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The Society for Protective Coatings

FEATURES



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GALVANIZING IN ACTION
CAPPING CORROSION ON HDG STEEL BRIDGES

By John Krzywicki, American Galvanizers Association

Hot-dip galvanizing, a process in which steel components are immersed in a molten bath to form a zinc protective coating, has been used for decades in industrial construction to provide a protective layer from corrosive elements. This article will highlight four bridge projects that employed galvanizing—both with and without duplex protective coating systems—to provide long-term, maintenance-free corrosion protection in different service environments.

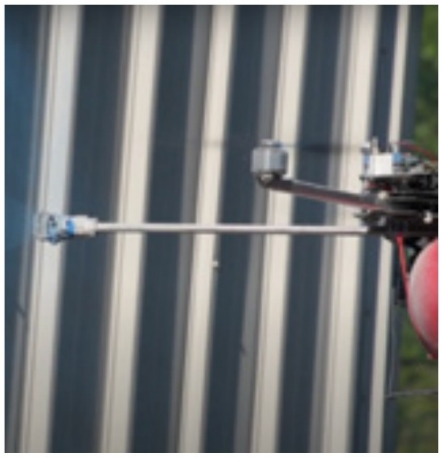


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PART II: INFLUENCE OF ULTRAVIOLET EXPOSURE

By Keith E.W. Coulson and James Ferguson, TC Energy

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INDUSTRIAL CLEANING AND COATING DRONES
A LOOK AT WHAT'S TO COME IN 2021

By Robert Dahlstrom, Apellix; and Michael Hindmarsh, AkzoNobel

Cleaning, coating and nondestructive testing at industrial sites requires extensive manual labor, often at heights, and drones can be used to perform some of these tasks while keeping workers safely on the ground. The authors discuss how nondestructive measurement drone capabilities have evolved over the past few years and offer a preview of cleaning and coating drone systems that are currently under development.

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Get Ready for the New JPCL

Change and consolidation always come with mergers and acquisitions. The recent merger between SSPC and NACE to form the Association for Materials Protection and Performance (AMPP) is no different. In fact, eliminating duplication and competing programs was often mentioned as one of the key objectives driving this merger.

The first significant announcement in this vein was that Bill Worms, Executive Director of SSPC for the past four years, was not going to be part of the new organization. Bill was a respected and trusted advocate for the SSPC membership, and losing his voice at that critical time was disconcerting to many.

The most recent decision announced by the AMPP leadership team was that JPCL would no longer be a member benefit to the SSPC heritage of the newly formed AMPP membership group. This officially ends a 37-year relationship between Technology Publishing Co., publisher of JPCL, and SSPC.

> **"Although our relationship with SSPC is coming to an end, our entire team is excited to reintroduce JPCL as the fresh, *independent* voice of the industry, effective with the April 2021 issue."**

JPCL remains the protective and marine coatings "bible"—having published significantly more editorial pages and sold more advertising pages than any other industry-related publication. Getting an article published in JPCL is a testament to the author's stature, knowledge and experience in the industry and remains a coveted professional accomplishment.

JPCL is unique: Articles don't promote products or companies—just credible, respected and trusted technical information from the best thinkers in the industry. JPCL content is archived exclusively on paintsquare.com and continues to be a go-to educational resource for the industrial coatings community. In 2020, more than 25,000 unique individuals accessed this archived content.

Although our relationship with SSPC is coming to an end, our entire team is excited to reintroduce JPCL as the fresh, *independent* voice of the industry, effective with the April 2021 issue. Along with the technical information you trust, you can look forward to a new design, revitalized content and added subscription benefits.

Be aware that the recent membership renewal letter sent by SSPC indicated that a JPCL subscription would continue to be a member benefit. That is no longer the case, now that AMPP has severed the relationship with JPCL. All readers will need to subscribe to receive the magazine and retain access to the online archive.

The good news is that **we have priced the subscription to be very affordable**. Our goal is to make JPCL accessible to *all* coatings professionals worldwide. Turn to page 4 in this issue for information about subscribing.

All of us at TPC thank you for your support and readership. We are glad that JPCL, the #1 publication serving the global protective and marine coatings industry, is a valued part of your professional lives.





Brion D. Palmer, CEO
Technology Publishing Co.
bpalmer@technologypub.com

JPCL, SSPC End 37-Year Relationship

On Dec. 22, 2020, at a virtual town hall meeting in which NACE, The Corrosion Authority, and SSPC: The Society for Protective Coatings, presented plans for their new, combined organization, leaders announced the termination of the publishing agreement between Technology Publishing Company and SSPC.

This ends a 37-year partnership that made JPCL magazine a member benefit and the "official voice" of SSPC. The reason given for discontinuing the arrangement is that JPCL "is owned by a third-party publisher."

This year's March issue of JPCL will be the final issue jointly published under the TPC-SSPC agreement. Starting with the April issue, TPC will publish JPCL independently.

"We always valued the relationship with SSPC," said Brion Palmer, CEO of TPC. "We were more than just a publishing partner. We were strategically aligned in many ways to help SSPC grow and prosper.

"That said, the JPCL team is now excited to reposition the magazine as the independent voice of the global industrial coatings community. We have a lot of changes and enhancements we will introduce to the publication that weren't possible under the former publishing agreement. We look forward to sharing details very soon."



For decades, JPCL magazine was included with an SSPC membership. Now, to continue to receive JPCL and access its vast digital archive, individuals and companies will need to subscribe. The JPCL article archive is exclusively available on PaintSquare.com/archive.

"We have always priced a subscription to JPCL in accordance with the price of an SSPC individual membership," said Palmer. "We wanted potential subscribers to strongly consider joining SSPC and receive JPCL as a member benefit. We didn't want the publication to compete with SSPC membership.

"Now we can be more aggressive with our pricing so JPCL is affordable to any industry professional, student or other interested party. We are also developing some very nice premiums to coincide with a subscription."

He added that specific information on subscribing to JPCL will be made available in the next few weeks.

AMPP Makes Industry Debut with Virtual Launch

Ringing in the new year, SSPC and NACE International officially launched their newly combined organization: The Association for Materials Protection and Performance.

While the combination occurred on Jan. 1, the AMPP (formerly referred to as "NewOrg" for the duration of the merging process) hosted a virtual launch Jan. 6, revealing the name of the new organization, as well as the logo, tag line and other endeavors that the branding team had been working on.

The virtual launch featured several event speakers, including AMPP CEO, Bob Chalker. Chalker opened the event, commenting on the many months it had taken to finally get to this point for the associations.



Bob Chalker, AMPP CEO, announced the organization's new name online.

The goal from the very beginning was to "create a unified voice for the corrosion control and protective coatings protection industries," and Chalker noted that the combined efforts have achieved just that. "I'm proud to be at the helm of this new organization," said Chalker.

However, Chalker noted, what most may not know is that this journey to create this new organization began well before the news of merger talks were ever published. To have it told from the men who got the ball rolling, Chalker introduced prior SSPC and NACE chairs, Joe Walker, Vice President, Elcometer, Inc. and Terry Greenfield, Principal Consultant, Consulex.

The two referred to the start of exploratory combination talks as "the big bump." Occurring at a 2018 SSPC Coatings+ conference in New Orleans, when Walker "bumped" into Greenfield. While not much follow-up could be noted from that encounter, two months later the two met again at the NACE convention, where discussions started to evolve even further. "The combination of the two allowed us to start from a clean slate and really make this organization global in its scope and focus for the members," said Walker.

> "We think [the name] defines both where we are around the globe, as well as what we do in the materials protection and performance space."
>
> — *Tim Bieri, AMPP 501 (c)(6) Chair*

Over the course of the conversation, Walker asked Greenfield about his biggest takeaway regarding the combination, to which Greenfield replied, "Here we are right now, instead of being on a stage together, exchanging works and handshakes, we're here in a digital format and I think we've all become more comfortable and more familiar with how to use it. "I see that as being a strong component of ... having true participation internationally on standards committees, on the program committees and task groups, whatever may pop up."

Echoing his response, Walker also noted on the achievement of the combination, pointing out that, unlike what he had expected, the associations had very little overlap in standards, training, certifications and others. The realization ultimately pushed the teams to make the new organization that much more effective, according to the team.

Up next on the virtual stage were Joyce Wright (AMPP 501(c)(3) Chair), Trade Manager for Strategy and Innovation, Huntington Ingalls Industries – Newport News Shipbuilding; and Cris Conner (AMPP (c)(3) Vice Chair), Vice President, Utility Service and Maintenance, Inc., who touched on the integration team efforts and how well members and staff from both organizations worked together to make the merge a success.

"I'm most looking forward to bringing together both organizations expertise," said Wright. "That's been instrumental in helping standards, educational courses, certifications, just to name a few, that will support and grow the needs of our industry across the globe. Together with one voice—contractors, owners, craftsmen, corrosion experts, manufacturers, consultants—we can do more together to advance the industry and protect societies across the globe."

Conner also noted that he was also looking forward to working within the net result of the merger and predicts it will be a better product than what the organizations had before.

Lastly, what all viewers had been waiting for, Tim Bieri (AMPP 501(c)(6) Chair), Principal Corrosion Engineer, BP Exploration & Production Operating Company; and Sam Scaturro (AMPP 501(c)(6) Vice Chair), President, Alpine Painting & Sandblasting Contractors, were brought on to announce the official name.

With the name and tagline, a new logo was also revealed and was described as representing the world (its circle centerpiece) and protection shield (surround hexagon shape often found in both science and nature). "We think it defines both where we are around the globe, as well as what we do in the materials protection and performance space," said Bieri.

Chalker then closed out the virtual launch, thanking the presenters, all the teams as well as the individuals who made up those teams, volunteers and many members for their hard work and commitment. "I think we all knew this would be a lot of work, but I'm not sure we ever imagined just how many moving parts there would be," said Chalker. "We could not have made it to this point without the dedication of an unbelievable volunteer workforce."

In ending the virtual event, Chalker noted that more information was expected to be released on AMPP's new website, ampp.org soon, as AMPP is expected to continue combining efforts of both organizations throughout the first half of 2021.



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NACE Announces Virtual Conference

Recently, NACE International, The Worldwide Corrosion Authority (now part of the newly formed Association for Materials Protection and Performance) announced that its CORROSION 2021 Virtual Conference & Expo would take place on April 19-30.

The news comes after the organization had to cancel its 2020 event due to the ongoing COVID-19 pandemic. Due to Utah's COVID-19 limitations on group gatherings, the organization has been prevented from hosting an in-person event at the Salt Palace Convention Center in Salt Lake City.

According to NACE, the virtual conference plans to offer dynamic programming, an expanded virtual exhibit hall and essential networking opportunities featuring AI-technology. However, while no schedules or committee meetings have been posted at this time, staff liaisons are slated to begin outreach efforts this month, with plans to publish a revised schedule no later than Feb. 15.

In regard to registration, any deferred registration fees intended for last year's conferences will be applied to CORROSION2021 Virtual Conference & Expo, although, these fees can also be transferred to the 2022 annual conference. Any slated attendees wishing to transfer the fees to a different event or product, or request a refund, can reach NACE International's FirstService team here. Refund requests must be received by 5 p.m. CDT on Jan. 22.

As for speakers who were scheduled to present at CORROSION 2021, the association notes that they can still present by completing a virtual speaker agreement. All authors must complete the speaker agreement and ensure that their employer will allow their presentation to be recorded and remain available on-demand in the event platform until Oct. 31. The speaker agreement and updated deadlines were sent out to authors/presenters earlier this week and are also to be completed by Jan. 22.

While details are still being ironed out, the association asks that interested parties and attendees continue to check the website and social media platforms for active updates. In the meantime, NACE FirstService is working to address questions and inquiries regarding CORROSION 2021. A full FAQ regarding the virtual conference can viewed at nacecorrosion.org/corrosion-conference-and-expo-2021-faq.



