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The Society for Protective Coatings

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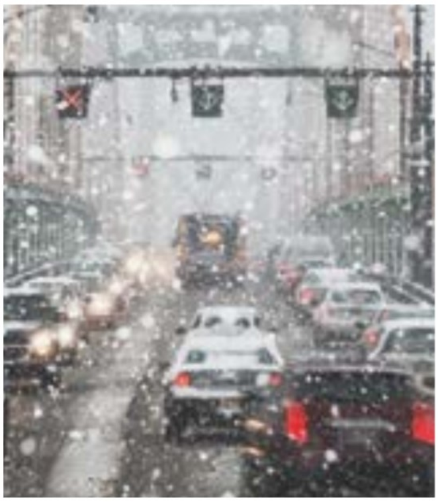
FEATURES



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STAFF

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SSPC Structure Awards: 2019 Nominations Open

SSPC is accepting nominations from its membership for the 2019 Structure Awards, given annually to honor the work of teams of contractors, designers, end users and coating manufacturers for excellence on protective coatings projects. The awards will be presented at the Awards Luncheon on the first day of SSPC's rebranded annual conference, Coatings+ 2019, which will take place at the Disney Coronado Springs Resort in Orlando, Florida, February 11 to 14, 2019.

Nominations for all types of structures, including bridges, tanks, concrete structures, and other industrial or commercial facilities, will be considered. Structure award categories are as follows.

The **E. Crone Knoy Award** recognizes outstanding achievement in commercial or industrial coatings work that demonstrates innovation, durability or utility. These qualities might include excellence in craftsmanship or execution of work, use of state-of-the-art techniques or products to creatively solve problems or provide long-term service.

The **Charles G. Munger Award** honors an outstanding industrial or commercial coatings project demonstrating longevity of the original coating. The structure may have had spot repairs or overcoating with the original coating still intact.

The **William Johnson Award** is given for outstanding achievement demonstrating aesthetic merit in industrial or commercial coatings work. The qualities considered for aesthetic merit include color, gloss or texture, or that the coating on the structure compliments the environment while enhancing the structure itself. The coating may represent a theme, an object or a specific graphic design.

The **George Campbell Award** recognizes outstanding achievement in the completion of a difficult or complex industrial or commercial coatings project. This may include work occurring in harsh or extreme environmental conditions; work completed under strict time constraints, work done with limited access or in high-traffic areas; work on a structure with complex structural components; or a project that required coordination with multiple trades or sub-contractors.

The **Eric S. Kline Award** honors outstanding achievement in industrial coatings work performed in a fixed shop facility. The project can be repair work or new construction.

The **Military Coatings Project Award of Excellence** is given for exceptional coatings work performed on U.S. military ships, structures or facilities.

The **SSPC Coatings Industry Spirit Award** recognizes a coatings project that demonstrates extraordinary service benefitting a community or the industry

With the exception of the Charles G. Munger Award, the Military Coatings Project Award of Excellence and the Coatings Industry Spirit Award, the work on the structures must have been completed between July 1, 2017 and June 30, 2018.

SSPC must receive your award submission by August 30, 2018. Please call Terry Sowers, SSPC director of member services, at 877-281-7772, ext. 2219; or e-mail sowers@sspc.org if you have any questions or to obtain a copy of the nomination form.

How to Access Job Notification and Other QP Forms

In recent years, the term "data-driven" has become a buzzword across many industries. As technology continues to evolve, those from small companies to large government agencies alike are looking for ways to harness data to improve how they do business and interact with their constituents, and SSPC is no different.

In 2016, we initiated a project to streamline where and how data is kept so that we could manage it more effectively and securely on behalf of our members, as well as provide easier access to them so they could self-manage.

Part of that effort is showing up in ongoing changes we're making to sspc.org, including moving QP forms into the "My Account" area of the website. This action was done specifically to enable us to tie submitted forms directly to contractor account profiles — previously a manual process.

Accessing the new forms is simple, but there are two requirements

1. You must have an individual account at sspc.org. Please note that you do not need to be a member and website accounts are free to set up.

2. Your sspc.org account must be tied to your company's account.

Most QP contractors have corporate SSPC memberships, so if you have an individual SSPC membership under your company, you should be in good shape. If you don't, or aren't sure, please contact customerservice@sspc.org when you are ready to submit your first form.

QP forms currently available include the Maintenance Application Form, the Corrective Action Plan Form, and the Job Notifications Form. Instructions for accessing these forms can be found at www.sspc.org/qp-job-note.

Once completed, a copy of the form will be emailed to the e-mail address listed on the company account. If your e-mail address is not listed on the company account, you will need to either update your company's record or contact the person whose e-mail address currently appears. To find out which e-mail address appears on your main company account, please contact customerservice@sspc.org.

If you have questions regarding the job notification submittal process, please contact certification@sspc.org.

Material Costs, Lowe's Breakup Fuel PPG Job Cuts

Global coatings manufacturer PPG announced on April 27 that it will be cutting more than 1,000 jobs in a restructuring effort that comes in the wake of rising raw-material costs and the ouster of the company's consumer brands from a major home-improvement box store.

The projected layoffs were reported in a filing with the U.S. Securities and Exchange Commission, which notes that a pretax restructuring charge of $80-85 million will be recorded in the company's second-quarter financial report. Most of that charge will go to employee severance and other cash costs, the filing says. About 1,100 employees will lose their jobs, according to the document.

The company has not yet indicated where the job cuts will occur, but said in the SEC filing that the move was brought on by "a customer assortment change in our U.S. architectural coatings business" as well as "sustained, elevated raw material inflation." PPG's Olympic paints and stains were removed from Lowe's stores in the first quarter of this year when the home-improvement giant inked an exclusive deal with The Sherwin-Williams Company.

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The previous week, PPG had announced a new deal with Home Depot — Lowe's primary competitor, and the largest home-improvement retailer in the United States — to sell Olympic products.

The layoffs will occur between now and the second quarter of 2019, according to PPG, and the company expects the restructuring to begin to pay off within two years. The company "continues to review its cost structure to identify additional cost savings opportunities," according to the SEC filing.

The news came just days after the company's first-quarter 2018 earnings report, which indicated an increase in net sales over the previous year but noted rising material costs. The quarterly report also admitted a possible accounting error that the company says may have resulted in expenses incorrectly not accrued for the quarter; PPG said it would be investigating that matter.

AkzoNobel Financials Report Revenue Dip

On April 24, coatings manufacturer AkzoNobel released its first-quarter financial report for 2018, indicating an increase in net income year over year, while also reporting a single-digit drop in revenue in all areas due to adverse conditions in foreign currencies and high cost of raw materials.

AkzoNobel reported that in total, revenue year over year was down 8 percent form 2.38 billion euros ($2.91 billion) to 2.18 billion euros. Volumes reportedly dipped 3 percent overall, and adjusted earnings before interest, taxes, depreciation and amortization dipped from 281 million euros to 209 million euros.

Both paints and coatings segments, Decorative Paints and Performance Coatings, saw drops in revenue at 8 percent (from 922 million euros to 846 million euros) and 9 percent (from 1.47 billion euros to 1.34 billion euros), respectively.

In Decorative Paints, while revenue was down in all regions, volumes were up in EMEA, the company noted, and price increases are taking effect everywhere. Akzo also notes that consumers in Pakistan now have access to Dulux Promise, the first launch in the country's mass market.

While revenue was down overall in the Performance Coatings segment, the Powder Coatings division saw an increase, from 288 million euros to 292 million euros. That was the only upswing, however, as Marine and Protective Coatings, Automotive and Specialty Coatings and Industrial Coatings all dipped. Of note was the opening of a new powder coatings plan in India, a 9-million-euro facility in Mumbai.

Numbers for Akzo's Specialty Chemicals segment was reported as Discontinued Operations and also dipped in revenue, from 1.29 billion euros to 1.25 billion euros.

The company successfully spun off its Specialty Chemicals segment into a separate business over the past year and subsequently sold it last month to global alternative asset manager The Carlyle Group for 10.1 billion euros.

CEO Thierry Vanlancker referenced the sale in the Q1 report, calling it a "key milestone." He also noted that even with the slight revenue drop, the company's pricing initiatives are on track to deliver 15 percent return on sales by 2020 (referred to as "Winning together: 15 by 20" initiative).

