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THE VOICE OF SSPC

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The Society for Protective Coatings

FEATURES



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DOWN THE HOLE WITHOUT A PADDLE
CORROSION MITIGATION OF WELLHEAD SURFACE CASINGS USING IMM COATINGS

Nicole de Varennes, P.L. (Eng.), IRISNDT Ltd; Mike O'Donoghue, PhD, and Vijay Datta, MS, International Paint LLC; and Norm Spence, Spence Corrosion Ltd.

A key component of oil and gas wells are the wellheads, which provide both the structural and pressure-containing interfaces for drilling and production equipment. Most corrosion mitigation procedures for wellhead surface casings have been met with limited success, but in the past five years, an idea that originated from the proven performance of a novel high-temperature inert multi-polymeric matrix (IMM) coating for mitigating corrosion under insulation has changed this picture dramatically. The authors explain this coating technology, which many oil producers have successfully trialed and adopted for existing wellhead surface casings.

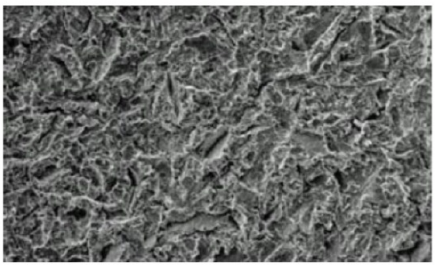


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STUDY OF STOCKPILED, FUSION-BONDED EPOXY-COATED PIPE

By Keith Coulson, James Ferguson and David Milmine, TC Energy

For a major new North American oil pipeline project, pipe was originally procured, manufactured and coated, then stockpiled in large quantities at several sites. The majority of the pipe stored in the outer layers of the stockpiles was coated with a whitewash acrylic resin coating to reduce or eliminate the effects of UV degradation. The inner piping at the stockpiles was not protected, as it was determined that the overlaying whitewashed coated pipe would eliminate the influence of UV degradation. This article describes the testing program developed to assess the integrity of the coating on the stored pipe, and to determine its fitness for purpose as a pipeline coating.



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UNDERBLASTED AND REBLASTED CARBON STEEL SUBSTRATES
TOPOGRAPHICAL AND PERFORMANCE EFFECTS

By Carl Reed, GPI Laboratories, Inc.; and Kat Coronado and Heather Cui, International Paint, LLC

Previous studies by the authors examined the effect of remedially blasting a previously prepared steel surface that had a profile that exceeded specification, as well as the effect reblasting might have on the corrosion resistance after a coating is applied to a steel surface. This article looks into the effects of remediation of a below-specification blast profile on a steel surface is examined by using test panels that were prepared using steel grit abrasive and coal slag abrasive at below-specification profile, at specification and remediated.

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OSHA on the Front Line

Recommended Practices for Safety & Health Programs

BY MICHAEL DAMIANO, SENIOR TECHNICAL ADVISOR, SSPC

For newly established painting contractors who need to develop a viable safety program, or for those existing contractors who want to revamp and improve how they practice safety, a good place to start is with OSHA's "Recommended Practices for Safety & Health Programs in Construction" (OSHA 3886, October 2016).

The focus of OSHA 3886 is to provide guidance for developing a proactive, rather than reactive, approach to jobsite safety and health. These recommended practices, says OSHA, reflect what the Administration has learned about the key components of best-in-class programs for small- and medium-sized construction contractors.

These recommended practices emphasize effective ways to manage a successful program, rather than telling the contractor what specific "rules" and "procedures" to place in a safety and health program. Painting contractors, who generally have safety professionals on staff, can write their own procedures by carefully reviewing all OSHA regulations applicable to their operations; safety data sheets for materials that they use; safe operating procedures for equipment they have on their jobsites; industry standards; and contractor certification standards, such as SSPC-QP 1 and QP-2, if the contractor intends to become certified. Management can also hire a qualified consultant familiar with industrial painting operations, such as a Certified Safety Professional, Certified Industrial Hygienist or Safety Trained Supervisor-Construction, to draft specific safety procedures.

Regardless of what the procedures say, the burden of successfully implementing and continually evaluating the effectiveness of the program while under constant production pressures to run a profitable job—and to deal with unforeseen circumstances such as the current COVID-19 pandemic—falls squarely on company leadership, and that's where these recommended practices come in to play. The best-written safety program will be ineffective if not routinely given "top-billing" by management as the company "value," implemented as designed or consistently evaluated for effectiveness.

OSHA 3886 describes seven core, interrelated elements, that add up to creation of a successful program:

1. Management Leadership;
2. Worker Participation;
3. Hazard Identification and Assessment;
4. Hazard Prevention and Control;
5. Education and Training;
6. Program Evaluation and Improvement; and
7. Communication and Coordination for Employers on Multi-Employer Worksites.

Because contractors and jobsites are different, it is important to keep in mind that the core elements are general in nature and need to be adopted to fit each company's practice.

MANAGEMENT LEADERSHIP

This element requires top management to demonstrate its commitment, in writing, to safety, and to make sure that commitment is communicated regularly to its workforce using whatever methods available to the contractor. Today's technology gives management numerous options to communicate safety and health "news" to its workforce. Examples include creating well-designed job posters in the work trailer that catch the crew's attention; sending group text messages, emails or both using language workers can understand; and

providing key field personnel with laptops or mobile devices.

Management leadership also means establishing safety goals and setting a good example. Owners and managers who work primarily in the office should visit the company's jobsites as often as feasible to personally evaluate operations and show work crews that management cares about their safety and health. When visiting jobsites, management must set a good example by following the same rules and wearing the same PPE required of the work crews on these sites.

Make safety a company "value," so that workers realize that above all else, ending each work shift safely is the company's top concern. Ensure that safety and health items are included in all job estimates. Employ progressive discipline for employees who violate company policies.

WORKER PARTICIPATION

This element makes sure that workers and their representatives, if applicable, are involved in all aspects of the program. Workers can be key in such areas as identifying hazards and recommending solutions, assisting with investigations, and being involved in revisions to procedures in general—when they are encouraged by management to say what they have to say with regard to safety, without fear of retaliation.

Also, consider giving your employees temporary stop-work authority if they see a potential safety issue or observe an unsafe condition. Develop incentives that recognize successful behavior by the workforce, while at the same time incentivizing personnel to report program shortcomings. Involve workers at all skill levels in creating solutions. Post information about whistleblower policies in languages your workforce understands.

HAZARD IDENTIFICATION AND CONTROL

This element calls for standardizing procedures, such as creation of an initial Job Hazard Analysis at job startup, followed by amending the JHA for different phases of a job. Once the JHA is developed and the hazards are documented, determine how to control them and then communicate the plan to worksite personnel. Once production is underway, incidents should be investigated, and root-cause analysis performed to identify what went wrong, followed by making program changes to avoid recurrence.

HAZARD PREVENTION AND CONTROL

For this element, management and workers cooperate to identify and select methods for preventing, eliminating or controlling job hazards. Controls are selected according to OSHA's hierarchy of controls, with engineering controls first and PPE last, but not least. Sites are inspected daily to confirm whether the hazards are being effectively controlled.

EDUCATION AND TRAINING

Management commits to training all workers under its control on the company's safety program. Managers are trained to assess risk and learn to implement the safety program through such courses as SSPC's Industrial Coating Safety Management Training, which discusses many of the recommended practices in OSHA 3886 as they apply to industrial coating operations; or OSHA 30, which covers basic OSHA requirements. Workers are trained on the hazards of each job, as well as general safety training such as OSHA 10. The education and training should go beyond the specific training required by contract. Toolbox talks, in language the workers understand, and short demonstrations are useful ways to keep current safety topics on each worker's mind during production.

PROGRAM EVALUATION AND IMPROVEMENT

Data on lagging indicators (such as EMR, OSHA Incident Rates and the nature of losses experienced) and leading indicators (such as site inspections, reporting of concerns, incidents and near misses) is collected, and trends are analyzed to see whether the safety program is working. Program changes should be made when shortcomings are discovered. This process involves getting managers, supervisors and workers together to go over changes such as purchasing new or different equipment, changing procedures that are not working as well as predicted, and setting new goals so that the message doesn't get stale.

COMMUNICATION AND COORDINATION FOR EMPLOYERS ON MULTI-EMPLOYER WORKSITES

All decision-making managers on a jobsite (including the GC, subcontractors and staffing agencies) hold regular communication through site safety meetings, conflict resolution meetings, routine progress meetings, and jobsite postings on safety rules so that all personnel on the jobsite are on the same page regarding safety. In the protective coatings industry, a painting contractor is often a subcontractor, but on occasion can be the prime contractor. Coordinated, frequent, strong and clear communication amongst all trades is crucial for jobsite safety as crews from one trade are not going to know what crews from other trades and contractors are going to be doing onsite—unless that information is communicated without hesitation. All parties need to continually inform each other of non-routine operations, emergencies and changes in conditions.

THE BENEFITS

OSHA says that implementing these recommended practices can bring a multitude of benefits to the contractor, with the main benefit of avoiding severe accidents that cause pain and suffering for the injured workers and their families, as well as financial devastation, untold damage to the contractor's reputation and potential loss of business.

In a study of Ohio contractors who participated in OSHA's Sharp program in 2011, a program that incorporated similar recommendations to those in 3886, results showed that:

- The average number of claims decreased by 52%;
- The cost per claim decreased by 80%;
- The average lost time per claim decreased by 87%; and
- Claims per million dollars of payroll decreased by 88%.

SSPC Releases New E-Course on Using SSPC-PA 2 Effectively

BY BREE MCCULLOUGH, MULTIMEDIA SPECIALIST, SSPC

The SSPC-PA 2 standard, "Procedure for Determining Conformance to Dry Coating Thickness Requirements," is SSPC's most downloaded standard to date and is one of the most specified standards in the protective coatings industry for frequency and acceptability of dry-film thickness measurements.

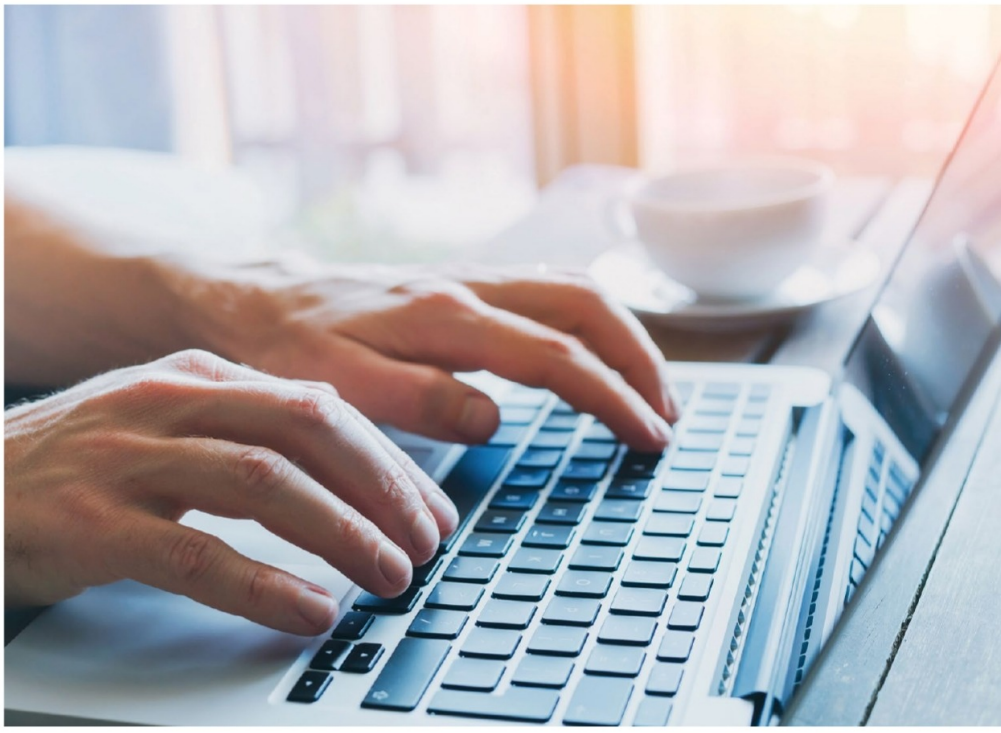
Widely used but highly technical and complex, it can be misinterpreted if not studied carefully. Yet, its very complexity has made it the perfect subject of SSPC's first multimedia e-course.