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PPG Announces New, Completed Transactions

Global coatings company PPG announced that it has agreed to acquire Nordic paint and coatings company Tikkurila in an all-cash transaction. The total transaction is valued at 1.1 billion euros ($1.35 billion).

"The combination of PPG and Tikkurila is extremely complementary, both geographically and from a decorative brand perspective," said Michael McGarry, PPG Chairman and Chief Executive Officer. "We have long admired Tikkurila's rich history of establishing very strong decorative brands and product offerings in several northern and eastern European countries where PPG has minimal decorative presence."

Tikkurila was established in 1862 and is headquartered in Vantaa, Finland. The decorative paint company has operations in 11 countries, with 80% of its revenue coming from Finland, Sweden, Russia, Poland and the Baltic states. Tikkurila's industrial paint business includes wood and protective coatings end-use segments, among others. The company employs approximately 2,700 people and reported sales of approximately 564 million euros in 2019.

"We will be able to provide customers with even more paint and coatings options by bringing together Tikkurila's high-quality and environmentally friendly decorative products and distribution capabilities in these countries with PPG's well-respected industrial and protective coatings. In addition, the combination will provide new cross-selling opportunities, growth opportunities for employees, and product solutions for new segments and customers. We look forward to welcoming the Tikkurila team to PPG and working with them to drive future growth," concluded McGarry.

The transaction is expected to close in the second quarter of 2021.

Just days after the Tikkurila announcement, PPG also disclosed that its acquisition of North Carolina-based coatings manufacturer Ennis-Flint was complete. That deal was initially announced at the end of November, and the agreement is valued at approximately $1.15 billion.

Ennis-Flint is reported to have a broad portfolio consisting of pavement marking products, including paint, thermoplastics and other advanced traffic technologies which are created from a network of manufacturing facilities within the United States, Europe, South America and Asia. The company employs approximately 1,000 people globally and its full year of 2020 revenue is expected to be approximately $600 million, with mid-teen percentage EBITDA margins.

PaintSquare Connect Releases Webinar Recordings

PART I: ABRASIVE BLASTING

Technology Publishing Co. has wrapped up PaintSquare Connect, its signature virtual event for the industrial and commercial coatings communities, sponsored by Sherwin-Williams, Carboline, Finishing First (Powered by LMCI) and McBrayer & Associates, but the archived library of its featured webinars remains available to registrants through May 31, 2021.

In the event curriculum, co-sponsored by 10X Engineered Materials and PPG, there were three tracks—Protective & Marine Coatings, Commercial Coatings & Solutions, and Surface Preparation. The latter included webinars on innovative product solutions, industry best practices and safe use of abrasives. This article highlights a few session recordings from the Surface Preparation track, archived at paintsquare.com/psc. If you're not already registered to watch the recordings, you can do so for free at paintsquare.com/shows/psconnect2020/registration.

NOVEL BLAST ABRASIVES

On Nov. 10, 2020, Stephen Ricci, PhD, Chief Technology Officer, and Jacob Vaillancourt, Partner, both of 10X Engineered Materials, presented, "A New Category of Blast Abrasives." In the webinar, Ricci and Vaillancourt discussed Superoxalloy Abrasives, a new type of blast media produced by the company. They explained how the particles are formed into a material matrix that yields "breakthrough speed and surface quality," with "no health or environmental risks," including no free silica and no beryllium, according to 10X .

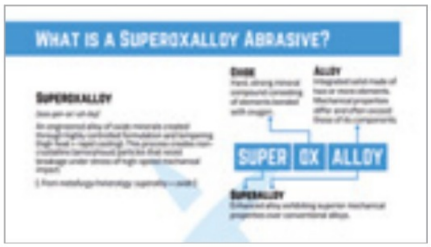


Stephen Ricci



Jacob Vaillancourt

Additionally, the duo covered field results in both contractor maintenance



10X introduced a new category of abrasive.

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In his talk, Thomas Enger discussed blasting safety considerations.



Clay Miller offered advice on how to choose abrasive media for a project.

and specialty applications, demonstrating what is achievable with an engineered abrasive and how the results can translate into higher financial returns.

Ricci and Vaillancourt also touched on the abrasive's additional benefits, which include increased blast hold time from substantially delayed rust bloom, low to no particle embedment, enhanced coating performance, and low dust for increased visibility.

SAFETY IN ABRASIVE BLASTING



Thomas E. Enger

In another health-related webinar regarding abrasive blasting, Thomas E. Enger, MS CSP Chmm, Director of Engineering Support Services, Clemco Industries Corp., presented "Identifying and Managing Inhalation Hazards Associated with Abrasive Blasting" on Nov. 12, 2020.

In the webinar, Enger cited employer annual ratings for occupational-related lung diseases due to toxic agents, noting that roughly 1.6 workers out of 10,000 (or 30,000 employees per year) experience these types of health issues. Throughout his presentation, Enger covered the most common inhalation hazards associated with abrasive blasting and their impact on lung diseases, along with the impact these diseases have on workers. The presentation also covered what employers and employees can do to prevent workplace inhalation dangers.

Specifically, Enger discussed:

- Inhalation hazards;
- Inhalation hazards from treated surface paint, epoxy, heavy metals;
- Inhalation hazards from abrasives sand, coal slags, steel grit, crushed glass, granite;
- Inhalation hazards from breathing air carbon monoxide, oil, odors, mist, breathing-air requirements; and
- OSHA requirements for NIOSH-approved supplied-air respirators.

The presentation also covered how one can become more aware of these hazards and how to ensure that employees can safely blast without exposing themselves to abrasive-blasting-related inhalation hazards.

SELECTING ABRASIVE MEDIA FOR BLASTING

Selecting the right abrasives for your application can be difficult, and in his Nov. 10, 2020, session,"Choosing Abrasive Media for Blasting Applications," Clay Miller of SurfacePrep presented a common-sense approach to abrasive selection—describing media types, characteristics, sizing, mil profiles, recyclability and more—to give blasters the knowledge needed to decide on the best media for their projects.

Miller started the presentation by reviewing the basics of the blasting process and outlining the traditional abrasive blast media types currently available on the market. He then went on to discuss the parameters that determine which blasting



Clay Miller

abrasive should be selected, including the type of surface to be blasted, the size and shape of that surface, the original condition and the desired finish.

Further selection factors discussed included anchor patterns, environmental regulations and the availability of certain abrasive types. After providing a review of the different abrasive types and discussing the characteristics of each, Miller took audience questions regarding concerns with recycled abrasives, abrasive disposal considerations, the future of crushed glass abrasives, the benefits of sponge media abrasives and more. **JPCL**

EXPLORE PAINTSQUARE CONNECT

For a wealth of information and inspiration, check out the session recordings and Product Pavilions, available on demand through May 31. If you are not registered, go to paintsquare.com/psc, click Registration, and sign up for free! We welcome your feedback about PaintSquare Connect. Email Jake Landon, Marketing Manager, jlandon@paintsquare.com.

COMMENTS IN RESPONSE TO:

"UHP Waterjetting: The Oldest 'New' Surface Preparation Method"

From *JPCL* October 2020

Author Brady DeRoche of Innovative Surface Prep used his article to explain the basics of ultra-high-pressure waterjetting and outline the potential benefits that can be realized by employing this process on jobsites.

Ric Beard:
"Great article, Brady. Hope this gets to the correct personnel. This technology is long overdue for proper attention and implementation."


COURTESY OF BRADY DEROCHE

"CA to Review Titanium Dioxide Classification"

From *PaintSquare Daily News*, Dec. 7, 2020

With California's Office of Environmental Health Hazard Assessment's Proposition 65 Developmental and Reproductive Toxicant Identification Committee set to meet to consider its new Prioritization Document, the discussion will touch on one controversial pigment sometimes used in coating formulations: titanium dioxide (TiO_2).

Tom Schwerdt:
"Keep in mind this is addressing just 'nanoparticle'-scale TiO_2 at the moment. [The] pigment used in paint is most often larger particles."

Michael Halliwell:
"Perhaps it needs a warning similar to asbestos in vinyl floor tiles—that it's not an issue when trapped in the matrix, but [during] any activities such as sanding, grinding or similar which may release particles may require special precautions. After all, like silica and asbestos, TiO_2 is a stable product...and that's where part of the problem lies, because if it is inhaled, the body cannot break it down and eliminate it."

Andrew Piedl:
"While I currently don't think the threat from TiO_2 is that great, it strikes me that the argument that 'any releases from weathering, sanding, demolition or disposal are expected to be negligible' is questionable, given the long history of people getting lead poisoning from lead paint dust as a result of [those activities]."

"Determining When to Coat Concrete"

From *JPCL* December 2020

This JPCL article from author Manuel Najar of V&A Consulting Engineers reviewed the typical areas where corrosion attack can occur in concrete wastewater treatment structures, and offered guidance on performing condition assessments and prescribing the right surface preparation and coating application methods.

Regis Doucette:
"Thanks for your thorough review with salient points throughout. I appreciate your efforts here because too often coating specialists minimize the importance of the topics you discussed herein which ends up costing the owners and the public for their short-sightedness."


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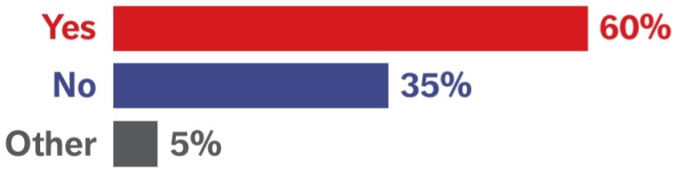


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PAINT POLL

From paintsquare.com/poll

The United States Navy recently announced the launch of its new research competition, "Rust-A-Thon." Do you think the endeavor will prove effective in developing new protective coating materials?



Michael Beitzel:

"For industrial structures and bridges in particular, I would suggest continued use of lead-based coatings. Lead-based coatings have been unmatched in performance in comparison with other corrosion inhibitive coatings ... Current regulations are sufficient to protect the public and workers from lead-based removal operations. In fact, these regulations are costing us millions of dollars in unnecessary expense because regulations do not account for structures that have minimal lead content found in all newer coatings and zinc primed coatings and require the same compliance requirements as high lead level coatings ... Wet abrasive blasting or vapor abrasive blasting procedures are unparalleled in reducing lead airborne exposures to workers and the public—so why isn't this method of coating removal the preferred and required removal procedure from structures?"

PROBLEM SOLVING FORUM

From paintsquare.com/psf

What are the reasons for different dew points from a sling psychrometer and a digital dew point meter at the same site, and what should be done to address this discrepancy?

Tom Swan:

"I actually presented a paper on this at an SSPC conference about 20 years ago, and I would like to thank the eight people that attended (first talk in the morning). Back in the old days of mercury slings, there was much greater agreement between the two. Assuming the thermometers are accurate, up to about 85 F there is good general agreement between slings and electronic meters. As the temperature increases over 85 F, slings become very inaccurate and at about 90–95 F, just throw a dart at a dart board with a sling and you will get just as accurate a number. To prove this, in hot weather do a sling in a normal manner then repeat the reading holding the sling in front of a fan. You will get two completely numbers. The one in front of the fan is the correct number ... Bottom line: if you have a red spirit thermometer in a sling, usually the electronic meter will be the most accurate. Remember when using either, you must acclimate the meter to the climate. This includes allowing the internal electronics to reach ambient temperature before using. This can take 20 to 30 minutes to get accurate readings."

Rob Francis:

"There is quite a significant uncertainty in relative humidity readings. Even weather bureau RH readings are +/-3% or so, so expect +/-5% or so in readings in the field from the electronic or whirly gauges. This error carries on to dew point which is calculated from RH."



