within the potential damage zone should receive an additional coat of primer. Note that "potential damage zone" is used because the specific pinpoints of damage will not always be readily apparent. If the shop primer is inorganic zinc, then organic zinc (rather than inorganic) should be applied to the damaged area. If the primer is organic zinc, organic zinc would typically be reapplied. In the case of the organic zinc,



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Fig. 8: The initial appearance of the lubricant/dye (center) and the appearance after cleaning for a project-specific cleaning evaluation.

the specification or manufacturer's recommendations will likely require SSPC-SP 7/ NACE No. 4, "Brush-Off Blast Cleaning" of the entire area of potential damage to prepare the primer to receive another coat.

If the shop coating involves a primer and epoxy intermediate coat, the intermediate coat specified for touching up the structure should be applied to the potential damage zone. Preparation of the

intermediate coat in the damaged area should be the same as is required by the specification for preparing the intermediate coat to receive the field finish. If the damage exposes the substrate, the primer should be spot-applied to those locations before application of the intermediate coat.

If all coats have been shop-applied, the extent of the damage must be assessed to determine whether the finish coat alone is adequate, or if spot application of primer and intermediate coat is required. When applying the finish, it is likely that the existing finish will need to be brush-blasted first to achieve good adhesion. It should also be recognized that the areas repaired with the new finish will be readily visible so it is important to square up the application, but if a patchwork appearance is not acceptable the finish will have to be applied to logical break points.

In order to avoid the need to blast-clean the bolts after assembly and deal with the repairs, when feasible, specifiers use galvanized bolts or treated bolts (with proprietary inorganic coatings, for example) that can be field painted after solvent cleaning and/or pressure washing and limited hand/power tool cleaning.

Galvanized Bolts

SSPC-PA Guide 13 recommends that galvanized bolts be cleaned by SSPC-SP 1, "Solvent Cleaning," SSPC-SP 2, "Hand Tool Cleaning," SSPC-SP 3, "Power Tool Cleaning," and/or SSPC-SP 12 (Waterjetting). Since the publication of SSPC-PA Guide 13, SSPC-SP 12 has been replaced by four individual waterjetting standards, SSPC-SP WJ-1 through WJ-4.

The Guide also addresses the removal of lubricant wax/dye applied to the nuts, indicating that it can be accomplished



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using an alkaline household cleaner such as ammonia with care to make certain that residue from the cleaner is also totally removed. One area of controversy regarding the cleaning of lubricant is whether or not all dye has to be removed. Section 5.4.4 of the Guide requires the removal of "excessive dye," and in commentary notes to 5.4.4 it states that, "Any dye coloring

remaining on galvanized nuts after weathering or the required surface preparation is not believed to be detrimental to subsequent coating performance or appearance. A white cloth wipe test with no color transfer can be used to confirm that all lubricant and nonabsorbed dye has been removed, leaving only the residual 'stain' on the surface."


While the Guide indicates that residual staining on the nuts should not be a problem, standards are not available to describe or depict the amount of staining that is acceptable so decisions must be made on a project-specific basis. Figure 8 (p. 41) shows the results of a project-specific examination of cleaning methods. The initial appearance of lubricant/dye and the stains remaining after cleaning are shown. For this project, MEK was found to be a more effective cleaning agent than ammonia. The stains passed the white cloth test and when painted with the system specified for the project, the adhesion was not compromised.

When the galvanizing is damaged during tightening and the fasteners are specified to be painted, specifications vary on how to address the damage. But first, the type of damage should be assessed. For example, "smeared" galvanizing is still protective. In areas where the galvanizing is totally removed and the steel exposed, specifications commonly require spot application of organic zinc primer or epoxy mastic (typically aluminum-filled) to the damaged areas followed by the same intermediate and finish being applied to the rest of the structure.

The most important issue with regard to the application of coatings to any type of fastener is to make certain that the coating is completely and thoroughly worked into the crevices and threads, and properly built up on edges, as these areas are the first to corrode.