"Using SSPC-PA 2 Effectively" is a new SSPC e-course featuring video lessons taught by Bill Corbett, Chief Operations Officer for KTA-Tator, Inc., and Chair of the SSPC Education Committee as well as the SSPC Dry Film Thickness Committee responsible for the SSPC-PA 2 standard.

"The purpose of any training is to change behaviors and take a willing learner from the current state of what they know and how they think, feel and do to a new and different state," said Corbett. "This e-course is designed to close the gap between what a learner currently knows about measurement of dry-film thickness and what they need to know to maintain competence and professionalism in the coatings industry."

In the course's video lessons with supporting animations, Corbett teaches how to complete gage readings properly on test panels and at the jobsite. This ensures that students gain valuable practice in verifying gage accuracy, taking spot and area measurements, and determining the extent of nonconforming areas. In the virtual workshops, students perform necessary calculations, examine coating thickness restriction levels and determine measurement frequency.

"Using SSPC-PA 2 Effectively" also details several of the standard's non-mandatory appendices, including frequency of spot measurements on pipe spools, test panels and coated steel beams and pipe sections, as well as using a scanning probe. This visual approach engages those who use the standard in an accessible way, giving them more confidence as inspectors.



ANYABERKUT / GETTY IMAGES

"The visual examples of instrument use provide context for the written instructions in the PA 2 standard," said Pamela Groff, SSPC Training Materials Development Specialist. "These videos bring the words to life, while the workshops provide practice through real-world examples for completing the calculations and measurements."

"It's important for all those involved in a coating project to understand SSPC-PA 2. When a consensus standard like PA 2 is specified and a contractor is awarded the work, the standard becomes contract law," Corbett added.

"Facility owners, coating manufacturers and engineering firms that specify SSPC-PA 2 must understand what they are requiring of the contractor and what options are available for coating thickness restriction levels," he continued. "Management and supervisors of painting contractor companies, steel fabrication shops and blast-and-paint shops must comply with the standard as a contractual requirement. Quality assurance and quality control coating inspectors who are responsible for verifying conformance to the project specification need to understand what has been specified and why."

Students who participate in SSPC's e-courses can access the course anywhere and at any time, giving them flexibility in balancing educational goals with work and family. For students who want to continue to expand their inspection knowledge and strengthen their professional skills, "Using SSPC-PA 2 Effectively" is a great preparatory course for SSPC's Protective Coatings Inspector, Bridge Coatings Inspector and NAVSEA Basic Paint Inspector programs.

For more information on the e-course, visit shop.sspc.org.

SSPC, NACE Enter into Definitive Agreement

SSPC: The Society for Protective Coatings and NACE International, The Corrosion Society announced July 1 that the two groups have officially entered into a definitive agreement to combine.

"This is an important and exciting step forward for everyone involved in the fields of corrosion and coatings," said SSPC President-Elect Sam Scaturro. "We're bringing together the best of two strong organizations and providing our stakeholders with more value at a time when they need it."

In March 2019, the two organizations announced the beginning of merger talks. By August, the organizations announced the mutual decision to bring McKinley Advisors on board as a guiding entity for the two organizations' merger discussions, in addition to advising the organizations through considerations related to strategic, financial and cultural barriers, among others.

At the beginning of this year, the organizations began releasing a series of updates, beginning Jan. 10, which gave a future overview of both update schedules and discussion-related milestones. The following week (Jan. 17), the associations announced a second update regarding certificate considerations and answers to some of the bigger questions involving this particular aspect of the merger efforts. According to that update, the SSPC-NACE Task Group was focusing on minimizing disturbance to the industry and wished to maintain overall program quality and continuity. The week after, the organizations released part one of the membership considerations update, and they released a fourth update regarding standards used by industry professionals worldwide.


GLOBALSTOCK / GETTY IMAGES

At the beginning of February, during SSPC's Coatings+ 2020 conference, SSPC's Board of Governors unanimously voted to continue discussions and bring the creation of NewOrg and NewOrg Institute—both developments have yet to be named—to a member vote. The NewOrg is slated to be a 501(c)(6) organization, while NewOrg Institute would meet 501(c)(3) requirements. Each organization will serve specific functions, but members will have access to both entities, and several functions will be conducted by both entities.

Prior to the end of the month, the organizations released their seventh update, which covered education, and an eighth update regarding the part two of the membership component of the agreement, along with a question-and-answer forum.

In April, the organizations opened a two-week-long voting period to its members after more than a year of discussions between the leadership of both organizations. The voting period closed on April 17, revealing that 88.3% of SSPC members and 89% of NACE members voted in favor of the merger.

"This was a vote of historical importance to SSPC members and to the coatings and

NACE Appoints Integration Leader



On June 11, NACE International, The Worldwide Corrosion Authority, announced that it had tapped Cynthia O'Malley, Executive Director of the Master Painters Institute LLC, to serve as the association's Chief Integration Officer. The decision arrives as NACE begins to combine with SSPC: The Society for Protective Coatings after members from both associations voted in favor of the merger back in April.

"Cindy has a long history with both NACE and SSPC and brings a wealth of experience, business savvy, and technical expertise in the field of protective coatings that will benefit the new organization during the transition and for years to come," said Bob Chalker, CEO of NACE International and the future combined NACE-SSPC organization.

In her new role, O'Malley will provide strategic and operational leadership to support the integration of NACE and SSPC into one new organization. Although she will continue to lead MPI as its executive director, O'Malley is slated to work with multiple ad-hoc committees composed of members and staff from both organizations.

"Cindy came to the NACE organization in the role of Executive Director in 2018. In less than two years she has transformed MPI into a high-performing organization with value-driven testing programs for the commercial coatings industry, with a strong strategic mindset toward future training and certification programs in that industry," said Helena Seelinger, Executive Director of the NACE International Institute.

"Her mission-driven business acumen, along with her member contributions to both NACE and SSPC, speaks to how Cindy will bring a valuable point of view that makes her ideal to help guide this process."

PAINTSQUARE COMMENTS

In Response to "Cracks Threaten Collapse of FL Bridge" (*PaintSquare Daily News*, June 19)

During a routine biannual inspection on June 16, large cracks and falling concrete were discovered on the southernmost span of the southbound Roosevelt Bridge in Stuart, Florida.

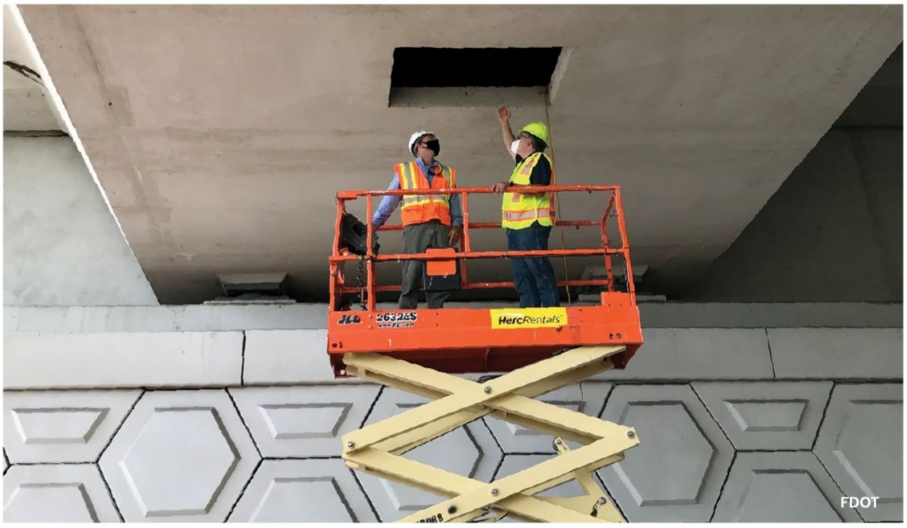
Following the inspection, the United States Coast Guard ruled that the structure was "at risk of an imminent collapse," and the Florida Department of Transportation District Four office closed the structure to road traffic, as well as commercial boating traffic on the St. Lucie River below, until a thorough safety inspection could be completed.

At press time, the bridge had reopened to four lanes of restricted traffic after initial inspections deemed it safe. Further inspections and planning for repairs of the southbound span are ongoing.

Mario Colica:
"It's another case of rust, which is the cause of the weakness of bridges. The corrosion has to be forecasted before the realization of the steel or concrete bridge. When rust has appeared, it is too late."

Erik Andreassen:
"Why don't the experts look at a non-destructive option, such as gamma ray [inspection] of the suspect areas? I carried out the same inspection of a cooling tower, which was the first power station cooling tower ever to be tested by radiography. The result was conclusive that the steel rebar had corroded to such an extent [that] the top 25 meters had to be demolished. It's simple and does not require destructive methods of testing, which will further weaken the sections under test."

Michael Beitzel:
"I am getting tired of these everyday disaster declarations. Please let the structural engineering experts weigh in. Until that happens, it is appropriate to err on the side of caution by authorities. But let the experts pass judgement in the long term. I, for one, would like to see electrical impedance testing of cables encased in concrete to help detect un-seeable corrosive changes."



FDOT

Problem Solving Forum

paintsquare.com/psf

What is the remedial action if a blaster produces too high a surface profile for the required primer thickness?

Gavin Gooden, BlastOne:
"I have found this issue where the surface had existing excess profile from a previous job where a large steel grit particle size was used. We effectively whip-blasted the surface again with a #80 or #120 garnet, and it reduced the profile by about 1 mil."

Jaime Marcos, Independent Professional:
"Increase the dry film thickness (microns), or change the primer. If it was a small surface, conduct mechanical sanding to reduce the ridges of roughness. Before starting the blasting work, it is necessary to select the appropriate abrasive to achieve the required roughness."

Michael Symbolik, MIK Industrial:
"Seriously, this spec is overlooked a lot at bidding and could be a costly mistake. Grit size, air pressure and technique will all have a part in this, but mainly, it's the coarseness of grit (#40, #80, etc.) that counts most."

PAINT POLL

paintsquare.com/poll



GRANDRIVER / GETTY IMAGES

In May, President Donald J. Trump officially gave the order to senior adviser Jared Kushner and associated aides to seek cost estimates for coating the United States-Mexico border wall. Do you think coating the wall will be a benefit to the infrastructure?

Yes. **51%** No. **42%** Other. **7%**

Michael Halliwell:
"Depending on the material of the wall and coating selected, I can certainly see it being a benefit, but maintenance could be an issue. If the system is designed to be coated and you cannot do maintenance for any number of reasons (including that one side is in another country), then the coating system could become a liability in the future as it fails."

Michael Beitzel:
"Portions of the wall near the seacoast in California and near Brownsville, Texas, may benefit from coating application, but the other portions through Arizona, New Mexico and central and west Texas would have corrosion rates are so low that a cost-benefit analysis would prove it not economical."