VIKTOR WALLON-HARS / GETTY IMAGES

PAINTSQUARE DAILY NEWS TOP 10

From paintsquare.com/news, Dec. 7–Jan. 10

1. **JPCL, SSPC End 37-Year Relationship**
2. **Results in on 50-Year Epoxy Resin Experiment**
3. **PPG Announces New, Completed Acquisitions**
4. **Water Recycling Plant Explosion Kills 4**
5. **Skanska Repairing FL Bridge "At a Loss"**
6. **Venice Floods After Dike Activation Fails**
7. **AECOM Agrees to Sell Civil Construction Unit**
8. **Deal Inked for Disney High-Speed Rail**
9. **CA to Review Titanium Dioxide Classification**
10. **SBA Releases PPP Borrower Data**

Cleaning and Painting Galvanized Steel

How many times have you seen paint peeling from a galvanized surface? Galvanized steel can be one of the easiest yet one of the most difficult surfaces to clean and paint properly. That's because zinc—used to galvanize steel—is an active metal. The surface starts changing about one day after the piece is removed from the galvanizing bath, and it does not fully stabilize for about one year. Special procedures for cleaning and painting galvanized steel are needed in the first year. But after that time, most paints will adhere with just a power wash.

This Applicator Training Bulletin will examine what happens on a galvanized surface. It will discuss cleaning the surface of both new and aged galvanizing, because the requirements differ. Finally, it will present information on painting materials and the painting of galvanized steel.

THE GALVANIZED SURFACE

Galvanizing is a process in which a coating of zinc is applied to a steel surface from a bath of molten zinc. This can occur in several ways. Coil steel, such as steel used to make automobile bodies, is commonly galvanized in a continuous roller process. The sheet of steel is fed into a bath of liquid zinc where the zinc is deposited on the surface. Alternatively, structural pieces and hardware are galvanized in a batch process by immersing them in a bath of molten zinc. This is called hot-dip galvanizing. Chemical reactions occur between the iron in the steel and the molten zinc. (See sidebar.) An outer layer of pure zinc covers the surface as the piece is withdrawn from the bath.

The corrosion protection of unpainted galvanizing comes from the formation of a thin, invisible layer of insoluble corrosion products. Zinc, being an active metal, reacts with oxygen in the air. Zinc oxide starts forming 24 to 48 hours after galvanizing. It takes about a year for the zinc oxide to cover the entire surface. The zinc oxide converts to zinc hydroxide upon exposure to moisture in the form of rain, dew, or high humidity. The final step is the reaction of zinc oxide and zinc hydroxide with carbon dioxide in the air to form zinc carbonate. This requires free-flowing air. Zinc carbonate is the dense, insoluble material that forms the protective layer (sometimes called the patina). Zinc oxide and zinc hydroxide are water-soluble and not very dense. They adhere loosely to the surface, so painting over zinc oxide or zinc hydroxide does not provide good adhesion of the coating to the surface. The practical problem is that zinc oxide, zinc hydroxide and zinc carbonate are all white. They give the galvanized surface a dull, matte grey appearance, and there is no way to determine visually what form of zinc compound is present. Knowing the compound is important because some forms are not suitable for painting over.



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The reactivity of zinc is well known to galvanizers. For instance, they know that if pieces are closely stacked for shipment, there will be no access to carbon dioxide in free-flowing air to form the zinc carbonate. Only loose zinc oxide and zinc hydroxide will form, so consumption of the zinc will be rapid. Unpack closely spaced galvanized pieces and you will see loose, white deposits on the surface. If this reaction process is allowed to continue, it can totally consume all the zinc by reaction with the moisture caught between the pieces. (This condition is, however, very rare.) Rusting of the unprotected steel may then occur, resulting in red rust present underneath the deposit. This white deposit is called "wet storage stain." Galvanizers will apply a light coating of oil to prevent wet storage stain. The oil forms a barrier to prevent moisture from

EDITOR'S NOTE: JPCL is pleased to announce the return of the Applicator Training Bulletin series, which offers practical advice for coatings professionals to employ on their jobsites. This month's ATB column was originally written by Lloyd M. Smith, PhD, of Corrosion Control Consultants and Labs, Inc., and published in the April 2001 issue of JPCL; it has been updated for this issue by JPCL staff.

reaching the zinc, thus preventing the zinc from being converted to the oxides and hydroxides. But paints don't stick to oil, so painting this surface without first removing the oil is a disaster waiting to happen, no matter what type of coating is applied. Another process used to prevent wet storage stain is quenching or passivating with chromates or phosphates. Quenching, i.e., cooling in a water bath, is not harmful in itself. But the quench bath can contain small amounts of oil and grease on the surface that will be picked up when the piece is removed. Paints also do not stick to chromate-quenched galvanizing, but phosphating improves adhesion. If the galvanizer does perform a post-treatment, you won't know which one was used. It is always recommended to consult with the galvanizer—preferably before items are galvanized—if you know they are to be painted.

SURFACE PREPARATION OF NEW GALVANIZING

New galvanizing, for the purposes of this article, means galvanized steel that is between one or two days old and up to about one year old. (It was noted above that a stable galvanized surface is formed in one year, but the possible presence of a light oil layer and weather conditions may actually extend the time.) Wet storage stain, if present, must be removed before surface preparation. This can be done by brushing the stain with a 1–2% ammonia solution such as diluted household ammonia. Severe cases of wet storage stain will require a mild acid solution such as one part of acetic or citric acid diluted with 25 parts of water. Remove the ammonia or acid with a warm water rinse.

The first step in surface preparation is to wash off oil, grease and dirt. In North America, this is accomplished by Solvent Cleaning (SSPC-SP 1). Water-based emulsifiers or alkaline cleaners work best. Make sure that an alkaline cleaner has a pH of less than 12 or 13, because zinc will dissolve in highly alkaline solutions. Apply the cleaning solution by dipping, spraying or brushing with soft bristle brushes. A temperature range of 140–185 F (60–85 C) works best, especially when dipping or spraying. Thoroughly rinse the surface with hot water after cleaning and allow it to dry. In countries where organic solvents can also be used for cleaning purposes, lint-free rags should be used. Change them often so as not to cover the surface with fibers. One way to determine if oil was applied to the galvanized surface to prevent wet storage stain is to contact the galvanizer. Another way is to perform a water bead test. Place a drop of water on the surface. If it beads, oil is probably present. The best advice is that when in doubt, clean the entire surface as described above.

After washing the surface, examine it for zinc ash. Zinc ash residue consists of particles of oxidized zinc that float on the surface in the galvanizing bath. It can be removed by washing the surface with a 1–2% ammonia solution. Thoroughly rinse the surface with hot water and let it dry.

The next step in surface preparation is to repair any defects or handling damage. Galvanizing can leave high spots and zinc droplets. High spots occur when excess zinc runs down the edges as the galvanized piece is withdrawn from the bath, and the zinc runs into a protrusion or irregular edge. Droplets form at edges where zinc drains from the piece. Droplets are knocked off with hand tools. High spots are usually ground off with power tools, but care is needed not to remove so much zinc that the thickness is below the specified minimum.

Damaged galvanizing can be repaired with organic zinc-rich paints. Consult the coating manufacturer about specific products and the method of surface preparation required. SSPC Guide 14, Guide for Repair of Imperfections in Galvanized or Inorganic Zinc-Coated Steel Using Organic Zinc-Rich Coating, may be consulted.

The unstable zinc oxide or zinc hydroxide may not have been entirely removed during the initial cleaning process. There is no simple method for identifying the presence of either, so the surface must be further treated. The common methods for treating the surface in the field are phosphating, use of wash primers, acrylic passivation and sweep blasting.

Phosphating

Phosphating (use of acidic zinc phosphate solution, mordant solution, or T-Wash) is accomplished by applying a phosphate-containing solution that forms a non-reactive zinc

THE GALVANIZING PROCESS

Hot-dip galvanizing is a batch process in which the coating is applied in a molten bath of zinc at about 840 F (450 C) after the workpiece has been cleaned and a flux has been applied to promote fusion of the zinc to the steel.

Chemical reactions between the iron in the steel and the molten zinc take place, forming four distinct layers. The gamma layer closest to the steel is 75% zinc and 25% iron. This is followed by the delta (90% zinc), zeta (94% zinc) and eta (100% zinc) layers.

The overall thickness of the galvanizing is determined primarily by the chemistry of the steel, provided the workpiece has remained in the bath for a sufficient length of time. The thickness of the eta layer is also affected by how quickly the molten zinc can drain from the surface when the item is removed from the bath.

Galvanizing is known for its bright, spangled surface. However, bath chemistry can affect the appearance and a dull finish can occur. This is an aesthetic issue and does not affect the corrosion protection of the galvanizing. Exposing the zeta layer will result in a brown appearance due to the presence of an iron alloy.

phosphate layer on the surface. The process slightly etches the surface and blocks the formation of zinc oxides.

The solution is applied by immersion, spray or soft bristle brush. It should be left on the surface for three to six minutes and then washed off with clean water. The treatment will give a black coloration to the surface. Therefore, any areas that were missed will be visible after washing, and they can be retreated. Allow the surface to dry before painting.

Phosphating can also be done at the galvanizing plant in a process called phosphate quenching. The workpiece is placed in a phosphating bath after galvanizing. If you're involved with a new construction project, contact the galvanizer to see if the pieces will be treated with phosphate. It will be less expensive, and the quality will be more consistent compared to field phosphating.

Phosphating is not recommended if a zinc-rich primer is going to be applied. Zinc-rich primers require intimate contact between the zinc particles in the paint and the zinc metal on the galvanized surface. Zinc phosphate acts as an insulator in the same way that iron oxide (rust) acts as an insulator on steel surfaces.

Wash or Etch Primers

Wash primers are coatings used to neutralize the surface oxides or hydroxides and to etch the galvanized surface. The most common wash primer is polyvinyl butyral (e.g., SSPC Paint 27), although other products are available. These materials are applied very thin (i.e., 0.3 to 0.5 mil) by brush or spray. Follow the manufacturer's instructions. The galvanized surface should shadow through the coating at this thickness. If the galvanized surface is completely hidden, the wash primer is too thick. Wash primers have poor cohesive strength and will split apart if they are too thick, resulting in paint disbondment.

Acrylic Passivation

Acrylic passivation is accomplished with an acidic acrylic solution that passivates and roughens the surface. Acrylic passivating materials are applied at 0.04 mils. In essence, acrylic passivation is a surface treatment. It must dry completely before the paint is applied.

Sweep Blasting

Sweep blasting—a method of lightly blast cleaning—can remove zinc oxides on the surface and roughen it without significant removal of the galvanizing. Sweep blasting should be performed with soft abrasives such as aluminum/magnesium silicate, corn cobs, walnut shells, limestone or some mineral sands. Use an abrasive with a Mohs' scale hardness of 5 or less. The particle size should be in the range of 8–20 mils.



BULGAC / GETTY IMAGES

Use a relatively low angle when blasting. Holding the nozzle perpendicular to the surface can quickly remove the galvanizing layer rather than just the zinc oxide particles on the surface. The recommended ambient conditions for sweep blasting are a minimum temperature of 70 F (21 C) and relative humidity of 50% or less.

For further guidance, consult SSPC-SP 16, Brush-Off Blast Cleaning of Coated and Uncoated Galvanized Steel, Stainless Steels, and Non-Ferrous Metals. For this standard, the zinc metal layer of hot-dip galvanized steel is considered to be the substrate, rather than the underlying steel.

FULLY WEATHERED AND AGED GALVANIZING

Fully weathered galvanizing (i.e., galvanizing that has been outdoors for at least one year and preferably two) should have a fully formed layer of protective zinc carbonate. All that is normally needed to prepare the surface is power washing at about 1,450 psi. Spot repairs of any damage also would be necessary.

Old, aged galvanizing that has been in service, uncoated, for a number of years and is showing signs of failure introduces a different concern. There may be areas of reddish-brown staining, which many people think is corrosion of the base steel. However, just below the pure zinc on hot-dip galvanized steel are zinc-iron alloy layers. What might be visible is the staining from these layers. Zinc-iron alloy is brown, while rusted steel is redder, but telling the difference can be difficult. The best way to do this is with a magnetic or electronic dry film thickness gauge. Measure the layer of galvanizing at any rusted or stained areas. Since galvanizing is non-magnetic, the gauge will measure it as if it were paint. If the gauge finds no layer of galvanizing, the area is most likely rusted. Mark the area for repair. The specified galvanizing thickness is related to the steel thickness and is usually in the range of 2–5 mils.