SUMMARY

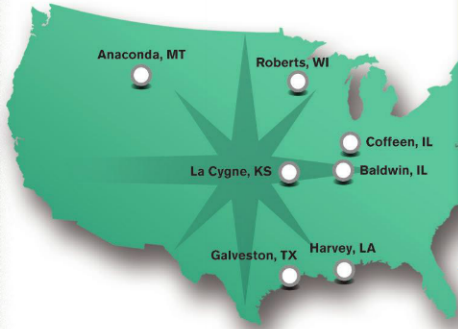
When bolted connections are slip critical, the certified coating must be applied within the thickness and thinning parameters called for in the certification and the joints not assembled sooner than the cure times used for the qualification testing. When TSC is used on faying surfaces of joints, based on testing conducted by FHWA, it should not be sealed. If the choice is made to apply the full coating system to the backside of splice plates before bolting, consider testing it first to make certain



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that any loss of pretension that might occur due to the compression of the coating does not adversely affect the tension creep results.

For bolt holes, unless some rusting prior to assembly is not acceptable, a common practice is to not require coating the interior surfaces, but allowing the coating to be deposited into the holes as part of the application to the face of the member. When black fasteners are installed after the paint has been applied, abrasive blast-cleaning in preparation for painting can create significant damage to the surrounding coating. Alternative fasteners should be considered if feasible, such as galvanized or treated, in order to avoid the need for blast-cleaning in the field. Before painting, fasteners must be cleaned of surface contamination, and in the case of galvanized nuts, the lubricant removed to the extent that adhesion of the subsequently applied coating is not compromised. If there are questions regarding the adequacy of the cleaning and the acceptability of remaining stains, the coating system can be applied on a test basis and the adhesion examined. In all cases, when fasteners are painted, it is critical that the specified coatings be thoroughly applied to threads, crevices and edges.

ABOUT THE AUTHOR



Kenneth Trimber is the president of KTA-Tator, Inc. He holds a Bachelor of Science degree from Indiana University of Pennsylvania, is an SSPC Protective

Coatings Specialist, is certified at a Level III coating inspection capability in accordance with ANSI N45.2.6, is a NACE-certified Coating Inspector and an SSPC-C3 Competent Person.

Trimber has more than 40 years of experience in the industrial painting field, is a past president of SSPC, chairman of the Committee on Surface Preparation, chairman of the Visual Standards

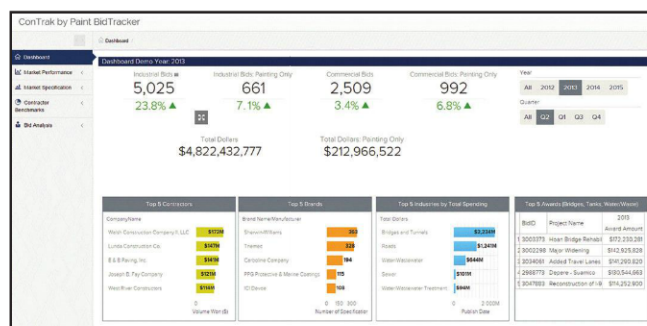
Committee, chairman of the Task Group on Containment and chairman of the SSPC Commercial Coatings Committee. He is also past chairman of the ASTM D1 Committee on Paints and Related Coatings, Materials, and Applications.

Trimber authored *The Industrial Lead Paint Removal Handbook* and co-authored Volume 2 of the handbook, *Project Design*.

He was the recipient of the John D. Keane Award of Merit at the SSPC National Conference in 1990 and is a former technical editor of *JPCL*. In 2009 and 2012 he was named by *JPCL* as one of the 25 Top Thinkers in the coatings and linings industry and in 2015 was the recipient of the SSPC Honorary Life Member Award. *JPCL*

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IMPROVING SURFACE PREP PRODUCTIVITY WITH RECTANGULAR BLASTING NOZZLES

BY CHANG-HUN LEE, BYEONG-HUN DO, WON-JUN YUN AND HAN-JIN BAE
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The purpose of surface preparation is ultimately to achieve the necessary coating adhesion between steel and the coated film in order to protect the structure adequately for as long as possible. Adhesion is a significant factor regarding the suitability and lifespan of protective coatings in corrosive environments. In the shipbuilding industry, abrasive blasting is a common method of generating proper surface roughness and achieving high productivity¹. Round nozzles are commonly used in abrasive blasting.