Gary Siler:
"Before granting contracts for the design and construction, the Trump administration should have consulted with true, non-government-tethered materials engineers on the steel selection ... Although the USACE has many good engineers, I'd prefer to see the decision of the system design to non-government professionals, because let's face it—the government never gets the top folks on the federal payroll. I've seen this fact proven time and again when providing services to government-controlled sites, like DoE facilities."



The first time baking soda was used for abrasive blasting was during the 100-year restoration of the Statue of Liberty

The aggressive cleaning ability and surface preservation characteristics of baking soda is what made it the only choice. Church & Dwight, makers of ARM & HAMMER™ products worked closely with the project engineers and donated 200,000 pounds of baking soda. Following this success Church & Dwight launched ARMEX, the first baking soda abrasive specifically formulated and manufactured for abrasive blasting.

To learn more about ARMEX visit www.armex.com

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DOWN THE HOLE WITHOUT A PADDLE

Corrosion Mitigation of Wellhead Surface Casings Using IMM Coatings

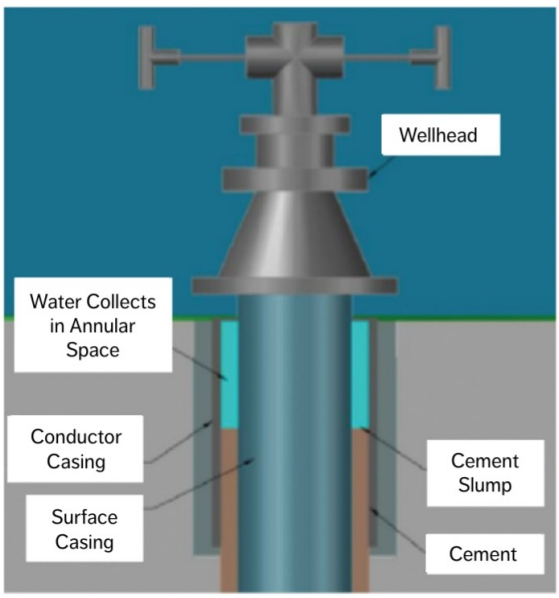
BY NICOLE DE VARENNES, P.L. (ENG.), IRISNDT LTD; MIKE O'DONOGHUE, PHD, AND VIJAY DATTA, MS, INTERNATIONAL PAINT LLC; AND NORM SPENCE, SPENCE CORROSION LTD.

For high-temperature thermal operations in the oil and gas industry, steam-assisted gravity drainage and cyclic steam stimulation are processes used to recover buried heavy oil, or bitumen deposits, from oil sands reservoirs.[1, 2] Associated with these processes, there are extremely costly challenges to mitigate failures and dangerous consequences that can arise if corrosion of wellhead near-surface casings takes place.

There are thousands of wellheads in the oil patch that are constructed from carbon steel. They operate up to 536–572 F (280–300 C) and are subject to significant temperature fluctuations; expansion and contraction; wet and dry oxidizing microenvironments; and a plethora of chlorides (from fluid ingress or leached from concrete) and other contaminants that elevate the corrosion rate. Not surprisingly, from the 1980s to date, most corrosion mitigation

Table 1: Type A Wellheads

Conductor Casing (CS)	Usually the first and largest diameter pipe installed down a hole during construction
	Typically, extend 25 to 45 metres (approx. 80 to 150 feet) below surface
	Cemented in place along its full length up to ground surface with ordinary portland cement concrete
	Holds back unconsolidated surface sediments
	Isolates shallow groundwater from the hole
Surface Casing (SC)	Once the conductor casing is installed and cemented, the hole is drilled deeper
	Installed and cemented along its length of about 600 meters (approx. 2,000 feet)
	Completely isolates the well from groundwater aquifers
Intermediate Casing (IC)	May be required after SC installation to isolate abnormally pressured subsurface rock formations from causing instability
Production Casing (PC)	The final length of steel pipe used in wellbore construction
	Usually runs the entire depth of the well
	May be cemented in place all the way to ground surface
	Primary purpose is to isolate the zone containing natural gas from other subsurface formations
	May pump hydraulic fracturing fluids into the producing formation without contacting other formations along the wellbore



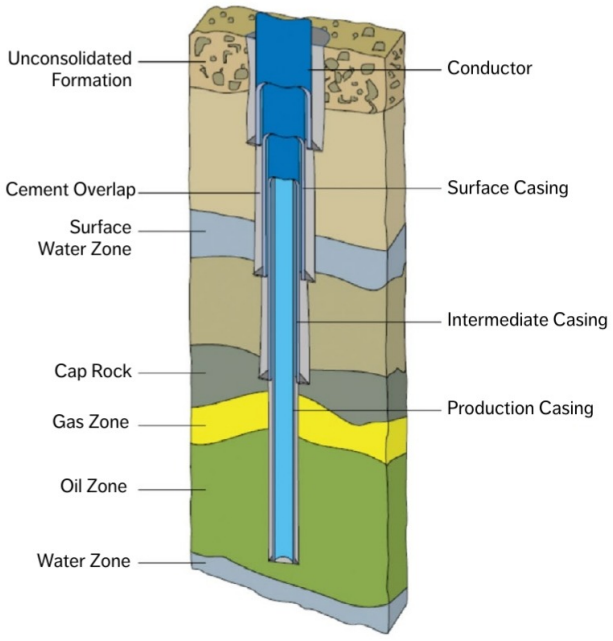


Fig. 1: (Left) Typical well construction. COURTESY OF IRISNDT (Right) Schematic of sub-surface casings and formations. COURTESY OF INDUSTRIMIGAS

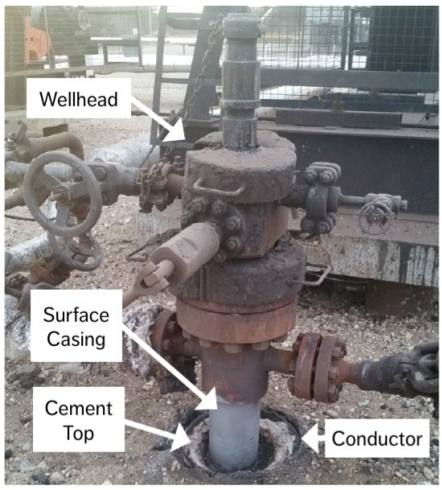


Fig. 2: Wellhead construction components
FIGURES COURTESY OF THE AUTHORS UNLESS OTHERWISE NOTED



Fig. 3: Examples of pitting corrosion of surface casings

procedures for wellhead surface casings have been met with limited success.

In the past five years, however, an idea that originated from the proven performance of a novel high-temperature inert multi-polymeric matrix (IMM) coating for mitigating corrosion under insulation has changed this picture dramatically. Many oil producers have successfully trialed and now adopted this coating technology as the newest corrosion mitigation technique for existing wellhead surface casings.

WELLHEAD CONSTRUCTION

A key component of oil or gas wells are the wellheads, which provide both the structural and pressure-containing interfaces for drilling and production equipment. Schematic diagrams of a typical wellhead at and just below ground level, and formations underground, are shown in Figure 1.[3,4]

Wellheads and their casings have somewhat different designs. Type A wellheads have a conductor casing, surface casing and a production casing, while Type B wellheads additionally have an intermediate casing. Figure 2 shows a schematic of a Type A wellhead. Table 1 lists the function of each casing.

CORROSION OF SURFACE CASINGS

Since 1970 in the Alberta oil patch, and 2005 on the North Slope of Alaska, surface casing corrosion of wellheads manifested itself in terms of pitting, exfoliation or from thermogalvanic effects.[5,6] Figures 2 and 3, respectively, show an exposed surface casing on a wellhead after excavation and typical pitting corrosion on the steel surface.

Historical records, field investigations and laboratory investigations have revealed that the following factors may influence surface casing corrosion.

High Temperatures: When the well is shut in, the surface casing is exposed to ambient conditions that can range from -40 F (-40 C) in the winter to 86 F (30 C) in the summer. During production, temperatures range from 176–482 F (80–250 C) and can reach up to almost 662 F (350 C) during steaming of high-pressure wells. However, the more typical maximum operating temperature is roughly 338 F (170 C), for production-only wells.

Cyclic Temperatures: Whether from weather changes or changes in the steaming and production process, as the temperatures change, the casing expands and contracts significantly.

Corrosive Fluids: Fluids that drip down from the wellhead include water, chlorides, oil and other contaminants. Rain water and seepage from groundwater in areas with a high water table also contribute to water ingress.

In some instances, the immersion service is exacerbated further with the presence of bentonite. A desiccant material, bentonite, has been used in the past to absorb moisture in the annular space between the conductor and surface casings. When it becomes saturated, however, it behaves like a wet-sponge, and holds the contaminated water against the surface casing.

Wet and Dry Cycles: During inspection of approximately 40 wells by one of the authors, it was noted that the majority of wells were typically immersed in water which had collected in the annulus between the surface casing and the conductor casing. Water and bentonite can be "blown out" of the annulus, which may be due to thermal changes or small leaks at the threaded joint connections during expansion and contraction cycles. In the event of "blowouts," the surface casing would dry out, and contaminants would concentrate on the casing until eventually the annulus would fill up with fluids again.

Cement Slump/Cement Depth/Cement Quality: Field investigations from multiple geographical locations and assets have determined that the main cause of surface casing corrosion is often related to the quality of concrete rather than the age or location of the well itself. The height of intact concrete also presents a significant correlation to surface casing failures.

When the concrete in the top of the conductor is intact and has not "slumped," it acts as a corrosion barrier to protect the surface casing from the corrosive environment. All inspected surface casings that showed mild to severe corrosion also exhibited some level of deteriorated concrete or "slumping," or

Table 2: Resistivity Values of Concrete and Mortar Samples

Concrete Type	Resistivity (ohm-cm)	Corrosion Rate Category
OPC Concrete (oven dried)	10^8	Low[7,8]
OPC Concrete (liquid nano-silicate pozzolan)	$>10^8$	Very low*
OPC Concrete	10^5 to 10^8	Low to Moderate[6]
OPC Concrete (saturated)	5×10^3 to 10^4	High[6]
OPC Mortar (polymer modified cementitious)	5×10^5	Low[3]

*authors' estimated value

Table 3: Qualitative Categorization of Carbon Steel Corrosion Rates for Oil Production Systems as per NACE SP0775[9]

	Average Corrosion Rate		Maximum Pitting Rate	
Corrosion Category	mm/year	mpy	mm/year	mpy
Low	< 0.025	< 1.0	< 0.13	< 5.0
Moderate	0.025 to 0.12	1.0 to 4.9	0.13 to 0.20	5.0 to 7.9
High	0.13 to 0.25	5.0 to 10	0.21 to 0.38	8.0 to 15
Severe	> 0.25	> 10	> 0.38	> 15

mm/year = millimeters per year
mpy = mils per year

evidence that there was simply improper installation (for example, the concrete top was well below ground level). The presence of even a small void above at the cement top allows for the ingress of water.

Electrolyte (in the form of soil, water and cement) resistivity is directly related to its corrosivity, with the relative amount of soluble salts in conjunction with moisture content and its dissolved oxygen being the major controlling factor (Table 2). Cement analysis performed in Alaska showed resistivities of saturated cement as low as 38 ohm-cm.[6]

Carefully formulated concrete should be used for new wellhead installations or for refurbishing existing wellheads. The concrete should exhibit optimal cement hydration and not contain calcium chloride. An impervious concrete to liquids and gas and one with high resistivity would result from a judicious mix design of ordinary Portland cement, a special admixture containing judiciously selected chemicals and a nano-silicate liquid pozzolan (as opposed to solid pozzolans like silica fume, fly ash, slag etc.). Normally, pozzolanic materials do not possess any cementitious value, but in the presence of water they will react with calcium hydroxide to form calcium silicate hydrates (gel) to further reduce and refine the pore capillary system.