"We are ramping up our pricing initiatives and have implemented various cost discipline measures to deal with higher raw material prices. Initial savings from creating a fit-for-purpose organization are also being realized," Vanlancker said.

Sherwin-Williams Reports Q1 Profit Increase

Coatings giant The Sherwin-Williams Company also released its first-quarter financial report for 2018 on April 24, marking a consolidated sales increase of $1.20 billion — or 43.6 percent — to $3.97 billion. The company primarily attributes the growth to the acquisition of Valspar sales, selling-price increases and higher paint sale volume for the Americas Group.


John G. Morikis

Omitting sales from Valspar, net sales from Sherwin-Williams' core operations increased 4.9 percent this past quarter.

According to Sherwin-Williams, new revenue standard ASC 606 dictates that certain elements of advertising support — namely classified as selling, general and administrative expenses — is now classified as a reduction of revenue, which had no material impact on consolidated net sales.

Sherwin reported an increase in net sales for The Americas Group of 6.6 percent (totaling $2.08 billion), which can be attributed to higher architectural paint sales volume across most end market segments, as well as selling price increases. Compared to the same quarter last year, there was also a 5.2 percent uptick in sales for stores in the U.S. and Canada that have been open for longer than 12 months. The Group segment profit increased $32.2 million to $337.4 million, partially due to the aforementioned reasons, along with a partial offset caused by the increased cost of raw materials.

Net sales for the Consumer Brands Group increased 103 percent to $656.4 million due to the inclusion of Valspar sales, but was partially lowered due to a decrease in volume sales to some retailers; Valspar sales increased Group net sales 108.3 percent for the quarter. Segment profit increased to $74.2 million in the quarter from $55.9 million last year, but acquisition impacts decreased net external sales from 17.3 percent last year to 11.3 percent this year. This quarter saw a segment profit increase from

Valspar operations profit of $56.7 million. This was offset by a purchase accounting amortization expense of $31.8 million.

Performance Coating Group's net sales increased 153.4 percent to $1.23 billion, with Valspar sales contributing 148.1 percent to Group net sales. Segment profit was up thanks to Valspar's operations profit of $98.1 million, which was partially offset by purchase accounting amortization expense of $57.5 million, but with an overall decrease from 11.8 percent to 7.4 percent

"For the second quarter, we anticipate our Sherwin-Williams' core net sales will increase a mid-to-high single digit percentage compared to last year's second quarter," said John G. Morikis, chairman, president and CEO for Sherwin-Williams. "In addition, we expect incremental sales from the Valspar acquisition to be approximately $600 million for April and May in the second quarter. For the full year 2018, we expect Sherwin-Williams' core net sales to increase by a mid-to-high single digit percentage compared to full year 2017."

Morikis went on to note that Sherwin expects incremental sales from Valspar for the first five months to roughly break down to $1.7 billion in 2018.

May Webinar Answers Questions on Equipment

A free online panel discussion that shows how equipment can help contractors overcome challenges will be available in webinar format to PaintSquare users this month.

"Equipment Questions and Answers," will be presented on Wednesday, May 16, 2018, from 11:00 a.m. to 12:00 noon, Eastern. Topics in this discussion include how surface preparation techniques have changed over the years, common mistakes that contractors make, and where exactly responsibility lies with regard to worker safety. Originally presented on November 9, 2017 at Technology Publishing Company's Contractor Connect event, this panel discussion was moderated by J. Peter Ault, president of Elzly Technology Corporation, who has more than 25 years of industry experience. Panelists for this session are Darrell Domokos, director of equipment, BrandSafway; Clay Miller, Territory Sales Manager, CLEMCO Industries Corp.; Bob Nash, President, Greener Blast Technologies; Nate Wayne, sales representative, Industrial Vacuum Equipment Corp.; and Chris Keenan, operations manager, MES.

This webinar is sponsored by Clemco Industries Corp., GreenerBlast Technologies, Industrial Vacuum Equipment Corp., MES LLC, and BrandSafway. To register free of charge, visit www.paintsquare.com/webinars.

PAINTSQUARE COMMENTS

In Response to "Anti-Mosquito Paint Approved in U.S."

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Japan-based global paints and coatings supplier Kansai Paint Group announced mid-April that the U.S. Environmental Protection Agency has approved the company's mosquito-repellent paint. It is the only anti-mosquito paint currently approved by the EPA and is expected to be available in the U.S. this summer

John Kern:
"I just hope after years of service this coating does not become a health hazard as so many of the coating systems in the U.S. have been labeled by the EPA. Best of luck with this company and I applaud their efforts to help rid the world of this nasty pest."

Meg Gholamian:
"Agree with John. So many countries will benefit."

In Response to "Russia Unveils Floating Nuclear Plant"

(*PaintSquare News*, May 3)

At the end of April, the world's only operational floating nuclear power plant, built by Russia's state nuclear corporation Rosatom, started making its way toward Chukotka, a Russian Arctic port, where it will provide power to remote industrial plants and port cities, as well as offshore gas and oil platforms. The floating power plant—known as Akademik Lomonosov—was built over the last nine years in St. Petersburg. In the fall, its two nuclear reactors will be loaded with nuclear fuel and started up, and the power plant is expected to be online in 2019.

Photo: www.twitter.com/RosatomGlobal

Tom Schwerdt:
"Perhaps the first floating civilian nuclear power plant. There are already many floating military nuclear power plants."

Tony Rangus:
"When the unit completes its mission and is decommissioned, they will just sink it in the Arctic ocean like they have done with their decommissioned nuclear submarines and submarine reactor cores."

Lou Lyras:
"The Russians, the Chinese, the French and others are building nuclear power plants — even this floating one. Only the U.S. is ignoring the cleanest and safest supply of energy that is needed to combat the alarming rise in CO_2 emissions.

Problem Solving Forum

paintsquare.com/psf

WHAT IS THE MOST IMPORTANT FACTOR TO DETERMINE IN A FAILURE INVESTIGATION AND WHY IS IT SO?

Steve Brunner, WPC Technologies:
"There are several important factors in any investigation, but perhaps the most important is to approach the investigation with an open mind, one free of bias. When performing the investigation in this fashion, one is able to analyze all the information provided objectively. When there is a bias, the investigator often has tunnel vision and may not find the root cause and thus future failures could occur."

Bill Jenkins, International Paint LLC:
"There are many factors in failure analysis that are not only important, but also essential. One of the most important is to have the ability to recognize patterns as they point to the root cause(s)."

Anne Andrews, The Sherwin-Williams Company:
"Get all the application conditions: temperature of the air, material and substrate; relative humidity; time between coats; sweat time; pot life; film thickness; film defects; hardness/ tackiness; identity of coatings; and any contamination or adhesion-interfering substances."

PAINTSQUARE NEWS TOP 10 *paintsquare.com/news, April 2–May 4*

1. **NTSB Issues Report on I-84 Bridge Collapse**
2. **MS Governor Orders 83 Bridges Closed**
3. **FAA Limits 787 Flights Over Corrosion Issue**
4. **Material Costs, Lowe's Breakup Fuel PPG Job Cuts**
5. **AkzoNobel Financials Report Revenue Dip for Q1**
6. **Safety Concerns Plague China Megaproject**
7. **F-35 Delivery Stopped Again Over Primer Problem**
8. **Sherwin-Williams Reports First-Quarter Profit Increase**
9. **Sales Up, Volumes Largely Flat for PPG in Q1**
10. **RPM Sets Sales Record in Q3, Names New VP**

Power-Tool-Cleaned Surfaces: New Insights into Surface Profile Measurement

BY JODY WENZEL, DEFELSKO CORPORATION

NAVSEA defines hand power tools as portable automatic devices used for surface preparation that can be broken down into three basic categories: impact cleaning tools (including air needle scalers), rotary cleaning tools (including bristle cleaners) and rotary impact cleaning tools (including roto-peen scalers).

While there are many standards relating to the measurement of surface profiles produced by abrasive-blasting of steel surfaces, there is little research or guidance for measuring profiles created by power tools. This article will examine three common measurement methods for determining surface profile parameters and evaluate their efficacy on power-tool-prepared surfaces: replica tape, depth micrometers and stylus roughness instruments. Profiles produced on steel test panels by air needle scalers, bristle cleaners and roto-peen scalers were examined for this study.