Surface preparation of old, aged galvanizing involves cleaning any rusted or stained areas as well as power washing the entire surface. Areas with red rust should be cleaned to bare metal while areas with brown staining from the zinc-iron alloy require only hand or power tool cleaning. Care must be taken when cleaning areas of red rust to remove as little galvanizing from the edges of the spot as possible.

It is common to use an organic zinc-rich primer when refurbishing old, aged galvanizing. Usually some of the galvanizing has been consumed, and the intent is to add more zinc for corrosion protection. Sweep blasting would be recommended prior to applying the primer to promote adhesion.

COATINGS FOR GALVANIZING

Many types of coatings can be applied over galvanizing. The choice sometimes depends, in part, on how the surface was prepared. SSPC Guide 19, Selection of Protective Coatings for Use Over Galvanized Substrates, provides guidance and selection criteria for choosing a coating system over galvanizing. However, there are certain types of coatings that are not recommended, especially oil-based alkyds. Most coatings can be applied by brush, roller, or spray. Check with the coating manufacturer on application methods. The most common coatings applied directly to galvanizing are epoxies and waterbornes.

Epoxies come in many varieties. Those selected must be specifically formulated for use over galvanizing. Make sure the manufacturer's technical data sheet for a particular product says it can be applied to galvanizing. Epoxies generally chalk in sunlight, so a topcoat would be needed for outdoor exposure. Aliphatic urethanes give good appearance and chemical resistance, so they are commonly used for this purpose.

Waterborne acrylic coatings are fast-drying. They make good topcoats and are easy to maintain. Acrylic latexes are preferred. Other waterborne latexes have properties similar to acrylic latexes. However, although the waterborne latexes dry quickly, they can take two to four weeks to thoroughly cure. Therefore, their adhesion and abrasion resistance will initially be low. This can present a problem for new construction because of possible handling damage.

Chlorinated rubbers and vinyls have been used in the past, but regulations concerning VOC content have severely limited their availability and use. They are best used on galvanizing that has been prepared by sweep blasting or with a wash primer.

Acrylics can be applied directly to a galvanized surface, although a wash primer is preferred. However, some acrylics contain ammonia, and if the pH of the paint is high, the ammonia may react with the zinc, causing the paint to peel.

Organic zinc-rich primers, such as an epoxy zinc-rich, can also be applied directly to galvanizing. However, not all organic zinc-rich primers are formulated for application to galvanizing, so check the product data sheet or with the manufacturer.

Oil-based and alkyd paints are not recommended unless they are specifically formulated for use on galvanizing. The problem is that zinc is an alkaline material. The zinc and the binder react in the presence of alkalinity to form a metal soap. (Sometimes, you can actually form lather by adding a little water to this soap.) This process, which is called saponification, breaks the bond between the galvanizing and the paint. Saponification requires moisture, so it occurs in a well-adhered coating film only after moisture starts permeating the film. The coating then falls off, or it can be completely removed in large sheets. Experience has shown that it takes six months to a year in outdoor exposure before the peeling occurs.

Some alkyds are formulated for application to galvanizing. To prevent saponification, manufacturers add Portland cement to the coating as a pigment.

No matter what coating material is used, the total coating thickness generally should be no greater than 4–6 mils. Don't forget that galvanizing is non-magnetic, so the thickness of the galvanizing will be included in the paint thickness measurement when using magnetic or electronic gauges. Specifications for structural steel generally require the galvanizing to be 2–5 mils, depending on the thickness of the steel. (The galvanizing thickness on sheet steel is lower.) The thickness of the galvanizing should be measured before any paint is applied so it can be subtracted from the overall coating thickness measured after each coating layer is applied. Galvanizing is often specified by weight of zinc per unit area, e.g., ounces of zinc per square foot (grams of zinc per square meter). These correspond to galvanizing thicknesses. The conversion is 1 oz/sq. ft. equals 1.7 mils.

Finally, if sweep blasting is used to prepare the surface, it should be painted within 24 hours because the blasting exposes fresh zinc that will start converting to zinc oxides. Wash primers and acrylic passivators will give you more time to apply the paint, but check with the coating supplier on how much more time you have.

CONCLUSION

Surface preparation is critical for galvanized steel surfaces to be painted. Zinc is very active and takes one to two years to stabilize. It is during this period that galvanizing is usually painted on new construction projects. Check with the galvanizer, if possible, to determine how the pieces have been treated. Then prepare the surface as appropriate. Use only paints intended for galvanizing. Always check the product data sheet or with the manufacturer to determine if the coating is appropriate for galvanizing. **JPCL**

GALVANIZING IN ACTION

Capping Corrosion on Bridges with HDG Steel

BY JOHN KRZYWICKI, AMERICAN GALVANIZERS ASSOCIATION

For decades, hot-dip galvanizing has been used extensively in the industry to provide corrosion protection to bridges and other steel structures. The following case histories highlight how hot-dip galvanizing has been employed—both with and without duplex protective coating systems—on recent bridge projects in order to extend service lives and limit costly maintenance down the line.

CHAMPLAIN BRIDGE

Amid the fanfare of the official opening of the $5.5 billion new Champlain Bridge in Montreal—which was projected to have 60 million annual crossings, making it the most expensive and busiest bridge in Canada—is the cautionary tale of the bridge it replaced. The new bridge, the largest in Quebec history, was designed under the shadow of the premature corrosion failure of the original Champlain Bridge.

Montreal, an island city with 3.5 million people today, was already quickly outgrowing the three existing bridges that connected it to the opposite side of the Saint Lawrence River in the early 1960s. In response, a new bridge was built and opened in 1962, but unfortunately, mistakes in its conception doomed it to fail prematurely, and taxpayers were exposed to untold risk and expense.

A French design concept gaining favor at the time—prestressed longitudinal concrete trusses and pre-stressed road deck—had been used. The bridge was constructed with unprotected rebar and tensioning cables throughout, including the piers and caps. The corrosion solution at that time was to simply specify that no deicing salt could be used on the bridge.

Given that Montreal has one of the coldest, dampest climates of any major city, it was not surprising that the very first snowfall



The new Champlain Bridge in Montreal is hailed as the most expensive, busiest bridge in Canada.
PIERRE-OLIVIER VALIQUETTE / GETTY IMAGES



Construction of the new Champlain Bridge (right) took place adjacent to the original, corrosion-plagued bridge. PHOTOS COURTESY OF AMERICAN GALVANIZERS ASSOCIATION UNLESS OTHERWISE NOTED





Galvanized steel, including rebar in the bridge deck, gave the new bridge corrosion protection lacking in the original bridge design.

after it opened led to hundreds of accidents. The rapid current of the river under the bridge prevented it from fully freezing, but even when there was no precipitation, the cold wet mist of the river regularly iced the bridge through the winter. As a result, the "no salt" rule was quickly abandoned, and every November to April since, deicing salts were spread continuously.

By its 30th birthday, the Champlain Bridge was already facing major corrosion problems. The entire concrete road deck and jersey barriers of the cantilever section required emergency replacement due to severe rebar corrosion. The piers and caps were also suffering from the same degradation, so the replacement deck and barriers were made of hot-dip galvanized steel rather than concrete to reduce the dead load on the weakened piers.

By 2009, the bridge was deemed to have "an unacceptable and indeterminable risk of catastrophic collapse" due to advanced corrosion. The prestressed concrete design revealed an even more dangerous circumstance: not only could the trusses not be replaced or repaired, but their design also prevented even proper inspection of their tensioning cables that were also most likely corroding. At this point, hundreds of millions of dollars had been spent on emergency repairs and constant maintenance and inspection. A few years later, one of the large longitudinal concrete trusses cracked due to tension cable corrosion, leaving two of the three lanes in that direction closed for months, while many other trusses were found to have smaller cracks from the same problem.

By 2013, hundreds of millions more dollars had been required in emergency repairs, including 94 externally rigged steel support trusses and six major shoring projects for corroded piers. The bridge also had 375 sensors installed in the hope of detecting minute indicators of pending catastrophic failure, and 50 full-time employees were charged with continual maintenance and inspection. Due to the imminent risk of collapse, it was eventually determined that, despite the financial costs that had already been incurred to maintain the old bridge, a replacement bridge would need to be constructed.

The new Champlain Bridge was built at breakneck speed, but also considered the lessons learned from the failures of the previous bridge. The design life of the new bridge targeted 125 years of reliable service. The 2.5-mile span was planned to hold six traffic lanes, two dedicated bus lanes and two light rail lines.

In total, more than 15,000 tons of steel were galvanized during this massive project. All structural steel that could physically fit in the local baths was hot-dip galvanized, along with all railings, anchors, signage and wind braces. Furthermore, all rebar that was within a certain distance from an outer concrete surface was either galvanized or made of stainless steel.

The new Champlain Bridge was completed 18 months ahead of schedule and opened on Canada Day, July 1, 2019. It is expected to safely transport more than 100 million people a year across the Saint

Lawrence River for decades longer than the bridge it replaced. This cautionary tale of two bridges highlights the dangers and costs of infrastructure corrosion and the multifaceted benefits that hot-dip galvanized steel can provide. Since the construction of the original bridge, hot-dip galvanized steel has been used extensively throughout the province in many sectors.

LONGFELLOW BRIDGE

Opened in 1906, the Longfellow Bridge is a historic steel rib arch bridge that spans the Charles River and is a vital link between Boston and Cambridge, Massachusetts. A combination railway and highway bridge, the Longfellow Bridge is one of the busiest in the Commonwealth of Massachusetts. Approximately 90,000 transit riders on the Red Line and 28,000 vehicles use the bridge daily, passing its iconic "salt and pepper shaker" towers.

In 2013, the Massachusetts Department of Transportation began a $270 million, multi-year rehabilitation project on the bridge. Because the bridge had been listed on the National Register of Historic Places since 1976, the project took careful consideration to safely repair the bridge, but retain its historical integrity.

The last major rehabilitation of the bridge had been performed in 1959, so there was significant deterioration of the steel arch ribs since then. Maintaining the bridge's historical character led to a more complicated rehabilitation project, but the overall result should be a better, safer bridge. One aspect of the project included removing the steel arch ribs, stripping and cleaning the rust, then galvanizing and repainting, including hot-dip galvanizing diaphragms, beams, columns



The Longfellow Bridge rehabilitation included hot-dip galvanizing and duplex coatings for extra corrosion protection.
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Diaphragms, beams, columns and other steel components were hot-dip-galvanized during the multi-year project.



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Hot-dip-galvanizing protects the Cape Fear Memorial Bridge's deck from corrosion in its high humidity environment.



Galvanizing offered extended protection compared to the traditional multi-coat system typically specified for bridge deck members.

and other steel components. The new ribs were then reinstalled to maintain the historic character of the bridge, while ensuring it complied with modern environmental and safety standards.

The hot-dip galvanizing and duplex coating system, where required, should ensure that the 2,135-foot structure will resist corrosion while enhancing the overall aesthetic of this iconic bridge for decades to come. The final phase of the rehabilitation project wrapped up in 2018.

CAPE FEAR MEMORIAL BRIDGE

The Cape Fear Memorial Bridge is a 3,000-foot steel vertical-lift bridge that connects Brunswick and New Hanover Counties in North Carolina. The bridge features a 408-foot-long lift span that can be raised 135 feet to allow ships to pass under. When construction completed in 1969, the bridge boasted the largest money appropriation in the state of North Carolina at $15 million.

North Carolina has an average relative humidity greater than 70%, which can wreak havoc on bridge and highway projects. The harsh, humid environment combined with nearly 50 years in service meant that by 2018, the bridge was in dire need of a structural renovation. The original project specifications from the North Carolina DOT required a multi-coat paint system on all of the bridge decking, which would have been standard for this type of project in the region. The project contractors, however, submitted a value engineering change proposal showing that a galvanized coating would provide more corrosion protection while reducing both the short- and long-term costs of the project. This is thanks, in part, to iron in the steel metallurgically reacting with the zinc to form a tightly-bonded alloy coating.