Rates of Corrosion on Surface Casings

The most severe corrosion found on the surface casings is normally within 1.6 feet (0.5 meters) of the air-soil interface. Based on vertilog inspections, corrosion occurs mostly within 1.6 feet (0.5 meters) of the casing bowl weld, but can occur down to 6.5 feet (2 meters).

Unfortunately, it is extremely difficult to calculate an accurate corrosion rate of surface casings for reasons that include:

- The age of the well is not always known;
- Highly cyclic conditions (wet/dry, hot/cold);
- Differential oxygen concentration cells;
- The pH of the soil; and
- The highly variable concrete quality.

A review of dozens of inspection and failure analysis reports has shown that corrosion rates have been observed ranging between 0.32 and 2.0 mm/year. As shown in Table 3, NACE standard SP0775 categorizes corrosion rates according to levels of severity.[9] This standard is used for corrosion coupons in oilfield drilling, production and transportation operations. Oilfield operations include oil, water, gas handling systems and drilling fluids. While the use of NACE SP0775 does not provide a direct comparison with surface casing conditions, it is, however, similar given that the surface casing is being exposed to an immersion-type oilfield environment.

When the surface casing corrosion rates determined in the present work are compared to carbon steel corrosion rates in Table 3, it is evident that the surface casings are, at best, experiencing a severe rate of corrosion.

Laser Inspection of Surface Casings

The use of optical-based 3D laser scanners allows technicians and engineers to measure and characterize corrosion on surface casings and visualize the corrosion morphology (Fig. 4).

Laser inspection is a highly accurate inspection tool that has been used to assist down-hole engineers in fitness for service and risk assessments, as well as casing integrity program development.

IMM COATING TECHNOLOGY FOR WELLHEAD SURFACE CASINGS

Numerous investigations had shown that mitigation techniques that had been tried, such as cathodic protection, leaving the cellar open and applying certain protective coating types, were not working particularly well. It was reported that, from a suite of inorganic and organic coatings, some high-performance epoxy linings had shown some promise both

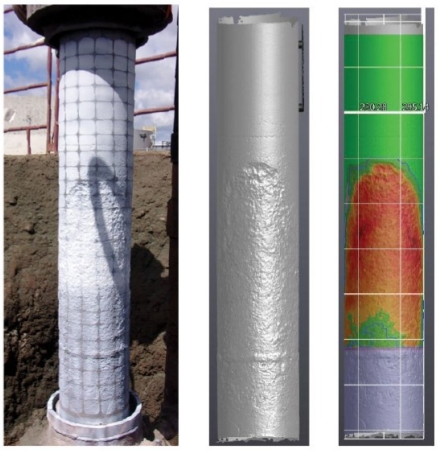


Fig. 4: 3D laser determines maximum pit depth and corrosion morphology

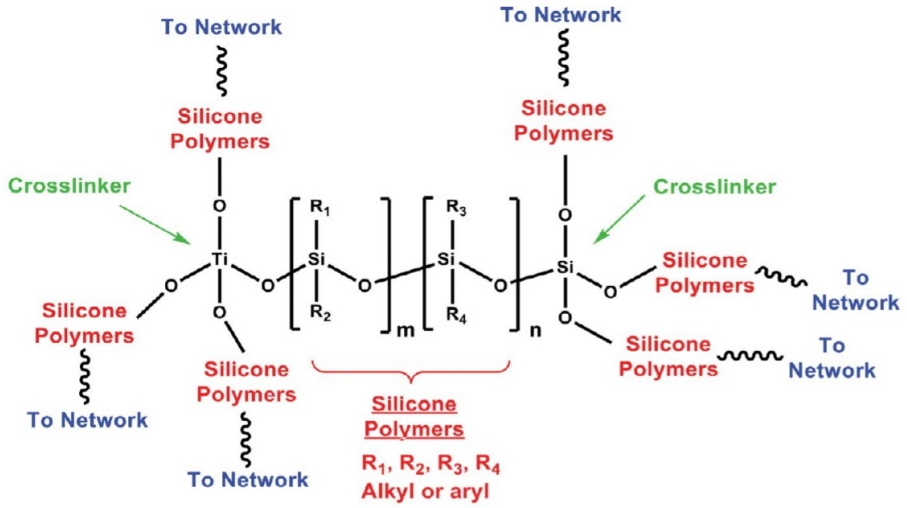


Fig. 5: The chemistry of the IMM coating's network

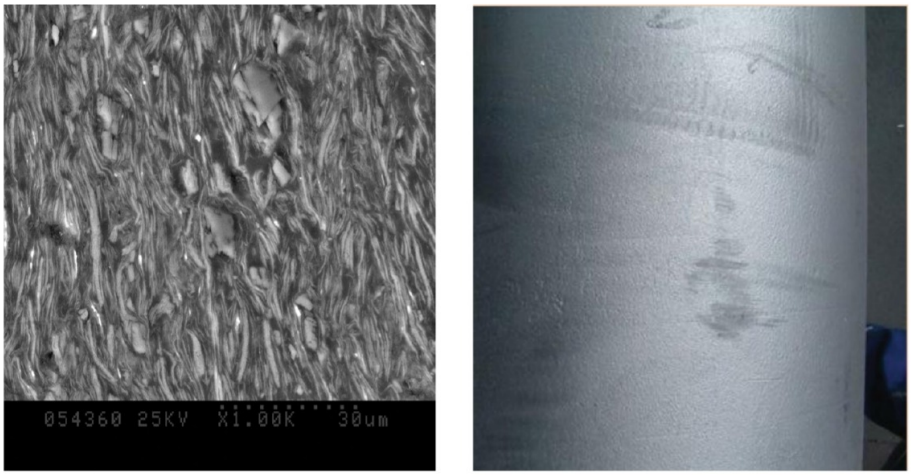
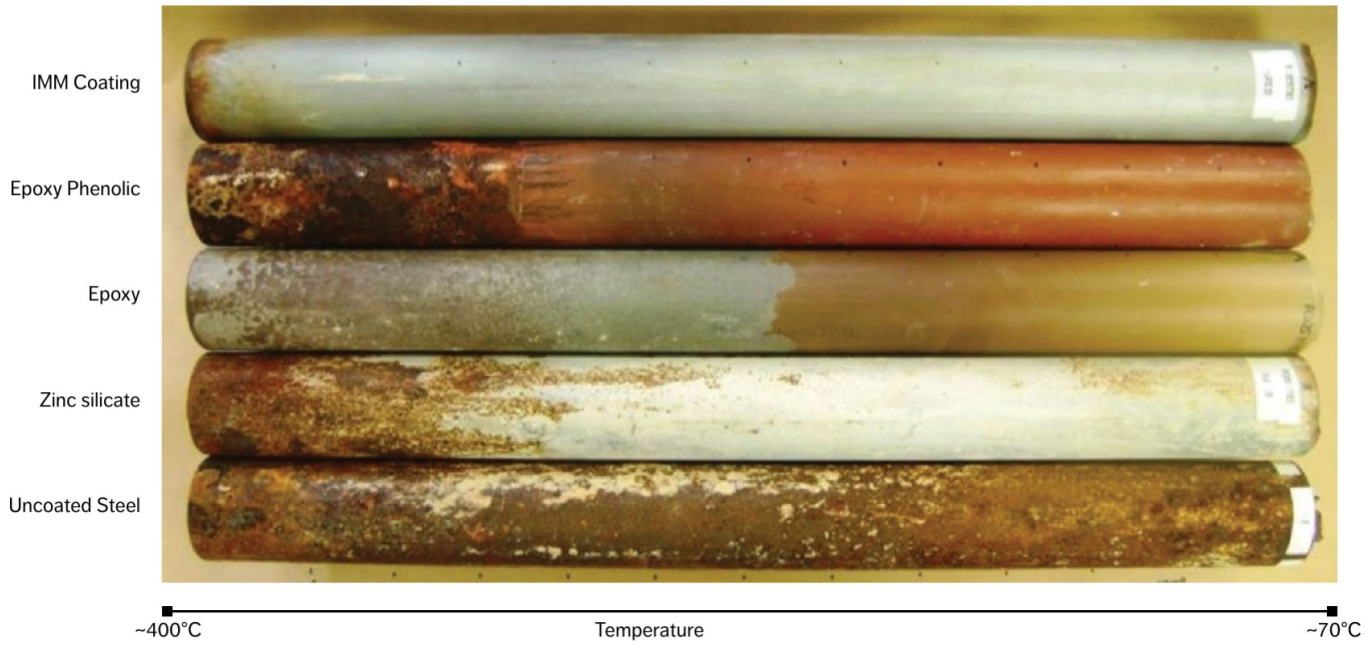


Fig. 6: (Left) SEM image of IMM coating after exposure at 752 F (400 C) (Right) Appearance of damage to the IMM coating

Fig. 7: (Below) Performance of coatings in Houston pipe test



from accelerated laboratory tests and field trials.[10] Five years earlier, however, another mitigation technique had been sought by the authors where the focus had turned to specialty inorganic IMM coatings.

"But they won't work!" was a cry by many at the time. However, these IMM coatings can perform well if chosen wisely. Previously, coatings had been discounted as a mitigation method because it was thought that in-service wellhead conditions would be too aggressive and cause premature coating failure. The rescue was residing in the domain of CUI mitigation.

An aluminum flake-pigmented multi-polymeric matrix coating with low viscosity; an ability to be applied to hot surfaces by brush, roll and spray application; and with over a decade of proven performance in real world CUI conditions, cyclic temperature swings and large thermal gradients was the genesis for the idea of using the coating for corrosion mitigation of wellhead surface casings.[11-13] The molecular architecture and network of the inorganic silicon based IMM coating is pictured in Figure 5.

Applied to carbon steel subject to cycling temperatures from sub-ambient to 752 F (400 C), the internal stress reduction, mechanical toughening, thermal shock and crack resistance were key attributes of the coating that were thought to offer promise, withstanding severe cyclic cold or hot

temperatures that normally lead to crack initiation and crack propagation of a coating.[14]

The interlacing of aluminum flake within the intact inorganic matrix of the IMM coating can be observed in the scanning electron microscopy photomicrograph on the left in Figure 6. In real-world service, this flexible IMM coating will smear across the steel surface when mechanically damaged. This contrasts with cracking or delamination that is often seen when the more rigid traditional epoxy phenolic coatings are damaged. Importantly, the aluminum flakes in the IMM coating also help reduce the extent of corrosion when the IMM coating is smeared by damage. It is noteworthy that the overlapping aluminum flakes in the IMM coating also provide the added benefit of a tortuous diffusion path against the intrusion of water, oxygen and dissolved salts, either from the external wellhead environment or from deteriorating concrete.