This article describes a study focused on the use of rectangular nozzles to achieve increased surface preparation productivity by avoiding concentrations of abrasive material typically seen with round nozzles². Rectangular nozzles can disperse abrasive material more evenly due to their shape. The rectangular nozzle used in this study is made of SKD-11 grade steel and has the same sectional area ratio as the reference rectangular nozzle used. The two nozzle types were compared regarding productivity and quality. Abrasive speed and spreading angle were compared using photos captured by a high-speed camera during laboratory scale testing (Fig. 1). Surface condition and profile achieved were compared using a microscope and quality of surface roughness in the field was assessed with measuring instruments.

Because of the round nozzle end, particles are concentrated in a small surface area. However, by changing the shape of nozzle from round to rectangular, particles can be discharged at a wider width for higher productivity. Also, a Venturi shape inside the nozzle can enhance particle velocity, which is the key element of surface cleanliness.

RECTANGULAR VENTURI NOZZLE

The internal shape of a blast nozzle affects the particle velocity, even distribution and working width. At the same input

pressure, a Venturi nozzle is more efficient than a straight nozzle as shown in Figure 2. The airflow quantity is the same at positions 1 and 2 due to the continuous condition, but the air velocity is different. According to equation 1 below, the multiplication of the cross sectional area and velocity at a certain position should always be the same. Therefore, when the sectional area decreases at position 2, the air velocity increases. Kinetic energy is expressed in equation 2 and shows an increase in kinetic energy due to increased air velocity.

Equation 1

$$A_1 \times V_1 = A_2 \times V_2$$

A_1 : Cross sectional area at position (1), V_1 : Velocity at position (1), A_2 : Cross sectional area at position (2), V_2 : Velocity at position (2)

Equation 2

$$KE = \frac{1}{2} \times m \times V^2$$

(KE: Kinetic Energy, m: Mass, V: Velocity)

The exit shape of the nozzle is related to the blasting pattern as shown in Figures 3 and 4. These figures show that the rectangular nozzle can discharge the particles at a wider width and more even distribution for increased productivity.

EQUIPMENT DESIGN AND DEVELOPMENT

As mentioned earlier, the advantages of the Venturi design and the rectangular shape at the point of exit were used to design this blasting nozzle. First, the ratio of a rectangular Venturi reference nozzle was calculated using the cross sectional area of the inlet, throat and outlet as shown in Figure 5. The ratio was calculated as throat/inlet and outlet/inlet, and then the blasting nozzle was redesigned with the calculated ratio to mount the hose as shown in Figure 6 (p. 46). Finally, a prototype of the rectangular nozzle was manufactured as shown in Figure 7 (p. 46).



Fig. 1: Still photos taken from high-speed video. The round nozzle blasts abrasive above and the rectangular nozzle below. Figures courtesy of the authors.

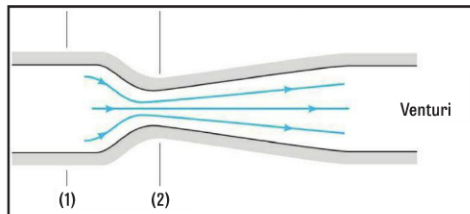


Fig. 2: Cross section of Venturi nozzle.

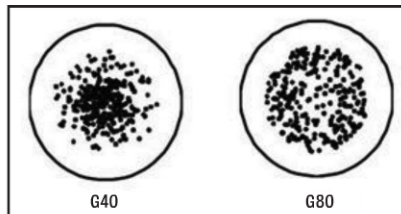


Fig. 3: Distribution of abrasive in round nozzle.