Attention will be paid to each measurement method's effectiveness to measure on all three power-tool-produced profiles and whether or not any of the power tools produce profile characteristics that present challenges. Through evaluation of data, plotting subsequent results and the use of 3-D surface imaging, a final recommendation will be made as to which measurement method is the most appropriate.

Abrasive impact produces complex, random patterns across the surface. However, surface profiles produced by power tools can exhibit repetitive patterns that present challenges to proper peak-to-valley height and peak density measurements.

In a February 2015 *JPCL* article, David Beamish illustrated how replica tape could be used to determine critical surface profile parameters for blasted steel surfaces and related these parameters to pull-off adhesion strength[1]. Specifically, the article discussed how significantly more information was available through replica tape measurements over other measurement methods, allowing for peak density (P_d) and developed interfacial area ratio (S_{dr}) to be determined, which directly correlated to pull-off adhesion strength. Further, it was shown that surface parameters measured using replica tape were closely correlated to established measurement techniques for blasted profiles, such as confocal microscopy and stylus profilometry. This article will also take this analysis further and determine the suitability of replica tape to not only measure surface parameters of blasted profiles, but to measure surface profile across a variety of power tool prepared surfaces.

RELATED STANDARDS

Within the painting and coating industry, there has been significant research into evaluating blast-cleaned profiles on steel substrates. ISO 8503-5, "Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 5: Replica tape method for the determination of the surface profile," describes the preparation of steel substrates before application of paints and related products and the surface roughness characteristics of blast-cleaned steel substrates.

ASTM D7127, "Standard Test Method for Measurement of Surface Roughness of Abrasive Blast Cleaned Metal Surfaces Using a Portable Stylus Instrument," describes the measurement of surface roughness of abrasive blast-cleaned metal surfaces using a portable stylus instrument.

ASTM D4417, "Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel," describes three methods for evaluating the surface profile of blasted steel surfaces, which are Method A: Visual Surface Profile Comparator, Method B: Surface Profile Depth Micrometer, and Method C: Replica Tape.

SSPC-PA 17, "Procedure for Determining Conformance to Steel Profile/Surface Roughness/Peak Count Requirements," provides additional guidance for determining conformance with surface profile requirements. Whereas ASTM standards describe how to take measurements, SSPC-PA 17 focuses on where to take these measurements and how often.

Largely absent from these industry standards are procedures and descriptions for the evaluation of power-tool-cleaned surfaces. As the use of power tools becomes more prevalent, it is increasingly important to determine the best and most accurate way to evaluate these surfaces.

Within these standards, there is only one mention of how to evaluate power-tool-prepared surfaces. ASTM D4417-14 paragraph 1.2 states, "Method B may also be appropriate to the measurement of profile produced by using power tools."

Lacking standards and/or guidance, there is little information as to whether ASTM D4417 Method B is the best method for all power-tool-cleaned surfaces or if there may be other, more dynamic solutions for measuring surface profile. In this study, power-tool-prepared surfaces exhibit characteristics that are not present in blast-cleaned surfaces, namely directional bias and peak density variations between tools. The impact of these characteristics on specific measurement methods is not well known.

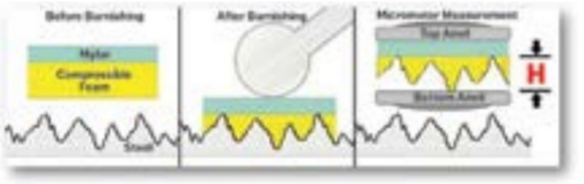

Fig. 1: Replica tape principle of measurement. Figures courtesy of the author.

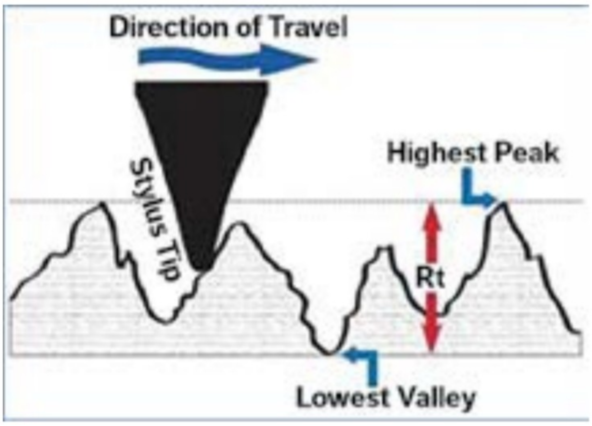

Fig. 2: Surface roughness instrument principle of measurement.

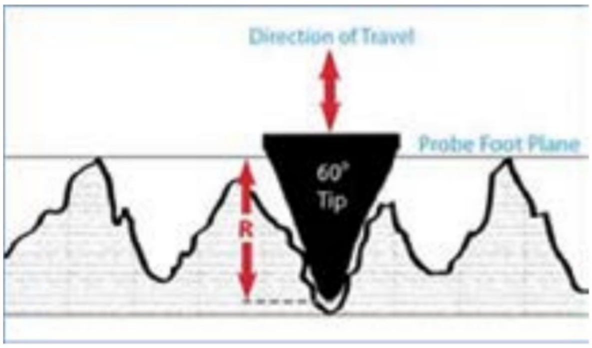

Fig. 3: Depth micrometer principle of measurement.

MEASUREMENT EQUIPMENT

Replica Tape

Replica tape has been used since the 1960s to measure the surface profile of blasted steel. Widely used in the coating industry, replica tape consists of a layer of crushable plastic foam attached to a non-compressible polyester substrate of a highly uniform thickness of 2 mils ± 0.2 mils (50 microns ± 5 microns). The foam thickness is dependent on the tape grade. Replica tape is available in two types, regular and optical, and two grades, Coarse and X-Coarse. For most applications, regular replica tape is sufficient. Optical grade replica tape is used when producing 3-D images of the tape surface. The two tape grades are Coarse, which measures profiles from 0.8-to-2.5 mils (20 to 64 µm), and X-Coarse, which measures profiles from 1.5-to-4.5 mils (38 to 115 µm).

When pressed against a roughened steel surface, the foam forms an impression, or reverse replica, of the surface. The foam can collapse to about 25 percent of its original thickness. Therefore, as the highest peaks on the original surface push up to the polyester backing, the fully compressed foam is displaced sideways. Likewise, the deepest valleys on the original create the highest peaks in the replica.

Placing the compressed tape between the anvils of a spring micrometer and subtracting the contribution of the incompressible polyester substrate (2 mils/50 µm) gives a measure of the average maximum peak-to-valley surface roughness profile (Fig. 1).

This method for surface measurement is rugged, relatively simple, inexpensive, and allows the user to retain a physical replica of the surface being evaluated. It is one of the most common ways of determining peak-to-valley height of blasted surfaces in the coating industry.

Replica tape provides added advantages over other measurement methods in that it measures the surface profile over a two-dimensional area, rather than a single point or straight-line measurement. The pointed probe tip on a depth micrometer measures a single point with a radius of approximately 0.05 mm (50 microns), for a sampling area of 0.007 mm^2. The typical sample line of a stylus roughness instrument is 12.5 mm long and 4 microns wide, for a total measurement area of 0.05 mm^2. The measurement area of replica tape is 31 mm^2. This represents a measurement area roughly 258 times larger than the measurement area of a stylus roughness instrument and approximately 4,400 times larger than the depth micrometer. Further, digital imaging of burnished replica tape can produce 3-D images of surface profiles, allowing a user to visually observe the surface prior to coating application.

Stylus Roughness Instruments

A portable stylus roughness instrument utilizes a stylus that is drawn at constant speed across a surface and records the up and down movements to determine the R_t, or the vertical distance between the highest peak and lowest valley within any given evaluation length. The instrument measures and records the vertical distance the stylus travels as it passes over the surface, as seen in Figure 2.

Typically, a predetermined evaluation length is divided into seven sampling lengths and the instrument measures the peak-to-valley height within each sampling length, R_y, of each section, disregarding the first and last sections. The average of the remaining R_ys is used to calculate R_z. For this study R_z is equivalent to R_{zDIN}, equaling the average of the distances between the highest peak and lowest valley in each sampling length, per ASME Y14.36M.

Surface Profile Depth Micrometers

A depth micrometer uses a flat base that rests on the peaks of the surface profile and a spring-loaded probe tip mounted inside the base which drops into the valleys of the profile. Therefore, each measurement is the distance between the highest local peaks and the particular valley into which the tip has projected, as illustrated in Figure 3. Depth micrometers have the advantage of being able to measure profile heights that exceed the range of many other instruments.