A literature review showed that the IMM coating performed well when tested according to the ISO12944-9-2018 standard, designed to provide an accelerated test that subjects the coating to conditions more closely related to those seen in the field. This includes UV and condensation exposure at high temperatures; exposure to hot salt fog, which accelerates corrosive conditions in a CX environment; and exposure to a freeze cycle to introduce the stresses associated with diurnal and seasonal temperature variations.[15]

The Houston pipe test was used to evaluate the performance of carbon steel pipes either coated with the IMM coating, an epoxy phenolic, an epoxy, and a zinc silicate or an uncoated bare steel pipe. (The cyclic test methodology is described in detail in a previous JPCL article by some of the authors.[11]) As evidenced in Figure 7, the inorganic IMM coating performed well at ambient to 752 F (400 C) in this test, whereas the organic epoxy and epoxy phenolic did not perform well at this temperature. However, under the conditions tried, the performance of the epoxy phenolic was good to 446 F (230 C), which was to be expected. The high-heat cyclic conditions of the Houston pipe test are germane to some degree to the real-life environment sustained by wellhead surface casings.

APPLICATION OF THE IMM COATING

Independent third-party testing is mandatory for all refurbishment projects. The abrasive blasting and coatings application to the surface casing was awkward given the narrow annular space between the surface casing and conductor casing (Fig. 8). However, a specialized sandblasting nozzle was able to reach inside this zone, the dimensions of which were approximately 1 foot (0.3 meters) in width and 6.5 feet (2 meters) in depth.

Abrasive blast-cleaning was carried out to an SSPC-SP 5/NACE No. 1, White Metal



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Fig. 8: Wellhead casing abrasive blast-cleaned to SSPC-SP 5/NACE No. 1, followed by dust and steel profile tape tests

standard with recycled glass to achieve a 2–3-mil profile. The SSPC-VIS 1 guide was used to ensure that this standard was met. After blowing down the surface casing with dry air, a chloride test (SCAT test) was performed on the bare steel to see if any chloride contamination was present. If chlorides were present and above 5 ug/cm^2 (32.3 ug/inch^2) they were removed using a proprietary water based cleaner.

Figure 9 shows the ensuing IMM coating application using both a fine horse hair paint brush and a 5mm no pilling roller. The roller allowed the coating to be "pushed" into the pits on the surface casing, as well as allowing the coating to be built up to its specified 8–9 mils dry film thickness.

In the coating procedure, ordinarily each wellhead would be turned off and allowed to cool, and then the surface casing would be abrasive blast-cleaned followed by the coating application. If the IMM coating was applied to hot steel surfaces beyond 203 F (95 C), it was difficult to obtain proper coating build-up on the casings' vertical surfaces.

After inspection of the coating and its acceptance, the wellhead would be turned back on. This allowed the heat from hot production fluids flowing through the casing to facilitate curing of the IMM coating. Typical inspection processes were affected by the extreme heat, as 131 F (55 C) was the hottest temperature at which certain tests could be performed, including the profile tape test and dust tape test.

Conventional methods to repair corroded casings near the surface of a well head are limited to casing replacement, or either steel or composite reinforcement sleeves. Without taking into account the cost of lost production during replacement, or while repairs are being carried out, the estimated cost in the event of a repair is between $50,000 and $150,000 per casing.

Interestingly, the cost of excavation, carrying out hydrovacing, abrasive blasting, application of a specialty coating system, inspection, concrete fill and contractor clean-up and demobilization may amount to only $3,000 to $6,000. On the other hand, by way of contrast, the installation of a completely new casing joint may cost an owner up to $1 million—or more.

PADDLE FOUND

From the outset five years ago, the service conditions were aggressive, but the IMM coating seemed to be a good fit for the harsh environment. The application process was not easy, but the coating was applied properly and according to a stringent specification.

So, did it work?

Figure 10 (p. 18) shows what the IMM coating looked like on application day, "Day 1." Figure 11 (p. 19) shows the same surface casing after roughly two-and-a-half years of exposure, and it appears to be virtually the same as Day 1. Through visual inspections within the industry on dozens of surface



Fig. 9: From left, application of IMM coating to surface casing; wet film thickness testing; and completed application

casings in service for up to five years, the coating appears very much the same as the day it was applied. Photos from later inspections were not available in time for this paper.

In the final analysis, for owners and engineers in the oil patch to have a level of predictability to successfully combat surface casing corrosion, certain "quality" criteria must be met, including:

- Specifications of judiciously selected high performance IMM coatings;
- Specifications of high resistivity OPC concrete with admixtures containingfor example, nano-silicate liquid pozzolans;
- Applications of all materials by qualified contractors; and
- Independent third-party inspections to ensure that the work is carried out properly.

Then, all parties will be "down-the-hole, but with a paddle."



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Fig. 10: From top, before IMM coating application; and immediately after IMM coating application

CONCLUSIONS

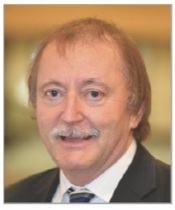
Near-surface casing corrosion has been a costly and sometimes unmanageable problem for owners and down-hole engineers. Between the high number of casings that require corrosion management (in the thousands), and the high potential for extremely corrosive environments, the management of surface casing corrosion has been difficult to say the least. Previous mitigation programs have been too high maintenance or ineffective. Up until recently, the most popular solution was to either use welded sleeve repairs or to replace the entire casing joint.

Using proper coating selection, testing, specifications, and talented coating applicators, an IMM coating has been applied on hundreds of surface casings in the oil patch. Based on subsequent inspections after approximately five years in service, the coating has been successful in arresting surface casing corrosion. **JPCL**

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Fig. 11: IMM coating after approximately 2.5 years in service



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STUDY OF STOCKPILED, FUSION-BONDED EPOXY-COATED PIPE

BY KEITH COULSON, JAMES FERGUSON AND DAVID MILMINE, TC ENERGY

TC Energy is a pipeline owning and operating company based in Canada that has been in business for over 65 years, delivering energy solutions to millions of North Americans. The company's natural gas systems operate over 57,000 miles (93,000 km) of pipeline transporting more than 25% of North America's supply. In addition, it has nearly 3,100 miles (5,000 km) of liquid pipeline system, providing over 2 billion barrels of oil daily, and as part of this liquid system, a major new oil pipeline project was designed to secure even larger reliable energy infrastructure within Canada and the U.S. The project comprised some 329 miles (530 km) in Canada, while the U.S. systems added just over 870 miles (1,400 km) of pipeline to connect with the country's refining hubs in Illinois, Oklahoma and the Gulf Coast of Texas. Pipe for the project was originally procured, manufactured and coated between 2009 and 2011. The pipe was then stockpiled in large quantities at several sites throughout Canada and the U.S. at locations close to the pipeline right-of-way. Once stockpiled, most of the pipe remained unused until an inspection and remediation program was started in August of 2018.

The majority of the pipe stored in the outer layers of the stockpiles was coated with a whitewash acrylic resin coating to reduce or eliminate the effects of UV degradation. The inner piping at the stockpiles was not protected, as it was determined that the overlying whitewashed coated pipe would eliminate UV degradation. The only exceptions were the overhanging pipe ends.

This article describes the short- and medium-term testing program developed to assess the integrity of the coating on the pipe stored at one site in the U.S., and to determine its fitness for purpose as a pipeline coating. The assessment program was carried out on pipes with the applied UV-resistant paint, as well as evaluating any degradation due to environmental exposure on pipe with little or no UV exposure.



Fig. 1: Stockpiled pipe stored in the U.S. FIGURES COURTESY OF THE AUTHORS

EFFECTS OF ULTRAVIOLET EXPOSURE ON FBE COATINGS

When exposed to ultraviolet rays, FBE coatings undergo polymer degradation, commonly referred to as chalking. Previous studies of exposed weathering of FBE coating had identified that this UV exposure could have a serious deleterious effect on the inherent physical properties of the coating.[1,2] This phenomenon is common to all FBE coatings that are primarily designed only for below ground service. Kehr[3] 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 by rain, wind or intense periods of UV exposure, then the new surface starts to suffer from the repeated process of chalking. As this breakdown and delamination of the outside layers continue, it is accompanied by a noticeable reduction in the coating thickness.[2] Work by Cetiner and Kehr concluded that this coating thickness reduction could average between 10–40 microns per year. The actual degree and effects of chalking depend upon the following factors:

- Susceptibility of the FBE's formulation to resist UV breakdown (in other words, not all FBE coatings perform the same when exposed to UV);
- The amount of exposure to UV (for example, the 12 o'clock position on a pipe generally suffers more coating breakdown than the less-exposed 3 o'clock or 6 o'clock positions);
- The intensity and duration of direct exposure to the elements. For instance, UV intensity in areas of the southern U.S. would be far greater than those in Canada, and hence lead to quicker and more rapid breakdown and chalking of the coating[4]; and
- Availability of water due to rain and morning dew.

Previous studies also demonstrated that when exhibiting chalking and reduced coating thickness, some FBE coatings would exhibit a reduction of their resistance to cathodic disbondment.[5] However,common to all FBE coatings is their struggle to retain their original flexibility when examined in accordance with the Canadian Standards Association Z245.20 cold temperature flexibility test method.[6] This aesthetic change of gloss and chalking is clearly accompanied by an embrittlement of the coating, as exhibited by loss of adhesion through the dry adhesion testing, and reduction of flexibility performance. Any form of reduction in the interaction of UV and the coating via tarping, whitewashing or any other means would therefore be clearly beneficial in reducing or eliminating the UV damage to the polymeric structure of the FBE.

PIPE DATA

Specific pipe sections representative of the pipe stocks were subjected to evaluation, namely:

1. 36-in. outside diameter × 0.465-in. wall thickness, API Spec 5L (44th Edition), PSL 2 PSL Grade X70 SAWH pipe coated externally with FBE to the requirements of CSA Z245. 20 System 1A, but noted as without any evidence of the application of an acrylic UV deterioration mitigation system (herein referred to as whitewash); and
2. The same pipe and FBE coating, but exhibiting the presence of a post-coating applied whitewashed UV deterioration mitigation acrylic paint on all exposed areas except the pipe ends.

This piping was generally stored four or five pipes high, with 19 mm ropes used as separators (Fig. 1).

In total, the whitewashed pipe in the storage facility was estimated to constitute at least 20% of the approximately 24,000 joints of 24-meter pipe lengths. This pipe had been stored for approximately 18–24 months before the application of the acrylic whitewash. That whitewash UV protective coating had been reapplied once after a period of about 4–5 years. In all cases, the last few feet at both ends were left bare, so as not to overcoat the stencil and pipe identification markings on each pipe end. However, even after replenishing, the whitewash acrylic resin coating appeared to have significantly faded, as shown in Figure 2. This fading potentially denotes that the effectiveness of this whitewash to resist UV degradation had gradually been reduced during its UV exposure over a 4–5-year period.

PROTOCOL FOR ASSESSMENT

The objective of this refurbishment assessment was, first, to determine the effects that weathering had on the pipe underneath the faded whitewash and to ascertain the quality of that FBE coating. Second, this assessment was conducted to establish a benchmark performance criterion for the coating on pipes that were stored internally in the stockpile and not exposed to UV.

An inspection and test plan (ITP) was prepared to assess the integrity of the pipe coating. The examination consisted of the following:

- FBE coating that had been coated with whitewash acrylic UV protective coating;
- FBE coating from pipes stored in the internal segments of the stockpile that was not exposed to UV (Fig. 3, p. 23); and
- FBE coating on the pipe ends or overhanging pipe that was not whitewashed but was exposed to some UV.

The ITP stipulated the following testing activities:

- Documentation of pipe numbers and correlation to location in the stockpile for selected pipe piles;
- Measurement of DFT on selected pipe, with the frequency and location on pipe to be determined and documented (for example. 12 and 6 o'clock positions);
- Measurement of DAT in accordance with ISO 21809-3: Annex Q: Adhesion Test[7];
- Holiday detection inspection on selected pipes; and
- Submission of selected pipe for laboratory testing at laboratories in the U.S.