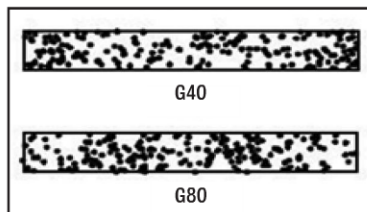


Fig. 4: Distribution of abrasive in rectangular nozzle.

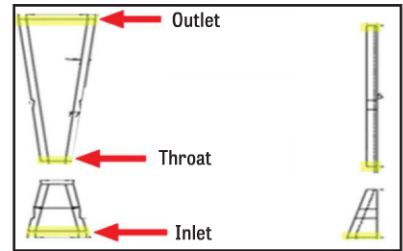


Fig. 5: Cross section of reference nozzle.

Comparison of Performance Using a High-Speed Camera

To compare the performance of the round and rectangular nozzles, the trajectory of abrasives was captured using a high-speed camera with a variable electronic exposure gate in microseconds. Experimental equipment was composed as shown in Figure 8 (p. 48) and a portable blasting machine used to propel abrasives is shown in Figure 9 (p. 48).

Input air pressure was 7 bar (700 kPa)

and coal slag was used as the abrasive. The abrasive feeding valve was opened at a 45-degree angle so that abrasives would merge uniformly with the airflow. The shutter speed of the high-speed camera was adjusted to coordinate with the particle's travel time. By changing the shutter speed, particles appeared in a streak line, which was relative to the distance traveled. Streak lines were measured using image-processing software to obtain useful abrasive speed data. The accuracy of this approach is in the range of ± 6 -to-11 m/sec³.

RESULTS AND DISCUSSION

Comparison of Velocity

The round nozzle was captured at 1/10,000th of a second and 1/15,000th of a second. The rectangular nozzle was captured at 1/15,000th of a second, 1/20,000th of a second and 1/25,000th of a second. Five streak lines were selected at random to calculate the particle's average velocity using equation 3. As a result, the average velocity of the rectangular nozzle was 115.70 meters-per-second, which was faster than the round nozzle as shown in Table 1 (p. 46).

Equation 3

Velocity = distance (length of streak) / time (shutter speed)

Comparison of Spray Width

Figure 10 (p. 50) illustrates the standard distance observed. In Figure 11 (p. 50), lines were drawn along the spray boundary to measure the vertical and horizontal distances. Lines were



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Rectangular Blasting Nozzles

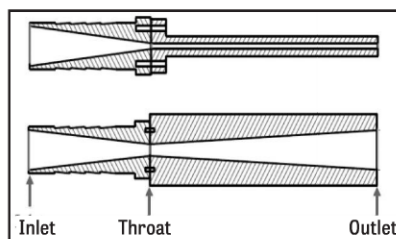


Fig. 6: The rectangular blasting nozzle was designed using the calculated reference nozzle ratio.

calculated to find the spray angle using a tangent equation. Table 2 shows that the rectangular nozzle's discharging angle was 8.341 degrees, which was wider than that of the round nozzle.

Comparison of Work Efficiency

An automatic carriage which could move along the wall at the same speed was



Fig. 7: The prototype of the rectangular blasting nozzle.

used to compare work efficiency. A blasting hose was then fastened to the automatic carriage (Fig. 12, p. 50). It moved at a speed of 0.18 meters-per-minute and 0.84 meters-per-minute to check the blasting width and surface cleanliness. There was no difference between the surface cleanliness achieved between the round and rectangular nozzles as per ISO 8501-1, "Preparation of steel

TABLE 1: COMPARISON OF ABRASIVE VELOCITY OF ROUND AND RECTANGULAR NOZZLES

	Round Nozzle		Rectangular Nozzle		
Shutter speed (sec)	1/10,000	1/15,000	1/15,000	1/20,000	1/25,000
Velocity (m/sec)	107.17	98.44	114.48	125.41	117.78
	104.73	97.00	116.81	111.23	111.62
	106.21	96.54	111.68	114.44	129.79
	99.743	92.39	120.62	102.51	115.64
	93.893	98.43	112.16	112.65	118.61
Average Velocity (m/sec)	102.349	96.56	115.15	113.25	118.69
(m/sec)	99.45		115.70		