SUMMARY OF TEST

Twelve steel plates were prepared using three different power tools: an air needle scaler, bristle cleaner, and roto-peen scaler. A third-party laboratory was enlisted to prepare these panels in accordance with the tool manufacturer's instructions and common industry practices. These panels were labeled 1 through 4 within each group. The following panels were evaluated.

- Four (4) steel plates prepared with a bristle cleaner; labeled BB1 through BB4.
- Four (4) steel plates prepared with an air needle scaler; labeled NG1 through NG4.
- Four (4) steel plates prepared with a roto peen scaler; labeled RP1 through RP4.

Surface profiles on the panels were evaluated with the following three instruments.

1. A portable stylus roughness instrument reporting R_z and R_{pc} (linear peak count). Per ASTM D7127, an evaluation length of 12.5 mm consisting of five 2.5-mm sampling lengths was used. R_{pc}, when squared, was used to estimate P_d.
2. A digital depth micrometer surface profile gage reporting R.
3. Replica Tape and a digital replica tape reader and imager reported average maximum peak height (H_L) by measuring burnished replica tape and applying a linearization algorithm; and P_d in accordance with ASME B46.1, measured as peaks/mm^2.

R_z, R and H_L are measurements of surface profile height that were shown in the Beamish article to be closely correlated. R_{pc} and P_d are measurements of the number of peaks in the profile, which have similarly shown correlation.

Testing was performed with each instrument in the following manner.

1. A portable stylus roughness instrument was used to determine R_z and R_{pc} for each panel. Three trace measurements were performed at five locations on each panel with each trace measurement having an evaluation length of 12.5 mm, and a sampling length of 2.5 mm. Measurement locations are detailed on Figure 4. It should be noted that on the bristle-cleaner-prepared panels trace measurements 2 and 4 are in the direction of bias, while trace measurements 1, 3 and 5 are against the direction of bias. For the roto-peen scaler panels, trace measurements 2 and 4 are against the direction of the bias and trace measurements 1, 3 and 5 are in the direction of bias.

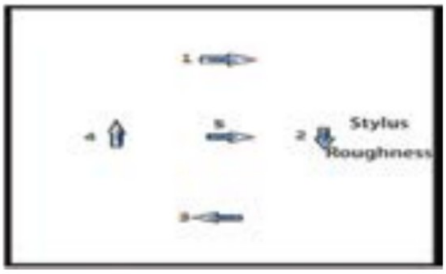

Fig. 4: Portable stylus roughness instrument measurement locations.

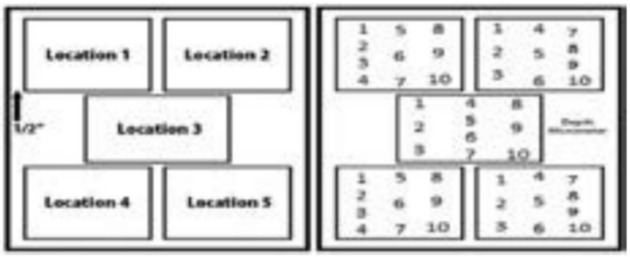

Fig. 5: Depth micrometer measurement locations.

2. A digital depth micrometer was used to determine R. Ten measurements were taken at five locations on each panel, for a total of 50 measurements per panel. Per D4417, 10 readings per location were taken. This study used five locations and the maximum values of the 10 readings in the five locations was recorded and averaged. The average of the 50 individual readings was also recorded. Sampling locations are detailed in Figure 5.
3. A digital replica tape reader and imager used replica tape to measure H_L and P_d. Four burnishings were taken per panel. Three were taken using regular replica tape (Coarse and/or X-Coarse) and one was taken using optical replica tape. Measurement locations are shown in Figure 6.

INITIAL OBSERVATIONS

Patterns were seen in the results. When examining images of the surfaces, directional striations were visible on the bristle-cleaner- and roto-peen-scaler-prepared surfaces. The readings taken by the stylus roughness instrument in the direction of this bias and against the bias confirmed clear differences in the surface parameters. Further, images of the air-needle-scaler-prepared surfaces showed they had few distinct peaks and valleys, leading to speculation that the depth micrometer may not have adequately captured true peak-to-valley heights. It was hypothesized that results would improve with modified measurement techniques that accounted for bias/peak density.

Bristle-cleaner- and roto-peen-scaler-prepared panels showed directional bias that presented challenges for portable stylus roughness instruments. A portable stylus roughness instrument may not be appropriate because readings are bias dependent. Initial specifications for measuring power-tool-cleaned surfaces do not account for bias and/or density of peaks. This may lead to under- or over-reported values on surface profile. Modifying the test

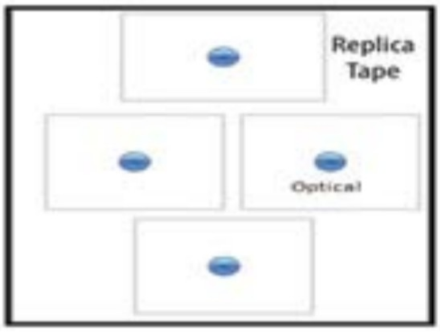

Fig. 6: Replica tape measurement locations.

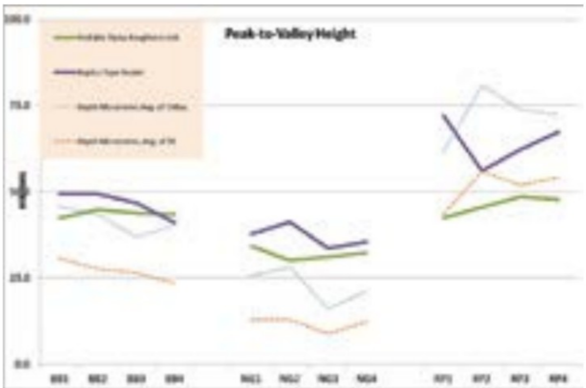

Fig. 7: Initial results for peak-to-valley profile height from three measurement methods.

method to ignore readings taken in the direction of the bias is necessary to produce meaningful results.

It was observed that the air-needle-scaler-prepared panels had very low peak density (peak frequency). It was proposed that increasing the number of measurements taken with the depth micrometer might help to account for this decreased frequency and produce a more accurate result. To evaluate this hypothesis, a second round of testing was done taking 20 measurements per spot in all five locations, for a total of 100 readings per panel. The average of the five maximums was reported.

Replica tape could be used across all three power-tool-produced profiles. Results aquired with a digital replica tape reader were not significantly affected by the bias and density that may present challenges to other instruments, and there was no need to modify the test methodolgy.

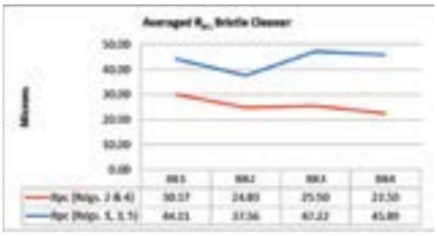

Fig. 8: Averaged R_{pc}, with (red) and against bias (blue), bristle cleaner.

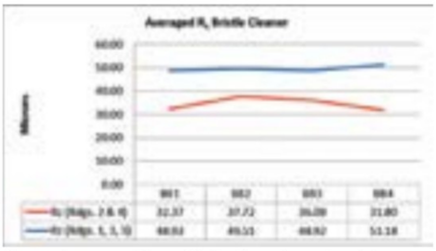

Fig. 9: Averaged R_z, with (red) and against bias (blue), bristle cleaner.

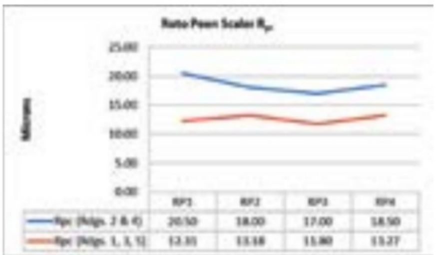

Fig. 10: Averaged R_{pc}, with (red) and against bias (blue), roto peen scaler.