Ultimately, the objectives of the assessment were:

1. To enumerate the correlation between DFT and DAT with the integrity assessment evaluations stipulated by the Canadian Standards;
2. To establish to the regulators that the DAT and DFT results do quantify the quality of FBE coatings being held at the stockpiles; and
3. To confirm the expected conclusion that the non-UV-exposed FBE coating was still



Fig. 2: Stockpiled pipes coated with the UV-resistant whitewash coating

Table 1: Dry Film Thickness and Dry Adhesion Test Results on Pipes Stockpiled for 9–10 Years in the U.S. (Sept. 19–20, 2018)

Pipe Number	Dry Adhesion Test Rating on Non-Whitewashed Fusion Bond Epoxy Exposed to Ultraviolet	Dry Adhesion Test Rating on Whitewashed Fusion Bond Epoxy Exposed to Ultraviolet	Thickness of Non-Whitewashed Fusion Bond Epoxy (microns)	Thickness of Whitewashed Fusion Bond Epoxy (microns)
A1009A26216	5	4	165 - 206	412 - 457
A1009A22997	5	3	124.5 - 188	416 - 546
A1009A22998	5	2	157.5 - 200	409 - 526
A1009A26247	5	2	142 - 162.5	396 - 434
A1009A25692	5	4	124.5 - 142	396 - 450
A1009A25343	5	4	190.5 - 208	391 - 429
A1009A26360	5	4	145 - 231	409 - 444
A1009A25787	5	4–5	206 - 234	424 - 485
A1009A26356	5	3	142 - 213	381 - 450
A1009A26853	5	3	180 - 260	412 - 465
A1009A41511	5	5	157.5 - 234	290 - 368
A1009262078	5	5	129 - 292	292 - 348
A1009A05252	1 *	Internal pipe	388 - 452	-
A1009A05256	1 *	Internal pipe	370 - 450	-
A1009A05238	1 *	Internal pipe	404 - 450	-

*Signifies an excellent pass. Specification required a coating thickness of 406 to 457 microns of FBE

Table 2: Dry Adhesion Testing on Non-UV-Exposed Pipe at U.S. Storage Site (Dec. 10, 2018)

Test Pipe	Dry Adhesion Test No.	Test Temperature (C)	Dry Adhesion Test Rating	Average Fusion Bond Epoxy Thickness (microns)	Intersect Angles (degrees)
34189	1	15.5	1	422	40
34189	2	11	1	423	40
34189	3	14.5	1	471	40
34192	4	19.5	1	476	40
34192	5	10.5	1	449	40
34192	6	16.5	1	450	40

fit for purpose as a below-ground anti-corrosion coating.

RESULTS OF THE FIELD ASSESSMENT PROGRAM

Initially, 12 joints of pipe that had been whitewashed and stored on the outside layers of the stock piles were removed. These 12 pipe joints, along with three joints from the interior of the stockpile, were assessed as specified in the ITP defined in the protocol for assessment.

Figure 4 illustrates the configuration of the whitewashed and non-whitewashed pipe in the stockpiles. All pipes were identified via the stenciling or barcodes.

The DAT and DFT results are presented in Table 1. With a few exceptions, the FBE coating on the piping that was whitewashed still had acceptable coating thickness measurements. The company's coating specification stipulated a requirement of 406–457 microns of FBE coating during manufacture. A range of 404–468 microns was recorded on this whitewashed coating, putting it completely in the range originally stipulated for this coating. However, the DATs performed on those whitewashed pipes no longer consistently met the minimum requirements expected of this coating. Table 1 illustrates that eight out of the 10 test joints failed to attain the acceptable DAT ratings of 1 or 2. On the other hand, the pipe that was not whitewashed and was exposed to UV continuously during storage (such as the overhanging exposed pipe ends) exhibited complete failures in DAT evaluations. In addition, this UV-exposed non-whitewashed FBE coating had a remaining coating thickness in the range of 162–215 microns. In comparison to the company specified coating thickness, it was apparent that an average coating loss of approximately 25.4 microns per year occurred on UV exposure. This coating deterioration was generally within the accepted industry range of 10–40 microns for FBE coating loss per year, when exposed continuously to UV.[3]

Initial testing on non-whitewashed coated pipe that had been stored in the interior of the stock piles provided excellent results and showed they were clearly fit for purpose (Table 1).

Also, two additional non-whitewashed joints from the interior of the stockpiles were more comprehensively examined at the stockpile site, and the results of that assessment are presented in Table 2. 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, 3, 6 and 9 o'clock positions. All coating on those pipes provided excellent results. The DAT results were of the highest standard, with each test producing a prefect rating of 1. Also, the average coating thickness was within the range of 450 microns, which was totally comparable with the original factory recorded average thickness readings of 430 microns.

Two test rings from each of these two pipes were then deemed as the focus for further laboratory testing. Each test ring was of sufficient size to allow for specimen preparation to perform the range of applicable tests

according to Table 4 of CSA Z 245.20-14 and Clause 7.3.3.3 of the company's specification (TES-CO-FBE-GL, Revision 09). One test ring from each pipe was shipped to a third-party lab in Texas, and the other test ring from each pipe remained for testing at a coating laboratory at the storage site.

LABORATORY ASSESSMENT PROGRAM

The non-whitewashed coated pipe that had not been exposed to the elements, and the whitewash-coated pipe, were assessed according to CSA Z245.20-14, Table 3 criteria for the following properties:

1. 2.5-degree flexibility testing at -30 C;
2. 24-hour cathodic disbondment test at 3.5 V and 65 C;
3. 24-hour water soak adhesion test at 75 C; and
4. Additional 1.5-degree flexibility at –30 C (three specimens, in accordance to Clause 7.3.3.3 of TES-CO-FBE-GL Revision 09), was included to examine and check for any stress, strain or pigment migration markings.

The use of differential scanning calorimetry was not considered for this program due to the deleterious moisture absorption effects on the interpretation of those thermal tests.[8]

RESULTS

The cathodic disbondment testing results of the non-whitewashed pipe ends exposed to UV were deemed total failures (Fig. 5, p. 24). The whitewash-protected coatings fared much better, with CBT results of approximately 5 mm disbondment, and water soak adhesion ratings of 2. However, this whitewash FBE coating demonstrated a serious deterioration in its flexibility performance.

The flexibility tests were all deemed failures on the UV-exposed pipe ends and whitewashed piping. The testing degree per pipe diameter length of pipe was reduced from 2.5 degrees to 2 degrees and then 1 degree; however, all demonstrated similar results of cracking within the coating.

Overall, the laboratory test results on non-ultraviolet-exposed pipe proved to be excellent. The results clearly demonstrated that the coating that was not exposed to UV or weathering was still totally fit for purpose and retained most of the properties it exhibited at its production.

OBSERVATIONS

All non-whitewashed pipe that was exposed to continuous UV at the storage site, such as pipe ends and stenciled areas, were deemed no longer fit for purpose. Coating loss was approximately 25.4 microns per year. All 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. The only exceptions were the pipe ends that may have been exposed to UV due to overhang in the stockpile.

All whitewashed coating exhibited good retention of coating thickness and cathodic disbondment and hot water soak adhesion characteristics. However, the flexibility of the underlying FBE had been adversely affected to the point where the coating was no long acceptable. This depression of the flexibility levels of the coating could have been caused by the combination of moisture absorption and elevated temperatures. When the faded whitewash coating no longer acted as a reflective mechanism, the surface temperature of the coating increased during the prolonged periods of exposure to intense sunlight. A future study is required to understand if pigment migration, plasticizer effects or changes in mechanical properties due to moisture absorption were the actual root causes of the phenomenon, whereby only the flexibility properties of the coating were affected in such a deleterious fashion.

The whitewashed protective coating was originally applied some 18–24 months after the pipe was coated. In the intervening years, there was only one other application of this whitewash coating. From the results gathered in this program, it can be inferred that if the whitewash coating had been applied on a more regular basis (for example, every two years), this deterioration of the coatings' flexibility may have been prevented.

CONCLUSIONS

The non-protected FBE coatings exposed to UV for periods of up to nine years completely failed to retain their original properties and attributes. Conversely, coatings that were completely protected from any UV exposure still possessed all their original coating thickness and physical traits.

Even after nearly a decade, the use of the whitewash UV-protective coatings proved to be extremely successful in preserving and retaining the original DFT of the FBE coating. Apart from the elasticity of the coating, UV-protective coatings conserved many of the physical characteristics of the underlaying FBE coating.

A more frequent application of non-fading whitewash coating to potential UV-exposed coatings, could possibly have also maintained the elastic characteristics of the FBE coating. **JPCL**



Fig. 3: Coated pipes from inside stockpile, removed for assessment



Fig. 4: Configuration of stockpiled pipes

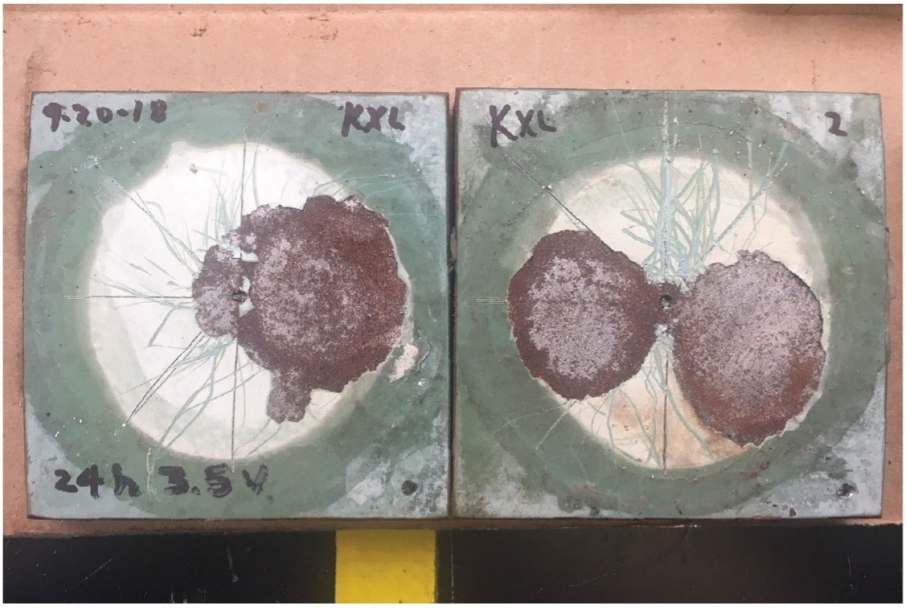


Fig. 5: Cathodic disbondment test results for non-whitewashed pipe ends exposed to UV

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UNDERBLASTED AND REBLASTED CARBON STEEL SUBSTRATES

Topographical and Performance Effects

BY CARL REED, GPI LABORATORIES, INC.; AND
KAT CORONADO AND HEATHER CUI, INTERNATIONAL PAINT, LLC

During the course of preparing a steel substrate by abrasive blasting to a specific profile level (often measured using replica tape) for subsequent coating in the real world, it is not uncommon for the resulting profile to be outside of the specification—either low or high. Reasons for such discrepancies are many and varied, but invariably, they will occur.