TABLE 2: COMPARISON OF SHOOTING ANGLE OF ROUND AND RECTANGULAR NOZZLES

	Round Nozzle		Rectangular Nozzle		
Shutter speed (sec)	1/10,000	1/15,000	1/15,000	1/20,000	1/25,000
Angle (deg)	4.584	5.380	7.689	7.649	9.002
	5.742	6.241	7.858	6.824	8.688
	5.223	5.494	8.706	9.293	8.203
	5.142	6.498	7.848	8.205	8.585
	6.005	5.209	7.890	10.019	8.659
Average Angle (deg)	5.339	5.764	7.998	8.398	8.627
(deg)	5.552		8.341		

TABLE 3: COMPARISON OF SURFACE TREATMENT AREA BETWEEN ROUND AND RECTANGULAR NOZZLES ACCORDING TO CARRIAGE SPEED

Automatic Carriage Speed [m/min]		0.18	0.84
Round Nozzle	Working width [m]	0.095	0.09
	Working area [m²/min]	0.0171	0.0756
Rectangular Nozzle	Working width [m]	0.135	0.11
	Working area [m²/min]	0.0243	0.0924

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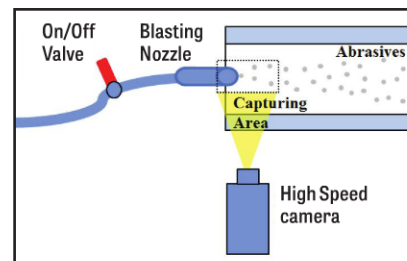


Fig. 8: Schematic design of experiment for capturing images of high-speed abrasives.



Fig. 9: A portable blasting machine was used to propel the abrasive.

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substrates before application of paints and related products — Visual assessment of surface cleanliness," but in all cases, the rectangular nozzle's blasting width was wider than that of the round nozzle. Therefore, the rectangular nozzle was found to be more efficient than the round nozzle as shown in Table 3 (p. 46).

CONCLUSIONS

Research was conducted to determine any advantages of using a rectangular nozzle over the traditional round shape. A rectangular nozzle was redesigned and manufactured using the ratio of the referenced nozzle. To determine the performance of the rectangular nozzle, the trajectory of abrasives was captured using a high-speed camera with a variable electronic exposure gate in microseconds. Images from the high-speed camera were processed with software to obtain particle speeds and blasting angles. From these results, the velocity of the rectangular nozzle was found to be faster than the round nozzle, and the blasting

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Rectangular Blasting Nozzles

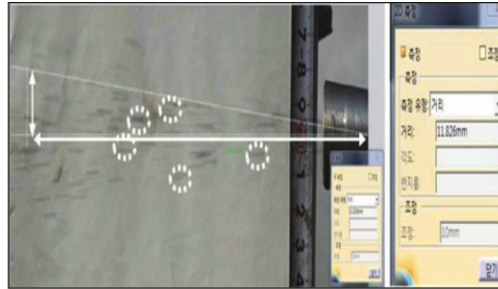


Fig. 10 (left): This image depicts the standard distance observed.

Fig. 11 (right): Lines were drawn along the spray boundary to measure the vertical and horizontal distances.



Fig. 12: Determination of surface treatment area using an automatic carriage.

angle of the rectangular nozzle was also found to be wider than the round nozzle. Finally, the rectangular nozzle was more efficient than the round nozzle as per the comparison of surface preparation data collected using an automatic carriage with consistent conditions.

ABOUT THE AUTHORS

Chang-Hun Lee is currently employed at Hyundai Heavy Industries, Co., Ltd. in the protective coating research department. He holds a mechanical engineering degree from Pusan National University.



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Byeong-Hun Do is senior researcher in the protective coating research department at Hyundai Heavy Industries, Co., Ltd. He holds a Bachelor of Science

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of surface preparation experience with painting technology and automatic production systems. He holds more than 50 patents and developed a variety of intelligent equipment for surface preparation working in the shipbuilding division at his company.