Thanks to the renovation work that completed in November 2019, the Cape Fear Memorial Bridge still stands as an iconic symbol for the city of Wilmington. With the ingenuity of having hot-dip galvanized grating, all 50,000 vehicles that cross the bridge daily can do so with the comfort of knowing that the bridge will be around for a while.

CHICAGO AVENUE BRIDGE

The Chicago Avenue bridge was built in 1914, and its central location in downtown Chicago makes it an important corridor that carries 20,000 vehicles and over 20,700 passengers on Chicago Transit Authority buses each day. So, when the City of Chicago determined that the original bridge needed to be demolished and replaced with an interim bridge—and completed within a three-month time period—it was essential for the project planners to come up with a solution to get the job done on time and resume traffic flow to this busy area of town.

According to the Chicago DOT, the original steel bascule bridge had deteriorated and been reduced to just one lane in each direction. The high-profile project required a durable coating in order to install a turnkey bridge quickly and be assured of the integrity



An interim bridge had to be constructed in three months' time to replace the original Chicago Avenue Bridge in downtown Chicago.



Thanks to galvanizing, the City of Chicago can extend the life of the temporary bridge if needed.

of the structure's coating system. Hot-dip galvanizing gave the fabricator, erector and contractor the flexibility to deliver and install the bridge expeditiously, without having to worry about damage to the coating or how it might look in the very populated area. The speed of installation and the characteristics of the zinc coating were vital to maintaining the timeline of the project.

While the temporary bridge calls downtown Chicago home for now until a permanent solution is chosen, there will be no maintenance required to the bridge coating—whether it stands for months or for decades to come. Aesthetically, the bridge blends into the bustling environment without the threat of unsightly corrosion. Even though the Chicago Avenue Bridge is intended to be only an interim bridge, the City of Chicago has the option to keep it in service for a longer period of time, if needed. **JPCL**

ABOUT THE AUTHOR



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STUDY OF STOCKPILED FUSION-BONDED EPOXY-COATED PIPE

Fig. 1: This shows stockpiled pipe in Saskatchewan.
FIGURES COURTESY OF THE AUTHORS

Part II: Influence of Ultraviolet Exposure

BY KEITH E.W. COULSON AND JAMES FERGUSON, TC ENERGY

A recent evaluation program by a pipeline owning and operating company in Canada was carried out on the coating integrity of stockpiled fusion-bonded epoxy-coated pipe in the United States for the expansion of the Keystone XL pipeline project. This program concluded that FBE pipe coatings from the outer layers of the stockpiles (with ultraviolet-protected whitewash coatings) maintained all but its elasticity characteristics, while the internally stored pipe that had been protected from the direct exposure to UV rays and weathering maintained all its original properties and performance levels. Field and laboratory appraisals demonstrated that the properties of the internally stored pipe coating mirrored those achieved during manufacture and hence the coating was still entirely compliant with the requirements and criteria of both company and national standards.[1]

The project comprises about 330 miles (530 km) in Canada, while the U.S. systems added just over 870 miles (1,400 km) of pipeline to connect with the U.S. refining hubs in Illinois, Oklahoma and the Gulf Coast of Texas. The FBE-coated pipe for the project was originally procured, manufactured and coated in 2009, 2010 and 2011. The pipe was then stockpiled in large quantities at several sites throughout Canada and the U.S. Once stockpiled, most of the FBE-coated pipe remained unused until an inspection and remediation program was initiated in August 2018.

This article describes the second portion of this overall refurbishment program of pipe stored within North America and deals specifically with pipe in Canada. In this part, the inspection and testing of each critical coating feature was conducted to assess the integrity of stockpiled pipe coating stored for nearly a decade throughout various sites within Western Canada. The determination of this optimum information could then be used to both examine the consequences of long-term storage on pipe coatings and to predict if the storage procedures rendered the FBE coating still "fit for purpose." The results of this engineering inspection approach of Canadian stockpiled pipe coatings were also compared and correlated to the

conclusions of the previous U.S. restoration study,[1] thereby determining if the practice of stockpiling pipe in the U.S. and Canada has the probability of producing varying or similar outcomes in respect to UV and weathering coating degradation.

EFFECTS OF UV EXPOSURE ON FBE COATINGS

As identified in the previous article, when exposed to UV rays, FBE coatings undergo polymer degradation commonly referred to as chalking. This phenomenon is common to all FBE coatings that are primarily designed only for below ground service. Kehr[2] stated that, if undisrupted, this layer of chalked FBE will protect the underlying FBE and enable the coating to retain most of its original properties. However, if this protective layer of chalked coating is removed, then the new surface will undergo this repeated process of chalking. Previous field studies[1,2,3] demonstrated that as this breakdown continues, it is accompanied by a noticeable reduction in coating thickness of between 10 and 40 microns per year. The actual degree to which this coating thickness reduction occurs depends on the following factors:

- Susceptibility of the FBE coating's formulation to resist UV breakdown;
- The amount of exposure to UV, which could be determined by the pipe's position in the stockpile and the duration of storage;
- The intensity of direct exposure to the elements (for example, intensity in areas of the southern U.S. would be far greater than those in Canada)4;
- Exposure to moisture due to rainfall; and
- Periods of protection from UV exposure by snow cover.

In all instances of direct FBE coating exposure to UV, there exists a reduction of the coatings' original flexibility when examined in accordance with the Canadian Standards Association Z245.20 cold temperature flexibility test method.[5] This aesthetic change of gloss is usually accompanied by an embrittlement of the coating as exhibited by loss of adhesion and as demonstrated by the dry adhesion test. As such any form of reduction of exposure to UV would be clearly beneficial in reducing or eliminating the UV damage to the polymeric structure of the FBE.

PIPE DATA AND STORAGE

Specific pipe sections representative of the pipe stocks was subjected to evaluation. The pipe and coatings conformed to the following specifications.

i. 36-in. (914 mm) OD × 0.465-in (11.8 mm). WT., API Spec 5L (44th Edition), PSL 2 PSL Grade X70 (483) SAWH pipe coated externally with FBE to the requirements of CSA Z245. 20 System 1A, but without the application of an acrylic UV deterioration mitigation system (herein referred to as whitewash).

ii. Same pipe and FBE coating but with an outer layer of a post coating applied whitewashed UV deterioration mitigation acrylic paint on exposed areas.

iii. All the pipe addressed in this Canadian study was manufactured in Japan and FBE coated in Canada. The subsequent whitewash coatings were applied in the field.

This piping was generally stored four or five high with 19 mm ropes used as separators (Fig. 1), and was stockpiled at locations in Alberta and Saskatchewan, Canada.

The whitewashed pipe in the storage facilities was estimated to constitute approximately 20% of the just over 28,000 joints of 78-foot (24-meter) pipe lengths that had been stockpiled for this project. This Canadian pipe had been stored for approximately 24–36 months before the first application of the whitewash coating. This coating was reapplied once after a period of about four years. In all cases, all the exposed areas of FBE coating were whitewashed with the exceptions of some uncoated windows to retain the external stencil and pipe identification markings on each pipe end. However, as the pipe markings were transposed to the internal surface as required by the CSA standards, most pipes were then fully whitewashed from FBE pipe cutback to cutback with UV-resistant acrylic paints. In most cases after recoating, the whitewash acrylic resin coating in the Canadian stockpiles appeared not to have significantly faded. This was unlike in the U.S. where significant whitewash fading was commonly observed. However, in some of the Canadian stockpiles there were some examples of whitewash adhesion failures and coating delamination, as shown in Figure 2. This whitewash coating delamination reduced the effectiveness of this whitewash to resist UV degradation as was exhibited by the loss of coating thickness at these specific locations



Fig. 2: This example shows damaged and spalling whitewashed acrylic coating over FBE-coated coated pipe at Shaunavon, Saskatchewan.



Fig. 3: This shows an example of whitewash acrylic coating in excellent condition at Shaunavon.

of delamination. While the root cause of this whitewash coating delamination was not firmly established, the probable causes of were likely pipe handling damage or most likely ineffective coating preparation or application procedures. But in general, the condition of the whitewash coating was still excellent even after nearly 10 years' exposure. An example of the excellent condition of the whitewashed coating in Canada can be seen in Figure 3.

The objective of this assessment was, first, to determine the effects in Canada that weathering had on the pipe underneath the whitewash, and to ascertain the quality of that FBE coating; and secondly, to establish a benchmark performance criterion for the coating on pipes that were stored internally in the stockpile and not exposed to UV. A coating inspection and test plan was prepared to assess the integrity of the pipe coating. The examination consisted of:

- FBE coating that had been coated with whitewash acrylic UV protective coatings; and
- FBE coating from pipes stored in the internal segments of the stockpile that was not exposed to UV.

The coating ITP stipulated the following testing activities:

- Document pipe numbers and their correlation to location in the stockpile for selected pipe piles;
- Assess performance of dry film thickness on selected pipe. Frequency and location on pipe to be determined and documented (for example, 12:00, 4:00 and 8:00 positions);
- Assess performance of DAT in accordance with ISO 21809-3: Annex Q: Adhesion Test;[6]
- Assess performance of holiday detection inspection on selected pipes; and
- Submit selected pipe for laboratory testing at laboratories in Canada.

The objectives of the assessment were:

- To enumerate the correlation between DFT and DAT techniques with the integrity assessment evaluations stipulated in CSA Z245.20-18;
- To conduct a series of laboratory testing to establish to the regulators' satisfaction that the dry adhesion and dry thickness testing does quantify the quality of FBE coatings being held at the stockpiles; and
- To confirm the expected conclusion that the whitewashed and non-UV-exposed FBE coating were still fit for purpose as below ground anti-corrosion coatings.

ASSESSMENT RESULTS

Initially, two of the pipes that had been whitewashed and stored on the outside layers of the stockpiles were removed for assessment. In addition, two joints that had not been whitewashed and stored in the interior of the stockpiles were also removed and assessed as specified in the ITP. The four joints were quarantined at the pipe coater's facilities and subjected to an intensive inspection for DFT along with dry adhesion testing. The testing was conducted inside the coating plant to minimize the effects of injurious inclement weather and provide consistent testing conditions (Fig. 4). The temperatures within the plant during this inspection process were consistently

Table 1: Dry Adhesion Testing on Pipe, Camrose, Alberta (Oct. 16, 2019)

Test Pipe No.	Date of FBE Application	Location	DAT, Near Pipe End	DAT, Pipe Middle	DAT, Far Pipe End	Range of FBE Thickness (Mils / Microns)	Whitewashed
DJ#1899	Sept 28, 2010	12:00	1	1	1	16.7-19.8 / 424-502	Yes
DJ#1899	Sept 28, 2010	4:00	1	1	1	15.4-18.5 / 391-470	No
DJ#1899	Sept 28, 2010	8:00	1	1	1	14.5-18.2 / 368-462	Yes
DJ#19640	Sept 27, 2011	12:00	1	1	1	17.3-20.5 / 439-520	Yes
DJ#19640	Sept 27, 2011	4:00	1	2	1	14.8-18.0 / 376-457	No
DJ#19640	Sept 27, 2011	8:00	1	1	1	15.5-19.3 / 394-490	Yes
DJ#8215	Oct 8, 2010	12:00	1	1	2	16.1-17.4 / 408-442	No
DJ#8215	Oct 8, 2010	4:00	1	1	1	15.1-18.8 / 383-478	No
DJ#8215	Oct 8, 2010	8:00	1	1	1	15.0-18.6 / 383-472	No
DJ#22659	Sept 19, 2011	12:00	1	1	1	15.5-19.0 / 394-483	No
DJ#22659	Sept 19, 2011	4:00	1	1	1	14.8-19.6 / 376-498	No
DJ#22659	Sept 19, 2011	8:00	1	1	1	15.0-18.1/ 381-460	No

recorded as being between 57 and 59 F (14 and 15 C); these temperatures were identical to the test temperatures in the U.S. evaluations.[1] These Canadian coated test pipes were then exposed to a subsequent laboratory evaluation.