In a 2018 study by the authors, the effect of remedially blasting a previously prepared steel surface that had a profile that exceeded specification was examined.[1] In that study, two remediation processes were used to attempt to reduce the profile to meet specification. These processes were to reblast with a smaller abrasive size and to reblast the existing profile at a severe angle in order to "knock over" the excessively large peaks. It was found that the reblasting with the smaller abrasive media did, in fact, reduce the profile to meet specification. Reblasting at an angle, however, proved to be ineffective at reducing the profile, as blasting from a severe angle merely moved the peaks over and did not "knock" them over. The results of this study confirmed the results of another study from 2017.[2]

Also examined in the 2018 study was the effect reblasting might have on the corrosion resistance after a coating is applied to a steel surface. Examined in this corrosion study was the resistance to scribe creep (the anodic corrosion at a break in the coating film) and cathodic delamination (the delamination away from the break in the coating film resulting from cathodic reduction reaction) when exposed to a 5% salt fog environment (ASTM B117). It was found that the method of blasting and remediation had no statistical effect on scribe creep. This was found to agree with similar testing from one study conducted in 2013.[3] Conversely, it was found that the profiled panels that exceeded specification showed much better cathodic delamination resistance than panels at the specified profile.[1]

In this article, the effect of remediation of a below-specification blast profile on a steel surface is examined by using test panels that were prepared using steel grit abrasive and coal slag abrasive at below-specification profile, at specification, and remediated. The topography of the blast profiles after blasting were examined using stylus profilometry, scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS). Panels with the various blast profiles were then coated with an epoxy coating and exposed in a 5% NaCl salt spray environment (ASTM B117) for 1,000 hours, with the scribe creep corrosion and cathodic delamination examined.

> **"The question of the effect that embedded mineral abrasive blast media may have on corrosion performance remains elusive in answering."**

Table 1: Replica Tape and Profilometry Test Results of Grit-Blasted Panels

Profile Description	Replica Tape, mils	Rt, mils	Ra, mils	Rpc, peaks/inch	Est. Increase in Surface (EF)
Low Profile	1.4	1.1 ± 0.2	0.13 ± 0.01	161 ± 33	1.000901
Spec Profile	3.0	2.7 ± 0.3	0.38 ± 0.06	75 ± 14	1.001600
Remediated Profile	1.5 → 3.0	2.4 ± 0.4	0.34 ± 0.05	80 ± 7	1.001480

Table 2: Replica Tape and Profilometry Test Results of Coal Slag-Blasted Panels

Profile Description	Replica Tape, mils	Rt, mils	Ra, mils	Rpc, peaks/inch	Est. Increase in Surface (EF)
Low Profile	1.4	0.9 ± 0.1	0.12 ± 0.01	181 ± 19	1.000902
Spec Profile	3.0	2.6 ± 0.4	0.33 ± 0.04	74 ± 14	1.001166
Remediated Profile	1.4 → 3.0	2.3 ± 0.4	0.30 ± 0.04	79 ± 18	1.001111

EXPERIMENTAL

To study the effect of reblasting of an under-blasted substrate (a substrate that was abrasive blasted not meeting the lower end of a specification), six panel sets were prepared. The panels used were 3 inches by 6 inches by 1/8-inch hot-rolled carbon steel (ASTM A36 equivalent). A description of abrasive blasted prepared panel sets is as follows.

Table 3: Corrosion Results for Steel Grit-Blasted Panels

Profile Description	Scribe Creep (mm)	Cathodic Delamination (mm)
Low Profile	2.0 ± 0.7	12.3 ± 1.2
Spec Profile	2.3 ± 1.0	32.3 ± 2.7
Remediated Profile	3.1 ± 2.0	24.0 ± 2.0

Table 4: Corrosion Results for Coal Slag-Blasted Panels

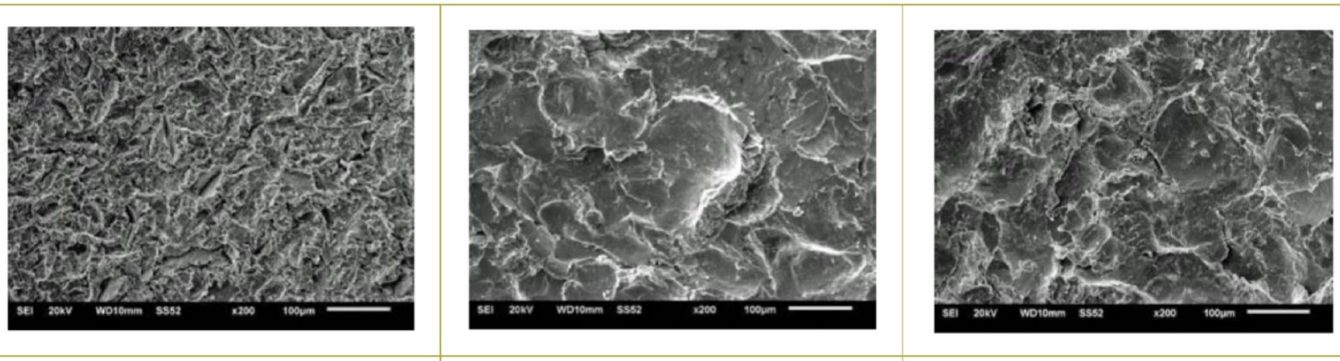
Profile Description	Scribe Creep (mm)	Cathodic Delamination (mm)
Low Profile	1.8 ± 1.2	27.2 ± 2.8
Spec Profile	1.3 ± 0.4	29.6 ± 2.1
Remediated Profile	1.2 ± 0.1	32.0 ± 2.3

- Low Profile Grit: Abrasive blasted with G80 steel grit to SSPC-SP 10/NACE No. 2 to a replica tape profile of 1.4 mils.
- Low Profile Coal Slag: Abrasive blasted with fine grade coal slag to SSPC-SP 10/NACE No. 2 to a replica tape profile of 1.4 mils.
- Spec Profile Grit: Abrasive blasted with G40 steel grit to SSPC-SP 10/NACE No. 2 to a replica tape profile of 3.0 mils
- Spec Profile Coal Slag: Abrasive blasted with medium grade coal slag to SSPC-SP 10/NACE No. 2 to a replica tape profile of 3.0 mils
- Remediated Profile Grit: Abrasive blasted with G80 steel grit to SSPC-SP 10/NACE No. 2 to a replica tape profile of 1.5 mils, then abrasive blasted again with G40 steel grit to achieve a replica tape profile of 3.0 mils.
- Remediated Profile Coal Slag: Abrasive blasted with fine grade coal slag to SSPC-SP 10/NACE No. 2 to a replica tape profile of 1.4 mils then abrasive blasted again with medium grade coal slag to achieve a replica tape profile of 3.0 mils.

The profile of a representative panel from each set of blasted panels was measured with a stylus-type profilometer recording the parameters: maximum peak-to-valley height (Rt), roughness (Ra) and peak count (Rpc). Ten separate evaluation lengths were measured for each panel set and averaged. Also measured was maximum peak-to-valley height using replica tape.

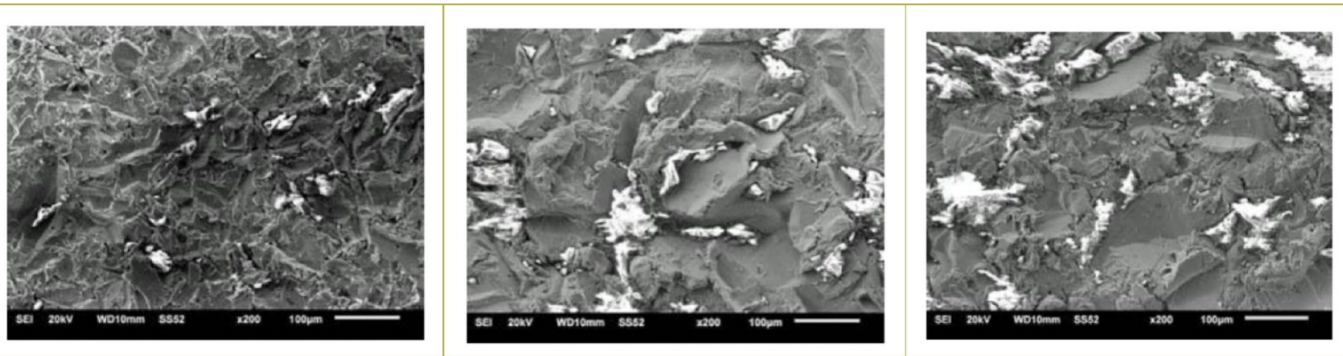
A representative panel from each panel set was imaged using SEM. The surface of the panels was analyzed for elemental composition using EDS.

To study the effect of corrosion on the panel sets, three panels from each set were coated with a commercial, phenalkamine-cured epoxy coating, two coats at 6 mils dry film thickness per coat, and were allowed to cure for 7 days. The panels were scribed with a 2-inch scribe using a pencil-type scribing tool and were placed in a 5% NaCl salt fog (ASTM B117) cabinet for



Low Profile	Spec Profile	Remediated Profile

Fig. 1: SEM micrographs of steel grit abrasive blast FIGURES COURTESY OF THE AUTHORS



Low Profile	Spec Profile	Remediated Profile

Fig. 2: SEM micrographs of coal slag abrasive blast

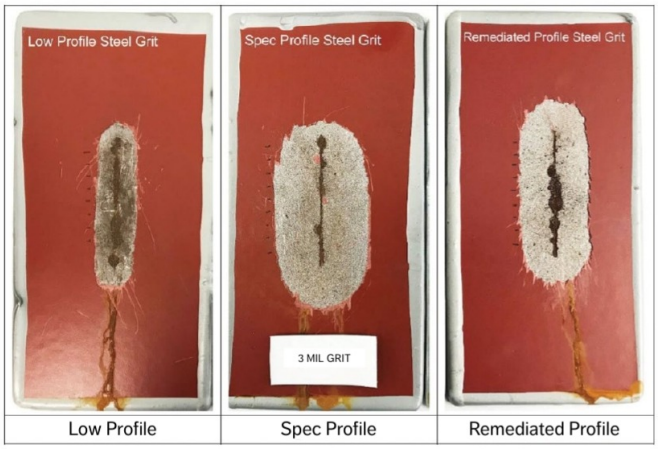


Fig. 3: Salt spray photos of steel grit abrasive blast

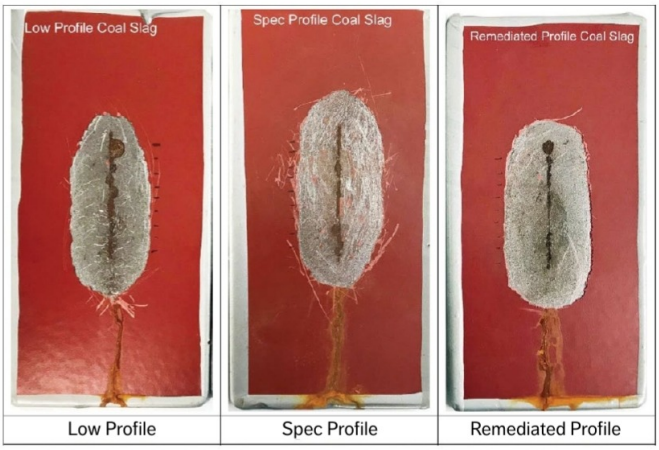


Fig. 4: Salt spray photos of coal slag abrasive blast

1,000 hours. After exposure, the panels were evaluated for scribe creep, cathodic delamination and any visual defects.

RESULTS AND DISCUSSION

Tables 1 and 2 (p. 24) show the results of the replica tape and profilometry evaluations for the grit-blasted and coal slag-blasted panels, respectively. The replica tape result shows the maximum valley-to-peak height of the profile in the evaluation area defined on the tape. Rt is the maximum valley-to-peak height of the profile, as measured with the stylus profilometer. Rt and the replica tape height values should be the same; however, the replica tape values are greater than Rt, which is consistent with the previous studies.[1,4] Ra is the arithmetical mean of the absolute values of the profile deviations from the mean line of the roughness profile. Rpc is the number of peaks per inch.