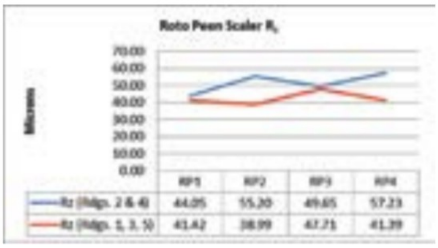

Fig. 11: Averaged R_z, with (red) and against bias (blue), roto peen scaler.

The depth micrometer results showed that using the average of the maximums for the five locations produced results that correlated more closely with results from the other measurement methods when compared to the average of the 50 individual readings.

SUMMARY OF INITIAL RESULTS

Figure 7 (p. 18) shows the initial results of the three measurement methods. The depth micrometer results are shown as both the average of all 50 readings and the average of the five maximums. It was observed in this testing that the characteristics produced by the tools challenged some of the measurement tools and made their results less consistent.

For the bristle cleaner panels, readings 2 and 4 were consistently lower for all parameters than readings 1, 3 and 5. Readings 2 and 4 were taken in the direction of the bias, while readings 1, 3 and 5 were taken against the bias (Figs. 8 and 9).

For the roto-peen scaler panels, readings 2 and 4 were consistently higher for all parameters than readings 1, 3 and 5. Readings 2 and 4 were taken against the direction of the bias, while readings 1, 3 and 5 were taken with the bias (Figs. 10 and 11, p. 20).

When peak densities of the three panel types were compared, the air needle scaler panel showed significantly lower measurements than the others.

Because of the lower densities, it was hypothesized that the depth micrometer readings could be detrimentally affected due to reduced probability of the instrument being placed in the lowest valleys.

When comparing measurement methods, initial observations showed that across the power-tool-cleaned surfaces and measurement methods, replica tape was the least affected by influences such as bias or peak count.

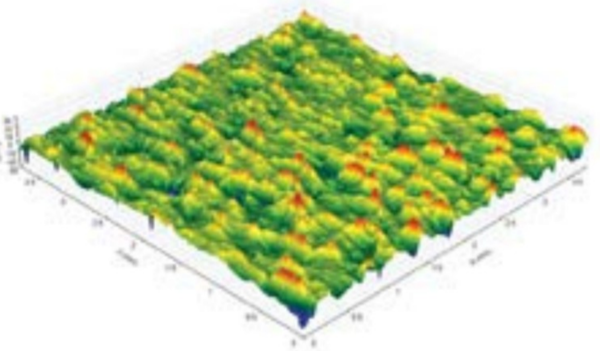

Fig. 12: 3-D rendering of bristle-cleaner-produced surface, obtained using a digital replica tape reader with 3-D imaging.

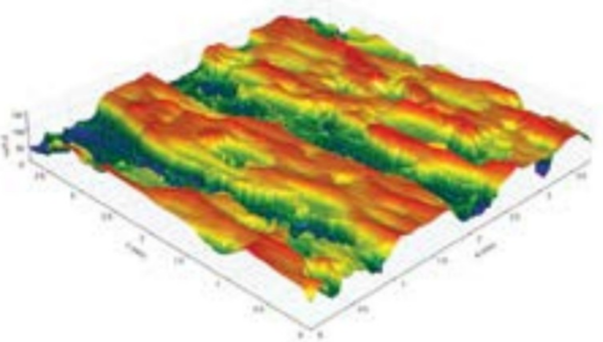

Fig. 13: 3-D rendering of roto-peen-scaler-produced surface.

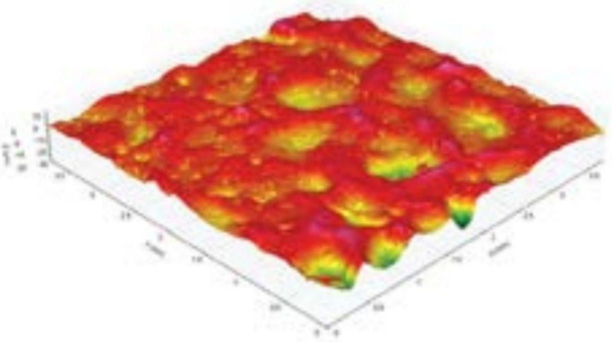

Fig. 14: 3-D rendering of air-needle-scaler-produced surface.

DIRECTIONAL BIAS

After testing was complete, analysis of the data showed that results acquired with the portable stylus roughness instrument seemed to be significantly impacted by the directional bias of the panels. This was most notably present in the panels treated with the bristle cleaner, and to a lesser extent with the panels treated by the roto-peen scaler.

The first 3-D image of a bristle-cleaner-prepared surface shows striations from the left to the right, corresponding to the direction the bristle cleaner was applied to the panel, essentially making valleys and/or peaks that align in that general direction (Fig. 12). The second 3-D image of a roto-peen-scaler-prepared surface shows similar characteristics (Fig. 13).

In order to confirm the effect this had on results acquired by the stylus roughness instrument, additional testing was performed on the bristle-cleaner-prepared panels with specific attention paid to the directional bias.

This additional testing was performed by taking four measurements with the bias and four measurements against the bias created by the bristle cleaner. Two values, R_{pc} and R_z, were then compared between the horizontal and vertical testing.

Measurements taken with the bias and against the bias yielded distinctly different results. Measurements taken by this method could lead to improper characterization of the surface if directional bias is not taken into account, or not known. This could lead to incorrect or insufficient application of a coating. Measurements taken by replica tape or depth micrometer instruments were not affected by directional bias.

PEAK DENSITY

Measurement results showed that the panels produced by the air-needle scaler showed low peak density when compared to the other power-tool-cleaned panels. Lower peak densities make it more challenging for the depth micrometer to find true peak to valley height. This is due to a lower statistical probability that the point of the micrometer will land directly into the lowest point of the profile. Unless the instrument finds the lowest depression of the profile, results will be erroneously low. A 3-D rendering of an air-needle-scaler-prepared surface is shown in Figure 14. It can clearly be seen that the surface contains few distinct peaks and/or valleys and appears mostly rounded and flat.

After low peak densities were observed using digital imaging of replica tape, it was determined that increasing the number of measurements taken with the depth micrometer produced more accurate peak to valley measurements. To test this hypothesis, the number of readings taken in each spot was doubled to 20, for a total of 100 readings per panel. By

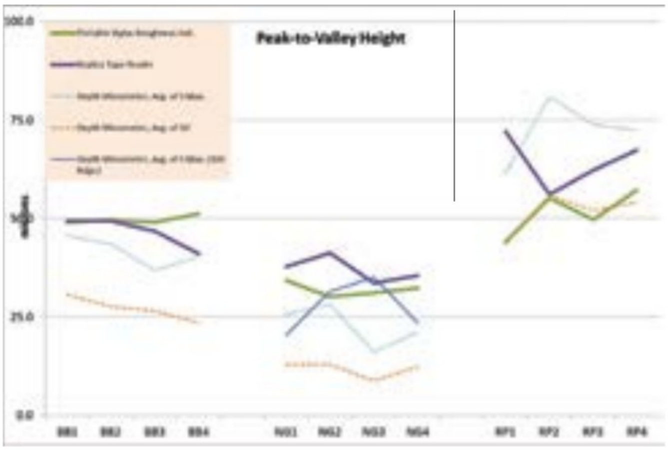

Fig. 15: Final results for peak-to-valley profile height from three measurement methods.

doubling the number of measurements, the result is more representative of those found with a stylus roughness instrument and replica tape.

For three of the four panels that were examined, doubling the number of depth micrometer measurements per spot resulted in values more closely correlated with the stylus roughness instrument and replica tape. Although not investigated here, further increasing the number of readings per spot may result in readings that are more consistent with other methods.

It is hypothesized that the stylus roughness instrument will be similarly affected by lower peak density. The stylus roughness instrument measures over a larger area than the depth micrometer, however, and this larger measurement area may be sufficient to capture the highest peak and lowest valley. Regardless, the probability of finding the true maximum peak-to-valley profile height on air-needle-scaler-prepared surfaces is reduced, simply due to the lower number of distinct peaks and valleys.

OBSERVATIONS ON REPLICA TAPE RESULTS

Measurements derived from replica tape were not affected by directional bias or peak density unlike measurements taken by other measurement methods. This method provided consistent results on all three power-tool-cleaned surfaces.

With panels affected by directional bias, the measurement area of the replica tape captures patterns in both directions of the bias. Since H_L is measured as the maximum peak-to-valley height across the entire area, the bias has no effect. Because of this, results from replica tape measurements were more representative of the surface and did not require modification to the measurement method to produce meaningful results.