The results of the DAT and DFT testing for all four pipe joints are given in Table 1. Basically, each joint was quarantined and tested at three separate locations along each pipe. At each location DAT and DFT testing was completed at the 12:00, 4:00 and 8:00 positions. This was repeated at locations near the end of each joint and at the midway location. All the piping that had been whitewashed still had acceptable coating thickness measurements. The company's coating specification stipulated a requirement of 356–506 microns of FBE coating during manufacture. A range of 401–502 microns was recorded on this whitewashed coating, putting it completely in the range originally stipulated for this coating. The only exception being on one sample, where one low reading of 368 mm was noted. The DATs performed on those whitewashed and non-whitewashed pipes consistently met the minimum requirements expected of this coating. Table 1 illustrates that all 36 DAT tests conducted on the four test pipes attained the acceptable DAT ratings of 1 or 2, with all but two of each of the tests producing a prefect rating of 1.

Test rings from each of these four pipes were then deemed as the focus for further laboratory testing. The test ring from each pipe was shipped to the pipe coater's laboratories in Edmonton for evaluation.

LABORATORY TESTING

The whitewashed and non-whitewashed coated pipe were assessed according to CSA Z245.20-18 criteria for the following properties:

- A 2.5-degree flexibility testing at -22 F (-30 C). If unsuccessful, reduced degrees of bend testing were introduced;
- A 24-hour cathodic disbondment test at 3.5 V and 149 F (65 C); and
- A 24-hour water soak adhesion test at 167 F (75 C).

Additional 1.5-degree flexibility at -22 F (-30 C) on three specimens (in accordance to TC Energy's requirements) was included to examine and check for any stress, strain or pigment migration markings.

As with the U.S. testing, the use of differential scanning calorimetry was not considered for this program because of the effects that moisture absorption has on providing misleading thermal test results.[7]

Results on UV-Exposed Whitewashed Pipe

With exception of the flexibility results, the testing of whitewashed pipe ends exposed to UV were deemed totally acceptable. The whitewash-protected coatings fared well with cathodic disbondment testing (CDT) results of between 4.4 to 5.2 mm disbondment (Fig. 5), and water soak adhesion ratings of 1. The flexibility tests were initially deemed failures on the UV-exposed whitewashed



Fig. 4: Test pipes were inspected at the internal coating plant in Camrose, Alberta.

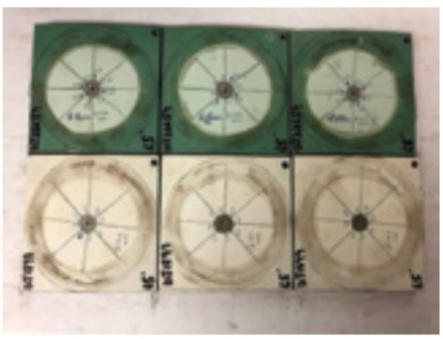


Fig. 5: Cathodic disbondment testing test specimens of whitewashed and non-whitewashed pipes exhibited excellent results.

Table 2: Test Results at Pipe Coater's Laboratories, Edmonton (Nov. 6, 2019)

Test	Pipe No.	Whitewashed	Results	CSA Z245.20-18	TC Energy
24-hr water adhesion at 167 F (75 C)	DJ#1899	Yes	1, 1, 1	1-3	1-3
24-hr water adhesion at 167 F (75 C)	DJ#19640	Yes	1, 1, 1	1-3	1-3
24-hr water adhesion at 167 F (75 C)	DJ#8215	No	1, 1, 1	1-3	1-3
24-hr water adhesion at 167 F (75 C)	DJ#22659	No	1, 1, 1	1-3	1-3
24-hr CDT at 149 F (65 C)	DJ#1899	Yes	4.6, 5.1, 4.4 mm	11.5 mm	5.5 mm
24-hr CDT at 149 F (65 C)	DJ#19640	Yes	5.0, 4.9, 5.2 mm	11.5 mm	5.5 mm
24-hr CDT at 149 F (65 C)	DJ#8215	No	4.4, 4.3, 4.5 mm	11.5 mm	5.5 mm
24-hr CDT at 149 F (65 C)	DJ#22659	No	5.4, 5.3, 4.5 mm	11.5 mm	5.5 mm
2.5-degree bend at -22 F (-30 C)	DJ#1899	Yes	Cracking	Fail	Fail
2.2-degree bend at -22 F (-30 C)	DJ#1899	Yes	Stretch Marks	N/A	N/A
1.7-degree bend at -22 F (-30 C)	DJ#1899	Yes	Pass	N/A	Pass
2.5-degree bend at -22 F (-30 C)	DJ#19640	Yes	Cracking	Fail	Fail
2.2-degree bend at -22 F (-30 C)	DJ#19640	Yes	Stretch Marks	N/A	Fail
1.7-degree bend at -22 F (-30 C)	DJ#19640	Yes	Pass	N/A	Pass
2.50-degree bend at -22 F (-30 C)	DJ#8215	No	Pass (no stress marks)	Pass	Pass
2.50-degree bend at -22 F (-30 C)	DJ#22659	No	Pass (no stress marks)	Pass	Pass

pipe (Figs. 6 and 7). The testing degree per pipe diameter length of pipe was reduced from 2.5 degrees to 2.2 degrees, but still showed some coating distress. However, at 1.7 degrees, the coatings demonstrated enough flexibility to pass the bend test when performed at -22 F (30 C).

It should be noted that the CSA flexibility test method reflects the temporary angle of deflection and not the total plastic or permanent bend or angle of deformation. In developing this test, Coulson and Temple[8] described the method in detail and explained that a percentage of overstrain applied in the laboratory bend test does not reflect those seen by the coating during cold field bend operations. As such, in the experiments conducted in this UV exposure study, it is critical to understand that the 2.5- and 1.7-degree CSA tests represent a plastic deformation of 1.9 and 1.1 degrees, respectively. Hence, by passing the 1.7-degree CSA cold bend test, the coating exhibits enough flexibility to successfully undergo a field bend of 1.1 degrees. Care must therefore be taken when interpreting these tests as simply substituting these laboratory test results for a projection of field bend performance, is an erroneous assumption. To correctly identify what coating materials can do in the field, there must be a proper and consistent analysis of the level of strain and the plastic deformation of the coating. This approach was applied in this study and, therefore, the forecasted compatibility of the coating materials to mimic field performances may be perceived as being correct.



Fig. 6: This shows a 50X side view of whitewashed, 2.5-degree bend exhibiting through coating cracks.

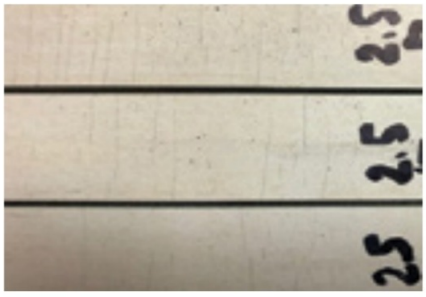


Fig. 7: Bend samples show cracking of the whitewash coating at 2.5 degrees of bend.

The whitewashed coatings in the U.S. that were exposed to UV suffered significant reductions in their flexibility performance. However, after the same period of weathering, the exposed whitewashed coatings in Canada appeared to retain nearly 60% of their original elastic characteristics. The possible causes for this variation in outcomes will be discussed in more detail in the section detailing the observations of these assessments.

Results on Non-UV-Exposed Pipe

Overall, the laboratory test results on non-ultraviolet exposed pipe test proved to be excellent. The results are given in Tables 1 and 2, and clearly demonstrate that the FBE coating that was not exposed to UV or weathering was still totally fit for purpose and retained all the properties it exhibited at its production. Examples of CDT test results for of both whitewashed and non-whitewashed coating are shown in Figure 5.

OBSERVATIONS FOR CANADIAN STOCKPILED PIPES

Canadian stockpiled coated pipe that was tested from the internal areas of

the stockpile, and thus not exposed to weathering, was deemed to be totally fit for purpose by passing all the required CSA tests.

In Canada, the whitewash coating exhibited good retention of coating thickness, dry adhesion properties and cathodic disbondment and hot water soak adhesion characteristics. However, the flexibility of the underlaying FBE was slightly affected; but unlike that in the southern U.S., not to the point where the coating was no long acceptable for exposure to field bending. The depression of the coating's flexibility levels could have been caused by the following combination of events.

1. As stated by Evans,[9] the alternate absorption of moisture in damp weather and its release in dry weather may have serious effects on the coating properties. While this was true for both Canada and the U.S., the protective layer of snow in the winter reduced these fluctuations in Canada and hence diminished the impact of this moisture absorption phenomenon. The elevated temperatures in the U.S. would also accelerate those moisture absorption and release cycles leading to far earlier breakdown of the underlaying FBE coating than was noted in Canada.
2. Figures 8 and 9 illustrate the difference in the condition of the coating when stored in Little Rock, U.S. and Camrose, Alberta, Canada. The blanket of snow in Canada acting as nature's "sunscreen" in reducing the intensity of the UV rays and inhibited the moisture absorption and release cycles that were more prevalent in the Little Rock facility.
3. Another factor, according to the study conducted by National Institute of Water and Atmospheric Research, Lauder, Central Otago, New Zealand,[4] the levels of UV intensity in Canada are far less than those recorded in the southern U.S., hence leading to a quicker breakdown of exposed FBE coatings in the U.S. than in Canada.

Hence, reduced levels of moisture absorption; a sunscreen of snow; and less intense UV rays in Canada, are the factors that most probably contributed to the lower level of injurious weathering effects suffered by Canadian pipe coatings during storage.

The whitewashed protective coating in Canada was originally applied some months after the pipe was coated. In the intervening years, there was only one other application of this whitewash coating. However, unlike in the U.S., where the whitewashed coating suffered significant fading, even after four to five years' exposure to the elements, the whitewash coating in Canada appeared generally in very good condition (Fig. 3). It is therefore unlikely that in Canada any additional



Fig. 8: Pipe was stockpiled at Camrose in November 2019; note the UV-protective coverage of snow.



Fig. 9: Pipe was totally exposed to the elements with no UV protection at Little Rock, October 2018.

applications of whitewash coatings would have contributed to a total retention of the elastic properties of the parent FBE coating.

CONCLUSIONS

With the exception of the reduction of some of its flexibility, whitewash-protected FBE coatings exposed to UV in Canada for periods of up to 10 years, retained much of their original properties and attributes. FBE coatings that were completely protected from any UV exposure still possessed entirely all of their original coating thickness and physical traits.

Even after nearly a decade, the use of whitewash UV protective coatings in Canada has proven to be extremely successful in preserving and retaining the original DFT thicknesses of the coating. Apart from the slight reduction in the elasticity of the coating, whitewash UV protective coatings preserved many of the physical characteristics of the underlaying FBE coating. Unlike in the southern U.S., the whitewash coated pipe stockpiled in Canada appeared to retain enough flexibility properties to enable the pipe to be classified as fit for purpose. Obviously, the lower intensity of UV levels in Canada, as contrasted to those in the southern U.S., played a part. The fact that the Canadian pipe was covered with snow for at least a few months of the year also resulted in reduced UV exposure to the underlaying FBE coating and hence were less liable to the embrittlement seen in the U.S. **JPCL**

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INDUSTRIAL CLEANING AND COATING DRONES

A Look at What's Coming in 2021

BY ROBERT DAHLSTROM, APELLIX; AND MICHAEL HINDMARSH, AKZONOBEL

The protective coatings world is undergoing a radical shift in corrosion protection, prevention, and control as it moves into the digital age. This transformational change is especially evident with the advent of robotics, particularly for use at height and "off the ground." Cleaning, coating and nondestructive testing of corrosion-susceptible and other surfaces at industrial sites requires extensive manual labor, often at elevations that create a dangerous occupational environment. Drones, also known as unmanned aerial systems, can be leveraged to perform some of these tasks, including cleaning and coating while keeping workers safely on the ground. Drone capabilities have significantly evolved over the past few years, and the ubiquity of these systems will continue to increase in the years to come.