The Estimate Increase in Surface (EF) is a factor that is used to estimate the increase in two-dimensional tortuosity resulting from the roughness profile. It is calculated by the following equation:

$$EF = 2\sqrt{\left(\frac{0.5}{Rpc}\right)^2 + Ra^2 \times Rpc}$$

where EF is the estimated surface increase factor, Rpc is the peaks per inch and Ra is the average absolute profile in inches.

For both methods of abrasive blasting, the replica tape and profilometry results are similar, except for perhaps Ra, where the steel grit abrasive shows slightly higher values. This results in, by calculation, slightly higher EF values for the steel grit abrasive.

Figures 1 and 2 (p. 25) show the scanning electron micrographs of the various surface preparations for each of the abrasive media.

The low profile for both abrasive blast media visually shows low valley-to-peak height, along with a fairly dense population of peaks, as might be expected when using a finer media size. Visually, it appears that the steel grit low profile surface is more consistent in its profile pattern—perhaps due to a narrower particle size distribution of the steel grit compared to the coal slag.

Using larger-sized media, the spec profile



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for both blast media shows deeper valley-to-peak heights and much lower peak density values. Also observed was that the remediation process from the low profile accomplished the goal of bringing the profile into specification, as shown in the profilometry data and the visual micrographs.

The biggest difference between the steel grit-blasted panels and the coal slag-blasted panels is the imbedded abrasive when coal slag is used. The embedded coal slag is visually apparent in the Figure 2 micrographs. The embedded abrasive appears as shiny blobs in the micrographs and was confirmed by EDS analysis. It was shown in an earlier study that mineral type abrasives are prone to leaving embedded residues behind.[4] This is due to the mineral abrasives being easily fractured into smaller particles with very sharp edges. These very sharp edges also provide for very sharp valleys and peaks, as demonstrated in the profile micrographs of the coal slag (Fig. 2) as opposed to the less sharp valleys and peaks of the steel grit abrasive (Fig. 1).

Tables 3 and 4 (p. 25) and Figures 3 and 4 (p. 26) show the corrosion resistance data for the test panels scribed and exposed to the 5% NaCl corrosion environment. Scribe creep is the average width of anodic corrosion (rust formation) occurring on the steel across the scribe. Cathodic delamination is the average width of delamination of coating away from the scribe caused by the NaOH formed at the cathodic half-cell.[5]

As seen in previous studies, the degree of scribe creep in this study is not significantly affected by the blast profile, whether below specification or at specification.[1,3,4] There were several cathodic-turned-anodic blisters that formed at the scribes on some of the panels that gave artificially larger scribe creep values.

For cathodic delamination, there is not a large difference between blast profiles—except for the low profile, steel grit panels that averaged less than half the cathodic delamination of the higher profile panels. It is not known why the low-profile steel grit panels displayed lower cathodic delamination values versus the higher-profile panels, or why the low-profile coal slag panels did not show similar lower cathodic delamination values. However, a similar trend was also observed with low-profile blast panels in the authors' 2019 study.[4]

An interesting observation is the relationship between cathodic delamination and the EF brought about by the blasting. The coal slag-blasted panels did not show much of a relationship between these two parameters, as evidenced by the very low correlation coefficient (Fig. 5). Perhaps this is due to the embedded coal slag in the profile having an effect.

On the other hand, the steel grit blast profiles showed a relationship indicating that



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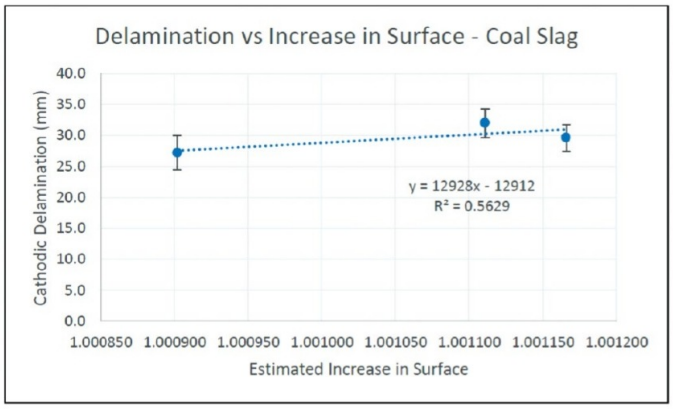


Fig. 5: Comparison of cathodic delamination to estimated increase in surface for coal slag-blasted panels

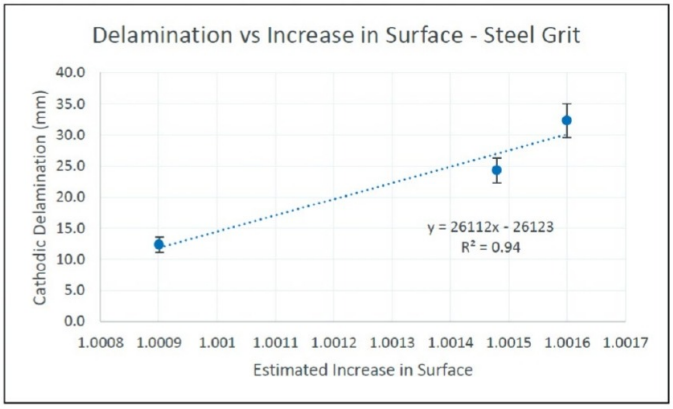


Fig. 6: Comparison of cathodic delamination to estimated increase in surface for steel grit-blasted panels

the cathodic delamination decreases with decreasing estimated increase in surface of the profile (Fig. 6). This runs counter to intuitive thinking and the work done by Weinell et al.,[6] which shows the opposite to be the case. It is worthwhile to investigate this topic in greater detail.

SUMMARY

This article has shown that an under-blasted steel surface can be easily remediated to meet higher specification requirements by using larger abrasive media and reblasting the under-specification surface. However, this study, along with earlier studies, poses the question: Is it really necessary to remediate an out-of-specification blast profile?

It is clear that the degree of blast profile, regardless of blast media, has little bearing, either way, on the anodic corrosion that occurs at a break in the coating film in a neutral corrosive environment. Cathodic delamination, on the other hand, also showed significant improvement with lower blast profiles with some blast medias both in this article and in a previous study. This is countered, however, in at least one instance in an earlier study, which showed that cathodic delamination improved in an over-blast situation.

The question of the effect that embedded mineral abrasive blast media may have on corrosion performance remains elusive in answering. It is clear from this and earlier studies that a substantial amount of abrasive blast media, especially coal slag, can shatter and embed into the steel, but to what effect?

It is typical in studies like this one that at the end of study, there are more questions than answers. This is certainly the case with this one. More work needs to be conducted to better understand the relationship between blasted surfaces and corrosion protection. **JPCL**

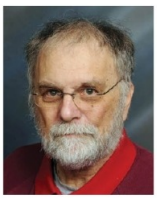


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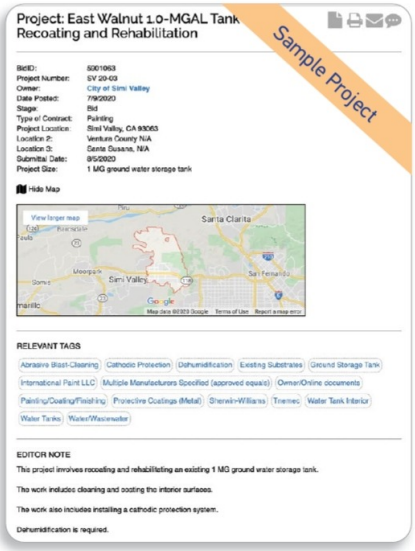
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SAFE Systems, Inc. 19

SSPC: The Society for Protective Coatings ..... 25, Inside Back Cover, Back Cover

CALENDAR

AUGUST 2020

SSPC COURSES: *Course information available at sspc.org*

Aug. 3–9	PCI Protective Coatings Inspector, Pittsburgh
Aug. 4–5	C7 Abrasive Blasting, San Diego
Aug. 6–7	C12 Spray Application Basics, San Diego
Aug. 10–13	C3 Lead Paint Removal, Houston
Aug. 10–16	PCI Protective Coatings Inspector, Manila, Philippines
Aug. 11–14	CCAS Concrete Coating Application Specialist, Paterson, NJ
Aug. 14	C5 Lead Paint Removal Refresher, Houston
Aug. 17–21	Ground Vehicle Corrosion/Protective Coatings, Pittsburgh
Aug. 17–39	PCI Protective Coatings Inspector, New Braunfels, TX
Aug. 18–19	Marine Plural Component Application, San Diego
Aug. 19–21	CAS Coating Application Specialist, Theodore, AL
Aug. 24–29	BCI Bridge Coatings Inspector, Pompano Beach, FL

CONFERENCES & MEETINGS

Aug. 31–Sept. 1	2020 AFPM Virtual Summit, afpm.org

HIGHLIGHTS FROM THE WEBINAR ARCHIVE

The PaintSquare webinar archive was recently updated to include new recordings of webinar broadcasts of educational topics in the coatings industry. Here are a few selections for the industrial coatings realm.

ADHESION TESTING

This webinar, originally broadcast in September of 2017, takes an in-depth look at each of the three different test methods used to measure the adhesion of coatings from substrates: cross-cut test, scrape adhesion and pull-off adhesion. It was presented by Joe Walker, Vice President of Elcometer, Inc.

COATING SYSTEMS: KEY ATTRIBUTES IN PURCHASING

This recorded panel discussion took place in November 2018 and features a live question-and-answer session with industry panelists on coating system attributes from a supplier's perspective. Panelists include Davies Hood, President, Induron; Allen Farris, Sales Director, Southeast/Caribbean Region, The Sherwin-Williams Company; Mike Masorli, Sales Manager, PPG; Larry Haack, Regional Specification Sales Manager, AkzoNobel; Cory Brown, Vice President of Technical Services, Tnemec; and Dwayne Meyer, Executive VP of Commercial & Technical Resources, Carboline.

TOO DEEP OR TOO SHALLOW—CAN SURFACE PROFILES BE CHANGED BY ADDITIONAL BLAST CLEANING?

Originally broadcast in August 2019 and presented by Bill Corbett, COO of KTA-Tator, Inc., this webinar describes the potential impact of insufficient or excessive surface profile of blasted steel on production and quality by analyzing the results of a research initiative on the subject.

To view these and other archived webinars, visit: **paintsquare.com/webinars**

PAINT BY NUMBERS

329 miles

The approximate length of new fusion bonded epoxy-coated pipeline constructed during a new pipeline installation project in the U.S.
See page 20.

51%

The percentage of PaintSquare Poll respondents who believe that the under-construction U.S.-Mexico border wall will benefit from protective coatings application.
See page 8.

ASTM B117

The industry standard regarding salt spray testing, which was performed on carbon steel test panels to assess the effects underblasted and reblasted steel can have on surface profile and corrosion protection.
See page 26.

OSHA 3866

OSHA's 2016 standard, "Recommended Practices for Safety & Health Programs in Construction," which sets guidelines for developing a proactive jobsite health and safety plan.
See page 3.

More than 900

Facility owners, equipment suppliers and painting contractors currently listed as SSPC Organizational Members.
See page 32.

$1 million

The cost of installing a completely new wellhead surface casing joint, as opposed to the greatly reduced cost of maintaining and repairing joints.
See page 10.