Similarly, replica tape measurements were not negatively affected by peak density. Since the replica tape measurement area is larger than the horizontal distance between peaks and valleys, the reduced density was not a factor. Again, because of the large measurement area of replica tape, readings were more representative than with the micrometer or stylus roughness instrument.

CONCLUSIONS

Surfaces created by power tools can exhibit characteristics that must be taken into consideration when selecting a surface profile measurement method. Tools that leave directional striations (bias) on the surface can result in inaccurate measurements of surface profile parameters when portable stylus roughness instruments are used. Tools that result in surface profiles with low peak densities are not anticipated in the standards (ASTM D4417) and as a result, lower peak-to-valley measurements are reported when using a depth micrometer in accordance with that test method. Failure to account for these characteristics can also produce inaccurate results.

Although there are limitations when using portable stylus roughness instruments and depth micrometers on power-tool-prepared surfaces, there are modifications that can be made to the measurement method that will allow these instruments to measure these surfaces effectively. These modifications include discarding all measurements taken in a certain orientation of a surface (to account for bias), or significantly increasing the number of measurements (to account for low peak density).

Figure 15 shows results across all measurement methods after adjustments had been made to account for errors caused by directional bias and low peak. Directional bias has been accounted for on the bristle-cleaner- and roto-peen-scaler-prepared panels by removing the trace measurements taken in the direction of the bias. This result was an average of 13.2 percent closer to the replica tape results for the bristle-cleaned panels, and an average of 8.9 percent closer to the replica tape readings for the roto-peen-treated panels.

Low peak density on the air-needle-scaler-prepared panels has been accounted for by plotting the results with both 10 and 20 readings per spot. By doing so, the readings taken by the depth micrometer showed a 15.9 percent closer correlation on average to the portable stylus roughness instrument readings, and a 14.2 percent closer correlation on average to the replica tape readings. This supports other studies that have been done with the same findings, notably "Surface Profile – A Comparison of Measurement Methods" by David Beamish, where this method was first proposed[2].

The replica tape results, however, are displayed as measured, with no modification for surface effects. It is clear that the tape's unmodified results are in line with other measurement methods.

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2. Beamish, David. "Surface Profile - A Comparison of Measurement Methods." DeFelsko Corporation, January 2013.

Fig. 1: A 5-million-gallon steel water storage tank was built at an elevation of nearly 12,000 feet in order to store water for snowmaking machines at a ski resort near Santa Fe, New Mexico. Photos courtesy of Tnemec Company, Inc.

NO DAY AT THE RESORT:

Constructing and Coating a 5 MG Water Tank in the Mountains of New Mexico

A ski resort located in the mountains near Santa Fe, New Mexico contacted a nearby tank contracting company to design and build a 5-million-gallon (MG) steel ground storage tank to store water for the resort's snow making machines, among other amenities.

The tank had to be built at an elevation of 11,800 feet to accommodate pressure and volume requirements for various slopes at the resort. With no roads or other dedicated paths suitable for getting heavy equipment and materials to the site, just getting to the work site was a challenge, and the contractor needed to devise a plan for transporting these items up the mountain.

Additionally, the project was constrained by a strict timeline, with work having to be completed in the summer months so that the tank could be up and running for the resort's busy winter ski season.

The tank was sized for maximum storage volume while still being able to blend into its surrounding environment, and the parties involved sought tank coatings that would provide the longest possible service life and be able to cure

Fig. 2: Construction and coating materials were transported up the mountain to the jobsite via bulldozer and other heavy vehicles.

Fig. 3: Using a primer with a long recoat window and fast-cure intermediate and finish coatings helped the contractors overcome some of the project challenges.

and perform in the demanding environmental conditions.

The high elevation of the site made painting difficult due to the short coating season and ever-changing weather. Even in the summer, temperatures can fall drastically at night in the area, and the contractor needed a coating that would not exhibit amine blushing or other issues due to the extreme temperatures.

The contractor decided to construct the tank with shop-primed steel one summer and come back to clean and apply additional coatings the next, as completing both construction and coating of the tank in a single summer was not possible. Because the tank would need to survive the winter season between construction and final coating with only its primer coating for protection, a primer with a long recoat window and resistance to environmental factors was selected.

During the first summer, the interior surfaces were prepared in the shop in accordance with SSPC-SP 10/NACE No. 2, "Near White Metal Blast Cleaning," while exterior surfaces were prepared in accordance with SSPC-SP 6/NACE No. 3, "Commercial Blast Cleaning." Both the exterior and the interior received a prime coat of a moisture-cured, zinc-rich urethane certified for potable water storage in accordance with NSF/ANSI Standard 61.

The shop-primed steel, along with the generators, air compressors, welding machines, blasting and painting equipment and other materials needed for the project were then transported up the mountain using an eight-wheel-drive military-style truck, which still needed to be both pulled by a bulldozer in the front and pushed by another bulldozer in the rear.

Tank construction was successfully completed in time for the resort's opening that winter and functioned the entire first season with its interior and exterior primer only.

The next summer, the contractor returned to clean and apply the intermediate and finish coats to the tank. The interior and exterior surfaces were brush-off blast-cleaned according to SSPC-SP 7/NACE No. 4, and the primer was touched up where needed. The interior received two coats of a high-build, potable-water-certified polyamide epoxy, chosen for its fast cure time at typical ambient temperatures and cold-temperature cure down to 35 F (2 C). The tank's exterior received an intermediate coat of the polyamide epoxy, followed by an acrylic polyurethane finish coat with high resistance to abrasion, wet conditions and exterior weathering.

The interior and exterior primer coating allowed for a long recoat window and proved tough enough to withstand a winter operating without additional protection, and the fast-curing properties of the intermediate coating were crucial — even in the summer months of July and August — due to the high elevation of the site.

At just the right height relative to the tree line, the tank blended into its surrounding environment perfectly. The tank fabricator and owner were both pleased with the result, and the resort continued to operate regularly.

Fig. 4: The finished tank serves its utility while blending into the surrounding environment.

REFURBISHMENT OR REPLACEMENT?

COST-EFFECTIVE SOLUTIONS FOR AGING WATER-STORAGE TANKS

BY NICK BRESSLER, WORLD INTERNATIONAL TESTING, INC.

Built in 1924 for the Washington Suburban Sanitary Commission (WSSC), the Alta Vista Standpipe in Montgomery County, Maryland was the oldest In WSSC's inventory and in dire need of rehabilitation or replacement. WSSC maintains over 60 water-storage facilities ranging in capacity up to 15,000,000 gallons. The tank measures 30 feet, 8 inches in diameter and is 94 feet, 9 inches tall. It provides potable water to adjacent property owners with its primary end users being the National Institute of Health (NIH), the National Naval Medical Center and the Walter Reed National Military Center.

The first order of business was to conduct a comprehensive tank evaluation in order to determine the overall condition and compile an inventory of deficiencies, repairs and upgrade objectives so that the project manual for the bid phase would include all necessary work to bring the tank to current AWWA standards while feasibly achieving the customer's long-term goals. These goals included 1) investing and maintaining their assets through capital improvement projects and maximizing dollars spent, 2) continuing to provide clean potable water with sufficient pressure to an expanding customer base and 3) improving the Alta Vista Standpipe in order to afford the Commission more time to plan and locate additional sites for future tank construction without a disruption in service (Fig. 1).

When the tank was drained for the evaluation, it was immediately apparent that this would not be a typical pre-design evaluation or design project.

Most tank refurbishment projects encounter a few site-specific challenges that are typically identified and evaluated in the schematic design phase. Based on the options available and the allotted budget, in most cases, these items will be included in a bid-ready manual. The Alta Vista Standpipe, however, was unique in that it contained a significant number of design challenges that would normally result in the tank being replaced or decommissioned due to the high cost of necessary repairs and upgrading the tank to current AWWA standards. To address the WSSC's specific needs, the following objectives and design challenges had to be met both in the evaluation and design phases.

- Prepare cost estimates for rehabilitation versus replacement.
- Address location, terrain, access and proximity to adjacent properties.
- Address operational, safety, security, compliance and obsolete design deficiencies.
- Address cleaning, painting, containment and lead abatement.
- Address vault and piping replacement (including lack of a tank overflow and sewer/sanitary drains).
- Make improvements to telecommunication mounts.
- Make aesthetic improvements.