While no cleaning or coating drones were commercially available at the time of this publication, one aerial robotics company—as part of a joint development with a large worldwide paint manufacturing company—developed a prototype spray painting drone that is expected to start tests with select industrial end users in 2021. This prototype aerial robotic spray-painting system is a custom-manufactured drone with a tether that delivers power and coating material from the spray compressor, coatings reservoir and power source on the ground.

That same aerial robotics company has also developed a cleaning "soft wash" system capable of limited cleaning for surface preparation (Fig. 1). The company also currently has a product on the market for contact-based corrosion measurements and visual assessments. All three systems—cleaning, coating and measurement—use an onboard computer and an array of various sensors and custom software to manage flight navigation and operations.

While the utilization of this new technology faces many challenges, it is important to recognize the potential and projected growth of such systems and their impact on the protective coatings industry. This article presents an introduction to the current state of cleaning, coating and measurement drones, along with limitations and benefits these systems can provide to the coatings industry.

CURRENT CAPABILITIES IN THE COATINGS INDUSTRY

Presently, drones have proven to be very useful in conducting visual corrosion inspections. Drones can also "merge" with robots with a robotic arm and hand (also called an end-effector) that can complete contact-based nondestructive testing and evaluation (Fig. 2). NDT is a group of techniques used to analyze and evaluate the properties of a materials, components or systems without causing damage. Three common NDT methods are ultrasonic (UT



Fig. 1: This shows the proof-of-concept version of the cleaning drone in action.
PHOTOS COURTESY OF THE AUTHORS

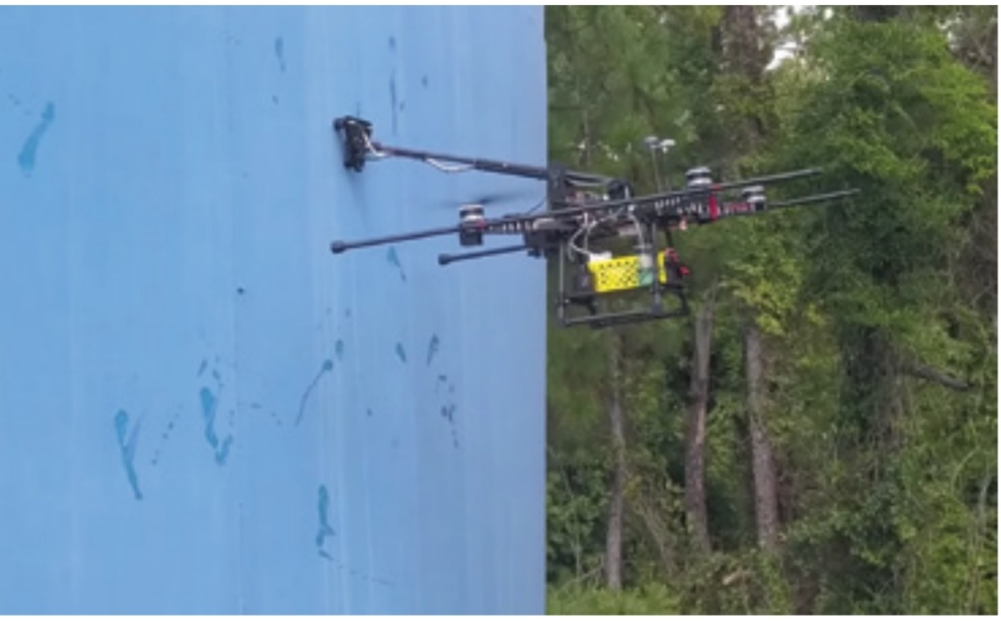


Fig. 2: The NDT measurement drone flies close to the structure and uses a robotic arm to make contact with the surface.

wall thickness), eddy current (DFT coating thickness) and visual testing.

Use of these systems can free inspectors from having to climb built-in ladders, erect scaffolding, use a lift, or employ other potentially complicated and costly access methods to take measurements. This can be especially valuable in situations such as obtaining visual assessment data and steel thickness measurements on in-service oil and gas assets such as flare stacks, storage tanks and the like.

These systems can quickly gather both visual and NDT data, obtaining high-definition video of the entire flight and up to 120 UT readings and 200 DFT readings per hour from physical contact during flight (Fig. 3). They are designed to work at heights up to 328 feet (100 meters) and allow real-time reposting of the findings as well as post-flight data analysis, including data to help create digital twins (Fig. 4).

Aerial robotic inspection and measurement systems hold the potential to perform jobs safer, better and faster than completing the same tasks with people.

Ultimately, though, it's all about the data that these systems are capable of generating. Because drones are, essentially, flying computers, they can acquire a considerable amount of data. For example, the UT measurement drone not only gathers the UT measurements, but also captures a digital record of the UT area number, UT condition monitoring location number, the UT thickness measurements and geolocation information. Further data gathered from high-definition cameras can include visual, hyperspectral, superspectral and other imaging data. This can be made available to aerographic services that utilize 3D and other computer vision, various AI, machine vision, computational geometry, simultaneous localization and mapping, live 3D point clouds, stereoscopic real-time video photogrammetry and other mature and evolving technology innovations.



Fig. 3: The measurement drones are also equipped with HD cameras that can capture detailed visual condition assessment data.



Fig. 4: This is an example of UT reading locations and minimum thickness measurements on an in-service flare stack.

TETHERED CLEANING AND COATING PREPARATION DRONES

Using the technology developed for the NDT aerial robotic systems—especially the precision flight control—a drone-based cleaning system is currently in the proof-of-concept stage, using a more powerful heavy-lift aircraft. While the NDT systems described above have approximately 55 pounds (25 kg) of lift, the proof-of-concept soft wash system has close to 110 pounds (50 kg) of lift.

Aircraft this large require huge amounts of power as they are heavy, are lifting a lot of weight and are subject to forces exerted by the spray wash as it pushes the aircraft away from the structure it is working on. While the previously mentioned NDT systems have a power tether option, the power consumption needs for their configuration (four arms and four motors attached to the airframe) are fewer, with 3,000 watts of onboard power for the drone and any accessories. In comparison, the heavy lift soft wash system makes 10,000 watts of power available onboard for its eight motors and onboard accessories. The ground-based power supplies on these systems require 230 volts AC power. Onboard the aircraft are emergency battery backup systems capable of about eight minutes of flight time in case of power stoppage from the ground (for example, if the generator runs out of fuel).

> "Aerial robotic inspection and measurement systems hold the potential to perform jobs safer and faster than completing the same tasks with people."

The heavy lift soft wash drone uses the previously developed stabilization and navigation technology developed for the NDT and the spray-painting drone systems. The robotics company that has been developing these systems has also developed and written the custom software the systems require.

The proof-of-concept soft wash system has been tested with a solution of 11% sodium hypochlorite (NaClO - bleach) at a flow rate of approximately 8 gallons per minute (30 liters per minute), 80 bars of pressure (approximately 1,200 psi) and up to 66 feet (20 meters) in height, with cleaning and rinse materials pumped to the aircraft via the tether. The system was designed for mold and mildew removal and remediation on elevated water storage tanks by spraying a stream of NaClO on the surface and following with a wash of water to dislodge and rinse off the dead mold/mildew.

In addition to the soft wash applications, chemical washes or even plain water rinses extend the usability of these systems—and depending on variables such as the water pressure, volume and height, it can enable some level of surface cleaning or surface preparation prior to the application of coatings. It will be interesting to see how this innovation develops and how long it will take to enable limited blasting brush-off blast-cleaning of steel surfaces with abrasives at an SSPC-SP 7/NACE No. 4 level.

TETHERED SPRAY-PAINTING DRONES

The spray-painting drone has been under development as part of a joint development agreement with a large global paint company that started in 2019 (Fig. 5). While much has been accomplished, there is much development remaining. Just as the data generated is key for the NDT measurement drone systems, the data is equally critical for the spray-painting drone, especially when it comes to protective coatings. For example, knowing the environmental variables such as ambient temperature, relative humidity and barometric pressure are necessary for precision coating applications where the thickness of the applied paint is measured in mils.

Aerial robotic spray-painting systems have the potential to improve the efficiency and efficacy of the coating process while simultaneously allowing the collection of data from a process in which almost no data is currently collected. As this technology matures, it will provide an easier, faster and safer method to spray paint structures at height while affording the ability to expand the science of coatings by collecting data from locations and situations where data was either inaccessible or difficult to obtain due to access issues, safety considerations and so on.



Fig. 5: The spray-painting drone is currently under development under a joint agreement between an aerial robotics manufacturer and a large global coatings company.

The aerial robotic spray-painting system has a ground-based power supply, ground-based spray paint pump (an "airless" sprayer), a tether for the paint and power, and a drone outfitted with sensors and flight control software with an onboard computer enabling it to apply coatings to a structure up to approximately 328 feet (100 meters) tall.

Presently, the spray painting processes at height require workers, who hold the spray gun and the attached supply hose connected to the pump on the ground (or sometimes on a platform on a lift), to access the work site using scaffolding, lifts or cherry pickers, ladders and other access methods that can potentially put the operator at risk.

Early manual flights quickly showed the importance of computer control. Precision flight with tight flight parameters require a lot of software to be contained within the drone. Additionally, drones were not designed or intended to fly close to or come in contact with structures and those limitations had to be overcome.

A drone basically needs three things for safe flight and operations:

- Location—The drone gets this from GPS technology, but if operations are

taking place behind an above ground storage tank, the drone may not be in range of GPS satellites;

- Direction—The drone gets this from magnetic north, but when operations are next to a large ship or large amounts of metal, the compass will believe the metal is north; and
- Altitude—Just like with airplanes, drones use barometric pressure readings for altitude; however, when operations are in close proximity to a wall or other surface, the barometric pressure readings will be incorrect.

To compensate for these limitations and to enable the exacting precision needed, the spray-painting drone is equipped with an array of multimodal sensors, computers, processors and software to enable the precision flight required to spray paint from an aircraft.

A robotic system differs from human painters in multiple ways—one of which is the system's ignorance of the outside world. Human painters are good at what they do, sometimes working intuitively to optimize the distance and speed of the spray wand, deciding which spray tip and what spray pressure to use and more. For a robotic system to be "as good as or better than a human," it first needs to be able to calculate the best parameters for a good spray fan.

When applying paint, by any method, it is essential to achieve a good coverage at the correctly specified thickness. For spray application, this is particularly important. The key to spray painting is the atomization of the coating. This has an impact on the coalescence of the applied film, the ability to achieve a consistent film thickness over the full surface area to be coated, and it may ultimately have an effect on the final aesthetics of the finished application. No one wants to see areas of low film thickness with low opacity, or indeed areas of high film thickness which may cause runs in the final film and in some cases may lead to cracks forming.

Film thickness and film build are controlled by choosing the correct tip and optimizing the spray pass velocity. The consistency of the film build is achieved by controlling the gun orientation and angle to the substrate, as well as understanding what areas have already been sprayed (especially in same color on color applications). Being able to do all of this, time and time again with accurate and precise reproducibility, is essential.