Han-Jin Bae is head of the protective coating research department in the research and development division of Hyundai Heavy Industries, Co., Ltd.

His areas of expertise include protective coatings of steel structures, surface

preparation technology and the automation of coating equipment. Bae is a registered member of The Korean Society of Industrial and Engineering Chemistry (KSIEC).

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3. Gary S. Settles and Stephen T. Geppert, October, 1996, "Redesigning Blasting Nozzles To Improve Productivity," *Journal of Protective Coating & Linings*, pp. 64-72. JPCL

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New Venue for International Bridge Conference



Photo courtesy of National Harbor

The Engineers' Society of Western Pennsylvania (ESWP) will hold its 33rd annual International Bridge Conference (IBC) from June 7 to 10 at the Gaylord National Resort and Convention Center in National Harbor, Md.

Previously held in Pittsburgh, Pa., the IBC attracts bridge owners, engineers and designers; senior policy makers and government officials; construction executives; and suppliers from throughout the U.S. and abroad, according to the ESWP. The conference comprises technical and special interest sessions,

workshops, seminars, committee meetings, receptions, facility tours, the annual "Bridge Awards" ceremony, and an exhibit hall. Session tracks include: ABC; Cable-Stayed Bridges; Construction/Fabrication; Design; Featured Agency; Foundation; Innovation; Inspection/Evaluation; Long Span; Proprietary; Rail; Rehabilitation; Segmental; and Special Purpose Bridges.

For more information about the 2016 IBC, including the complete conference program, visit eswp.com/bridge.

EXHIBITORS AT IBC 2016

The following exhibitors at IBC 2016 may be of interest to bridge and highway coatings professionals. The list is current as of press time. For a complete list, visit the IBC website.

All Access Rigging Co.	308
Anderson Hydra Platforms.....	114
AZZ Galvanizing Services	314
ChemCo Systems	347
CONCORR, Inc.	323
Euclid Chemical Company.....	102
Evonik Corp.	226
Greenman-Pedersen, Inc.	414
HRV Conformance Verification Associates, Inc.	220
Klaas Coatings (North America), LLC	109
NANOKOTE North America, Inc.	107
PDCA (Paint and Decorating Contractors of America).....	133
Safway Services, LLC	325
Sika Corporation	401
Spider	223
Stronghold Coating Systems.....	150
Vector Corrosion Technologies	412
Wasser Coatings.....	249

AWWA ACE Returns to Chicago



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From June 19 to 22, the American Water Works Association (AWWA) will present its 2016 Annual Conference and Exposition (ACE16) at McCormick Place West in Chicago.

The ACE16 conference kicks off June 19 and will feature technical and professional programs, workshops, facility tours, networking opportunities and more, according to the AWWA. The exposition, which opens June 20, will showcase products and services from more than 500 exhibiting companies.

The following programs and meetings held during ACE16 may be of interest to protective coatings professionals in the water and wastewater fields. For more information, visit awwa.org.

SUNDAY, JUNE 19

- "Water Main Rehabilitation: Materials, Lessons Learned, and Demonstrations," 9:00 a.m. to 4:00 p.m.

TUESDAY, JUNE 21

- Subcommittee Mtg.: D102 Coating Steel Water-Storage Tanks, 8:00 to 9:00 a.m.
- Committee Mtg.: Protective Interior Coatings, 9:00 to 10:00 a.m.
- "Distribution Systems: Gaining a Better Understanding of Unknown Challenges," 9:00 a.m. to noon

WEDNESDAY, JUNE 22

- Subcommittee Mtg.: D102 Coating Steel Water-Storage Tanks, 9:30 to 10:30 a.m.
- Committee Mtg.: Steel Elevated Tanks, Standpipes/Reservoirs, 11:30 a.m. to 1:00 p.m.