REHABILITATION VERSUS REPLACEMENT

The cost of rehabilitation versus replacement was the first design consideration. Typically, an older riveted-style tank would be replaced with a new steel or composite-style design, which ultimately can achieve a 100-year life expectancy with routine maintenance. The plot size of the Alta Vista West Cedar Lane site would not meet current permit requirements for a new tank installation and replacement project. To compound matters, there were no other lots available in the immediate area. With respect to acquisition of another site, real-estate values in Bethesda and adjoining areas were among the highest in the nation at that time and although a suitable lot was never located, if purchased, the land value would have easily exceeded $ 1,000,000. The high cost of acquiring a new site (coupled with the potential delays for permitting and rezoning in a heavily regulated county and state) weighed heavily in the decision to refurbish the tank. Finally, removing the standpipe from service, demolishing it and then relying on other storage facilities to meet pressure and demand requirements was not an option due to the potable water and fire suppression needs of the NIH, Walter Reed National Military Center, the National Naval Medical Center and other medical facilities located nearby.

LOCATION, TERRAIN ACCESS AND PROXIMITY

Location, terrain, access and proximity to adjacent properties created challenges in the design phase that would also impact costs and the refurbishment phase. The topography of the site showed that the tank was located approximately 30 feet above West Cedar Lane with no access stairs and very limited parking on the bottom slope off of the main road. Accessing the tank during damp or wet conditions posed a slip and fall hazard on the hill. The only access road to the tank was located on the west side and belonged to the Knights of Columbus, a private club that was actively used by members and for events. To make matters worse, a portion of their parking lot was leased by the club to the nearby Bethesda Medical Center which was undergoing renovations to their parking facility. The Center's employees were transported to the club's only parking area behind the tank via the one-lane access road. Preparation of the bid-ready manual had to identify restrictions to potential bidders, such as average daily traffic (ADT), difficulties associated with topography and limitations regarding accessibility to the site, parking and staging areas.

Fig. 1: Built in 1924, the Montgomery County, Maryland Alta Vista Standpipe tank was the oldest in the owner's inventory and in dire need of rehabilitation or replacement. Photos courtesy of the author

OPERATIONAL, SAFETY, SECURITY, COMPLIANCE AND OBSOLETE DESIGN DEFICIENCIES

The proposed improvements included standard upgrades per AWWA, the National Fire Protection Association (NFPA), OSHA and EPA design standards such as new manways for improved internal access and confined-space access, a new roof ladder access system with resting platforms, new circular roof guardrails, a frost-resistant roof vent and other miscellaneous items (Fig. 2, p. 32).

This tank was not equipped with an overflow pipe; one was included in the scope of work. The new overflow pipe would receive an overflow sensor and an overflow security valve for vulnerability assessment improvements. These repairs and improvements made up approximately 15 percent of the tank's refurbishment costs. The assumption was that aside from some minor repairs or dismantlement costs, these improvements would have been incidental in a new tank design. Comparatively speaking, this was not an area where options needed to be evaluated (as the primary goal for the consultant was to bring the tank to current standards). There were some tank deficiencies that were compliance-related and also considered to be health and safety risks. For these reasons, deficiencies in this category would automatically be mitigated no matter what the cost.

CLEANING, PAINTING, CONTAINMENT AND LEAD ABATEMENT

Similarly to the aforementioned tank repairs, AWWA, OSHA, EPA and NSF standards and requirements were to be part of the contract documents. This tank was repainted in the mid-1990s and the majority of the existing lead was abated at that time. However, initial sampling identified small traces of lead below the EPA-mandated threshold. Considering the location, lead abatement protocol would be required to ensure the safety of workers and adjoining properties.

Aside from the lead issue and limited equipment staging area, the most critical concern with respect to cleaning and painting was the riveted steel design of the standpipe. The last applied protective coating system achieved only 10 years of service. The goal for this design was to ensure that the refurbishment cycle would double or possibly triple the life expectancy of the last refurbishment cycle. Assuming that there would be additional costs for a more efficient cleaning and painting specification, the next step was to select a system that would effectively work on the obsolete riveted standpipe and achieve the design life expectancy goal. The tank exterior was not considered to be an issue — a few additional stripe coats on the riveted seams that could be incorporated into a zinc/epoxy/fluoropolymer system would not greatly increase costs and should easily meet the life expectancy goal.

An additional expense would involve selecting a cost-effective solution to address the aging riveted immersion area. Based on the initial pre-design tank investigation performed, section loss was evident by the presence of pitting, crevice corrosion, vertical striation attack and corroding rivet heads. On a positive note, however, corrosion mapping using ultrasonic testing showed sufficient wall thicknesses for abrasive blasting. Historically, abrasive blasting on older riveted steel tanks can result in leaks around the riveted seams after the tank is put back into service. The solution chosen was to apply a high-build, plural component, NSF International-approved lining.

The lining system could not be limited in film thickness so that areas where isolated and localized section loss was present (including all riveted seams) could receive additional film coverage to ensure a leak-free tank and without compromising the integrity of the coating. The system would also have to address crevice corrosion in lapped roof plates above the water level in the vapor zone. The additional cost of the coating system would be approximately double per-square-foot but the cost of the abrasive blasting (where most of the expense typically lies) would not change. The decision to apply the high-build lining would also increase the life expectancy of the interior protective coating system by an additional 10-to-20 years (ultimately achieving 35-to-40-plus years of service). When amortized annually, the additional cost could actually be less than a conventional epoxy system due to the elimination of one interior coating-replacement cycle

Fig. 2: The proposed improvements included new manways for improved internal access and confined-space access, a new roof ladder access system with resting platforms, new circular roof guardrails, a frost-resistant roof vent and other miscellaneous items.

that typically would be required in 15-to-20 years after the initial application.

Also, selecting a more expensive high-build lining and applying a corrosion-resistant zinc primer prior to its installation could eliminate the need for a cathodic protection system (which might range from $10,000 to $15,000) (Fig. 3).

VAULT AND PIPING REPLACEMENT

An evaluation of cost-effective solutions for replacing the obsolete and outdated brick altitude valve vault, the tank bottom access vault, all piping, valves and installation of drains would be difficult as these costs would typically be high with refurbishment or replacement and consequently, few options were available. The chosen approach to potential savings was to locate all historical data regarding subsurface conditions along with any record drawings in order to provide any bidding contractor with as much data as possible. This strategy would ultimately minimize some exploratory digging and test pits, and could prevent some unforeseen delays and potential change orders during construction. A new tank site would likely have required a geotechnical study for the tank fabricator and most of the information referenced previously would be provided to a degree.

However, the aforementioned vault, piping and valve work could not feasibly be completed in a future phase. The design phase for the Alta Vista tank's refurbishment would have to address the temporary shutoff of water service for a new tank isolation valve. The sequence of work for the contractor would require that the first phase of work included a tap into the main transmission line and installation of the new valve so that the tank and vaults could be isolated from the system. Tapping the main transmission line for the new shutoff valve would require a traffic control plan and notification to residents of service interruption. The goals were to minimize the amount of time residents would be

Fig. 3: Selecting a more expensive high-build lining and applying a corrosion-resistant zinc primer prior to its installation could eliminate the need for a cathodic protection system (which might range from $10,000 to $15,000).

without water service and also to schedule the excavation work on West Cedar Lane later in the evening when traffic was minimal.

Finally, the tank was not equipped with an adequate drain system or overflow. Tank draining operations were done by natural consumption to a comfortable level well above the mud and silt line, then by gravity through a hydrant at the base of the hill and then via approximately 200 feet of fire hose into a storm drain (which was not a method approved by the Maryland Department of the Environment [MDE] storm-water management standards).

Consequently, the grandfather clause coupled with dechlorinating the residual remaining water was the only feasible option at the time. It should be noted that original drafts during preparation of the bid-ready manual called out for the overflow to discharge into riprap. Tank draining procedures would remain the same, through the hydrant and a fire hose. Prior to the bid phase, WSSC was notified that the State of Maryland Department of Transportation State Highway Administration (SHA) would be upgrading roads and various utilities which included the installation of a storm-water management system on West Cedar Lane. This unexpected good news provided a cost-effective and compliant solution for routine overflow discharging events and also periodic tank draining requirements. In addition, this eliminated potential future costs that may have occurred to bring the tank up to full compliance with respect to the strict Maryland storm-water management standards. The plans were revised to incorporate these changes. The only issues prior to finalizing the plans were in acquiring the State's proposed drawings and coordinating the construction schedule.