Since spray painting was invented, the industry has relied on human beings to interface between the pressurized atomized paint from the spray gun to the substrate. We have created an army of highly trained professional paint applicators. However, spraying paint is not the most glamourous of professions and if we start to lose the ability to recruit



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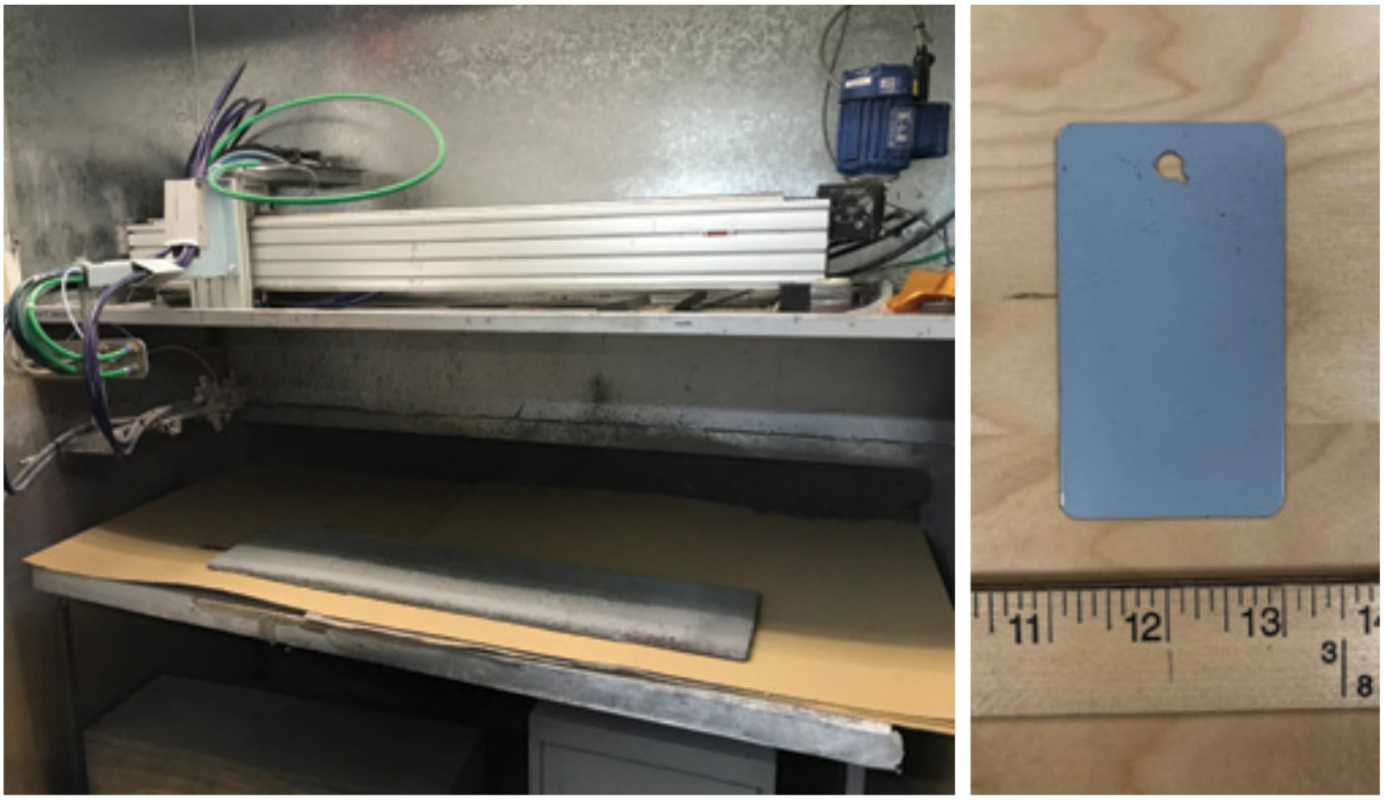


Fig. 6: Testing was performed using a custom spray rig (left) and steel test panels (right) to equip the spray-painting drone with the optimal spray fan pattern.

people into the industry, then we may end up with lower levels of quality. Paint failures in service are generally associated with poor application rather than product failures.

Even the most well-trained and experienced professionals can encounter some potential application issues, including:

- Maintaining perpendicularity;
- Triggering the gun at the start of each pass and untriggering at the end of the pass, which is not only good practice, but is vital to ensure consistent film thickness;
- Knowing what has already been applied, especially when using same colors;
- Moving between one area to another from heights of up to about 65 feet (20 meters) in the air; and
- Combatting tiredness or fatigue, which can cause a reduction in quality.

A spray-painting drone doesn't suffer from any of these issues. Give it power and paint and it will do what it is told without any reduction in performance.

The importance of getting optimum film performance has already been mentioned, but it bears repeating. Coating companies spend millions of dollars developing high-performance coatings, and this performance has been optimized for film thickness or number of coats. We know how professional painters achieve film thickness control, but what about the robot or drone?

> "Give [the spray-painting drone] power and paint and it will do what it is told without any reduction in performance."

In the development of the spray-painting drone there were a number of steps taken to attempt to optimize the parameters for a good spray fan pattern using an aerial robotic system to apply the coatings. A custom jig system was built to allow controlled parameters within a controlled environment. The jig system could, for example, be placed a measured and consistant distance from the surface, and the spray tip held constant. The speed of the spray gun could be moderated. The jig was inside a large warehouse to isolate it from many environmental variables such as wind and humidity.

To achieve the best parameters before testing outside on the aerial robotic system, the jig was used to measure practical spray fan characteristics and results under controlled "laboratory" conditions. Panels were used to measure both the wet film thickness and the dry film thickness of the applied coatings (Fig. 6).

Each paint or coating is specifically formulated, and each has its own specific set of application parameters (optimized by the supplier and listed on the technical data sheets supplied). These include:

- Recommended pump pressure;
- Recommended tip size;
- Film thickness to be applied; and
- Pass velocity (normally "learned" by the paint sprayer, but can be fully "dialed in" for the drone).

Once the parameters are known, they are transferred to the brain of the drone. The drone then controls distance from the substrate,

perpendicularity and the desired pass velocity. Once programmed, it just keeps on going.

In the initial prototype phase of the spray-painting drone joint development project, some very impressive results have been achieved. The system can maintain the pass velocity accurately. Distance from the substrate is controlled by sensors within the desired limits, but more can be done that will improve the system. The perpendicularity has been verified from the onboard video footage and analysis of the coating. The width of the fan is as expected from the precision airless spray tips. There is a slight difference in the final film thickness than what was expected, as the DFT measurements tended to be on the low side. It is suspected this has more to do with the fact that optimization was done indoors on a spray jig with no external air movement, whereas in reality the spray-painting drone encounters air movement from being outdoors. This has been factored in for further iterations.

While the utilization of this new technology faces many challenges, it is important to recognize the potential and projected growth of such systems. The drone-based coating system discussed here shows a sophisticated attempt to measure and determine the variables for the "perfect fan" for an airless spray paint system. Thus, the current state of spray-painting drones show definite promise and quantifiable measurements as to the efficacy of the coating thickness, demonstrating that there is much promise for these systems in the future.

As this technology matures it will provide an easier, faster and safer method to spray paint structures at height while affording the ability to expand the science of coatings by collecting data from locations and situations where data was either inaccessible or difficult to obtain.

WHAT TO EXPECT IN 2021

The three drone systems detailed in this paper—cleaning, coating and measuring—demonstrate a radical shift in corrosion protection, prevention and control for protective coatings. The use of the disruptive technology of aerial robotic systems for use at height is a transformational change with the potential to change how we think about coatings and quality. Cleaning, coating and nondestructive testing of corrosion-susceptible and other surfaces at industrial sites with these aerial robotic systems has profound safety and quality implications and can completely change our performance assumptions and assumptions regarding costs of application, as well as scheduling. Early evidence also indicates these systems can increase transfer efficiency, decreasing adverse impacts on the environment. **JPCL**

ABOUT THE AUTHORS

Robert Dahlstrom is the founder and CEO of Apellix. He has been an active member of SSPC, NACE, the Society of Petroleum Engineers, the American Society for Nondestructive Testing and the IEEE Robotics and Automation Society. He holds a Bachelor of Science degree in industrial and organizational psychology from California State University – East Bay and an MBA from Florida State University.



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CALENDARS



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2021 INDUSTRY CONFERENCES & EVENTS

Information is current as of press time and is subject to change.

April 19–30	CORROSION 2021 Virtual Conference & Expo; nacecorrosion.org
April 27–30	PCI Powder Coating Week, Renaissance Orlando at SeaWorld, Orlando, FL; conference.powdercoating.org
June 7–10	International Bridge Conference, Gaylord National Resort & Conv. Center, National Harbor, MD; eswp.com/bridge
June 7–10	World of Concrete 2021, Las Vegas Convention Center; Las Vegas, worldofconcrete.com
June 9–11	Eastern Coatings Show 2021, Harrah's Resort Atlantic City, NJ; easterncoatingsshow.com
June 13–16	AWWA ACE 2021 (In-Person and Online), San Diego; awwa.org/ace
June 15–17	Middle East Coatings Show 2021, Dubai International Convention & Exhibition Center, Dubai; coatings-group.com/mecs/dubai
Sept. 1–3	Asia Pacific Coatings Show 2020, PT Jakarta International Expo, Jakarta, Indonesia; coatings-group.com/apcs/jakarta
Sept. 14–16	European Coatings Show 2021, Exhibition Center, Nuremberg, Germany; european-coatings-show.com
Sept. 21–23	MegaRust – East Coast, Hampton Roads Convention Center, Virginia; navalengineers.org
Oct. 16–20	WEFTEC 2021 Conference & Exhibition, McCormick Place, Chicago; weftec.org
Oct. 17–20	Western Coatings Symposium 2021, Paris Las Vegas Hotel & Convention Center, Las Vegas; westerncoatings.org
Oct. 26–28	2021 WJTA Conference & Expo, New Orleans; wjtaexpo.com
Dec. 1–3	International WorkBoat Show, New Orleans; workboatshow.com
Dec. 13–16	SSPC Coatings+, Phoenix Convention Center, Phoenix; sspc.org/coatings-2021

SSPC COURSES

FEBRUARY 2021

Course information available at sspc.org

Feb. 1–5	Coast Guard Basic Pt Insp, Norfolk, VA
Feb. 1–5	NBPI NAVSEA Basic Pt Insp, San Diego
Feb. 1–7	PCI Prot Ctgs Insp, La Porte, Texas; Greensboro, NC
Feb. 8–9	C7 Abrasive Blast, Paterson, NJ
Feb. 8–10	CAS Ctg Application Splst, Portsmouth, VA; San Diego
Feb. 8–11	C3 Lead Pt Removal, Marlborough, MA
Feb. 8–12	Concrete Ctg Insp Program, LaPorte, Texas
Feb. 8–12	NBPI NAVSEA Basic Pt Insp, Norfolk, VA
Feb. 8–14	PCI Prot Ctgs Insp, Pompano Beach, FL
Feb. 8–20	PCI Prot Ctgs Insp, Surabaya, Indonesia
Feb. 10–11	C12 Spray App, Paterson, NJ
Feb. 12	C5 Lead Pt Refresher, Marlborough, MA
Feb. 15–18	CAS Ctg Application Splst, Glendale Heights, IL
Feb. 18	Thermal Spray App Training, San Diego
Feb. 19	Thermal Spray Insp Training, San Diego
Feb. 22–23	SHIPBOARD Surface Prep & Pt App, Ketchikan, AK
Feb. 22–26	C1 Fundamentals, South Boston, VA
Feb. 22–27	BCI Bridge Ctgs Insp Program, Paterson, NJ

37 YEARS

The tenure that JPCL served as the official voice of SSPC; JPCL announced the end of the affiliation last month, after SSPC and NACE International combined to form the Association for Materials Protection & Performance (AMPP). *See p. 5*

840 F

The temperature of the molten zinc bath used for the hot-dip galvanizing process for steel. *See p. 13*

60%

The percentage of PaintSquare Poll respondents who believe a new, U.S. Navy-led research competition will lead to development of new coating materials. *See p. 12*

15,000 TONS

The amount of steel that was hot-dip galvanized during construction of the New Champlain Bridge in Montreal, which replaced an older bridge that had fallen victim to corrosion. *See p. 17*

1,200 MILES

The length of new pipeline being constructed for the Keystone XL expansion project in North America; a pipeline owner and operator recently evaluated the performance of coatings on stockpiled pipe to be used for construction. *See p. 22*

300 FEET

The approximate height that a prototype aerial robotic spray-painting drone can reach, potentially keeping workers from having to apply coatings at such heights. *See p. 29*