EXHIBITORS AT ACE16

The following exhibitors at ACE16 may be of interest to water and wastewater protective coatings professionals. The list is

current as of press time. For a complete list, visit the ACE16 website.

3M.....	679
AkzoNobel Protective Coatings.....	855
Ameron Water Transmission Group, LLC.....	1011
Caldwell Tanks, Inc.	1431
Corrpro Companies, Inc.	933
Denso North America	2038
Devoe High Performance Coatings	855
Farwest Corrosion Control Company	327
HydraTech Engineered Products	565
Induron Coatings, LLC.....	1234
Insituform Technologies, LLC	933
International Paint	855

JPCL.....	2331
NACE International.....	415
Parker Hannifin Corp.....	2346
Pittsburg Tank & Tower Maintenance Co., Inc.	747
PPG Protective & Marine Coatings	1341
Protech Powder Coatings Inc.	406
The Sherwin-Williams Company.....	714
Short Elliott Hendrickson Inc. (SEH)	269
Sika USA	2233
Specialty Products, Inc.	2305
Tank Industry Consultants	1913
Themec Company, Inc.	1419
Trenton Corporation.....	1853
Western Technology	314

San Diego Welcomes Mega Rust 2016

Mega Rust 2016, the American Society of Naval Engineers' (ASNE's) annual naval corrosion conference, will take place June 21 to 23 at the San Diego Marriott Mission Valley in San Diego.

Mega Rust is held annually to discuss corrosion issues impacting the U.S.

Navy and provide updated information on programs, policies, standards and new technologies and strategies for controlling corrosion, according to the ASNE. Participants include representatives from military, industry and government organizations involved with research and

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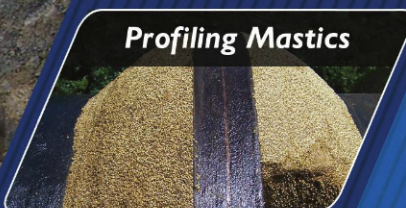


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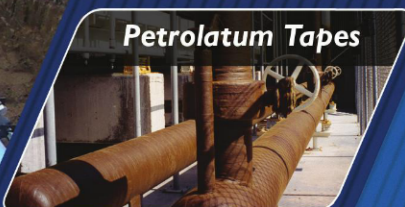
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development, design, engineering, construction, maintenance, modernization and operation of naval systems that are potentially affected by corrosion. The scheduled guest speakers, technical sessions, presentations, meetings and exhibition will follow the theme of this year's conference, "Corrosion Impact on the Warfighter."

A number of SSPC training courses will be offered at Mega Rust 2016, which can be found in the "Coming Up" section of this issue, p. 72. All courses will take place at the San Diego Marriott Mission Valley. To register for courses, visit sspc.org.

For more information on Mega Rust 2016, including the full conference agenda, visit navalengineers.org. Questions may also be directed to 703-836-6727 or megarust@navalengineers.org.

EXHIBITORS AT MEGA RUST

The following exhibitors at Mega Rust 2016 may be of interest to protective and marine coatings professionals. The list is current as of press time. For a complete list, visit the Mega Rust website.

Av-DEC 12
A. W. Chesterton 21

DeFelsko Corporation	33
DESCO Manufacturing Co., Inc.	28
Dex-O-Tex Marine, by Crossfield Products Corp.	23
DoD Corrosion Policy & Oversight.....	TBD
Fischer Technology, Inc.....	13
Graco, Inc.....	30
Industrial Vacuum Equipment Corp.	32
International Paint LLC	24
ITW Engineered Polymers	31
Jessup Manufacturing Company.....	18
Munters Corporation	15
NACE International Institute	5
NCP Coatings, Inc.....	19
Polygon US	27
PPG Protective & Marine Coatings	1
The Sherwin-Williams Company.....	17
Shield Technologies Corporation.....	9
Sponge-Jet, Inc.....	44
SSPC: The Society for Protective Coatings	36
Sulzer Mixpac USA, Inc.....	36
Technofink	29
V.O. Baker Company	14
Western Technology, Inc.	22

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