IMPROVEMENTS TO TELECOMMUNICATION MOUNTS

The Alta Vista Standpipe provided a source of revenue to the WSSC from third-party communication tenants and the intention was to continue leasing the space as well as allow for future tenants. However, two existing problems that drove up costs needed to be addressed.

First, the equipment-mounting procedures employed created inaccessible areas that could not be properly coated, and therefore, forced contractors to increase costs to allow

Fig. 4: Aesthetic improvement was an important consideration in the design phase from a public outreach standpoint.

Fig. 5: The Alta Vista Standpipe is located on a small hill and is visible to thousands every day. The owner's intent was to provide a message to the public and taxpayers that WSSC is fully committed to maintaining its assets and investing in capital improvements.

for added rigging or delays in protecting equipment owned by others.

Secondly, contractors added costs to their bids to accommodate typical delays associated with the coordination of work with telecom companies and working around their equipment, particularly when installing a containment system.

One solution proposed was to have all telecommunication equipment temporarily removed from the tank (at the telecommunication company's expense) prior to contractor mobilization on-site. The cell carriers would be required to provide a portable, mobile cellular site, or "cell on wheels" (COW), giving the contractor full and unobstructed access to the entire tank.

Another solution involved including a mounting system in the contractor's scope of work for the telecommunication companies. It would incorporate appropriate standoff brackets for coax bundles and a roof antenna ring that could be used during the remounting phase once the contractor was off of the tank. All new mounting brackets and components would provide sufficient space between the tank and the telecommunication equipment so that the equipment could remain on the tank during future maintenance painting. Also, additional bracket runs would be provided to allow for future tenants, and therefore, potential future revenue, without having to weld directly onto the tank and possibly damage the new interior lining.

AESTHETIC IMPROVEMENTS

Aesthetic improvement was an important consideration in the design phase from a public outreach standpoint (Fig. 4). As mentioned, the Alta Vista Standpipe is located on a small hill and is visible to thousands every day. The intent here was to provide a message to the public and taxpayers that WSSC is fully committed to maintaining its assets and investing in capital improvements (Fig. 5). Allocation of revenue to this project would also emphasize the Commission's continued dedication to deliver clean and potable water to the public. To achieve these objectives in a cost-effective manner, the following requirements were included in the design phase and scope of work.

1. Select a finish coat that would be aesthetically pleasing.
2. Provide a new fence for security purposes to replace the obsolete, damaged fence.
3. Provide a decorative stone finish on the altitude valve vault retaining wall (midway up the slope).
4. Provide a decorative stone finish on the retaining wall for the new parking pad on West Cedar Lane, including decorative numbers for the address.

SUMMARY

Although rehabilitating the Alta Vista Standpipe posed numerous challenges, the cost savings versus replacement were estimated at $1.25 million. The improvements will also ensure that the tank will join the elite centennial club in a few years. In addition, improvements to the site were an important consideration in the design phase from a public outreach standpoint. The refurbishment of the water storage facility allowed the structure to blend in harmony with the environment and based on the positive feedback from the community and adjoining property owners: "Mission Complete."

ABOUT THE AUTHOR

Nick Bressler is a graduate of Ohio State University and the CEO and cofounder of World International Testing, Inc., a consulting and inspection firm specializing in nondestructive testing, structural integrity assessments and preparation of technical specifications for tanks, bridges and industrial structures in both private and civil sectors. Over the past 34 years, Bressler's extensive experience has been used for advisement and management in the fields of corrosion, painting, QA/QC inspections, underwater inspections (ROV or commercial diving/scuba) and nondestructive testing. He holds numerous certifications and his past and present affiliations include AWS, ASNT, SSPC, NACE, DOT and IUW, as well as serving as the past chairman for the SSPC Penn-Ohio Chapter. ***JPCL***

FEATURE

Three-Coat & Epoxy Mastic Bridge Coating Systems in Adverse Environments

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Protective coatings are widely used on steel bridge infrastructure in aggressive exposure environments to extend the service life of the structure. Even with ongoing development of coating technologies, steel bridges remain susceptible to corrosion deterioration. Periodic maintenance that may include coating repair is required for long-term bridge serviceability. The effectiveness of coating repairs can be impacted by improper application, exposure to adverse environments and presence of contaminants. Generally, coating repair applications require adequate removal of surface contaminants (including hygroscopic salts) from the steel substrate, appropriate surface roughening and appropriate curing environments. Repair of the degraded coating material should not be overly complicated and must be effective. Coating maintenance includes spot painting, overcoating and recoating based on the severity of degradation. For spot painting, epoxy mastic and polyurethane finish coats are often specified either with or without an epoxy penetrating sealer[1]. For repair by overcoating, the selection of coating material that is compatible with the base coating is crucial. For recoating, typically an organic or inorganic zinc-rich primer and epoxy midcoat with a polyurethane or polysiloxane finish coat are used. Loss of coating adhesion or cohesion, cathodic disbondment and scribe creep have been reported for conventional coating materials applied on poorly prepared surfaces containing rust and salt[2]. Adhesion loss at the steel/primer interface has been reported when the salt concentration and relative humidity exceeds a critical value[3,4]. Hygroscopic salt absorbs moisture at relative humidity above 76 percent and stimulates corrosion through osmotic action[5].

As described previously, it is generally understood that poor surface preparation, improper application, and aggressive curing and exposure environments can negatively impact the resiliency of a repair coating. As novel repair coating systems (that may have enhanced robustness in some adverse environments) continue to become available, establishment of a baseline behavior of conventional repair coating materials is important for appropriate comparison and validation. As part of a larger study in progress to assess novel coating materials, this article presents experimental results of coating degradation and corrosion development on three-coat zinc-rich primer coatings and aluminum epoxy mastic repair coatings on steel with deficient surface preparation and subjected to cyclic salt wet/dry exposure cycles.

METHODOLOGY

All coated steel samples were made from plain carbon steel plates (3-inches-by-5-inches-by-⅛-inch). The steel plates were either sandblasted or abraded with a grinder (60 grit) in order to identify the influence of complete and partial removal of existing coating layers. Samples that were sandblasted were done to SSPC-SP 10/ NACE No. 2, "Near-White Blast Cleaning" conditions. Samples that were abraded had partial remnants of an existing layer of a zinc-rich primer. After the surface preparation, the samples were exposed to various humidity levels for two days (5-percent, 75-percent and 100-percent) and surface salt contamination. For the salt-contaminated samples, 0.5 ml of 3.5-percent NaCl solution (~50 µg/cm² Cl^-) was placed on the surface and then immediately dried with warm air. Minor tarnishing was observed on these salt exposed samples. After the conditioning, the repair coatings were immediately applied over the samples (following manufacturer-recommended procedures) without any other surface preparation. The conventional three-coat zinc-rich primer system was only applied over sandblasted steel samples and aluminum epoxy mastic was applied over both sandblasted and abraded steel samples. The coatings were applied at the same time under similar environmental and application conditions (~74 F and ~80-percent relative humidity [RH]).

In the laboratory, the samples were exposed to cyclic testing in salt wet/dry conditions for four months. The cycles consisted of a sequence of exposure of two days of salt water immersion (3.5 weight percent NaCl), two days of salt-fog exposure (following ASTM B117, "Standard Practice for Operating Salt Spray [Fog] Apparatus") and three days of dry exposure up to approximately 20-percent RH. Electrochemical tests were made during the water-immersion sequence. These included open-circuit potential (OCP) measurements, linear polarization resistance (LPR) measurements and electrochemical impedance spectroscopy (EIS). The OCP was measured with respect to a saturated calomel reference electrode (SCE). LPR measurements were made from 0mV OCP to -25mV OCP at a scan rate of 0.08 millivolts per second (mV/s). The corrosion current, I_{corr}, was calculated from the resolved polarization resistance (Rp) following the relationship I_{corr}=B/Rp where B was assumed to be 26mV for corrosion conditions. EIS measurements were made from 1 MHz to 1 Hz at 0V OCP with AC perturbation amplitude of 10 mV. Photo documentation was also made after each dry cycle. All testing was replicated in duplicate samples.

RESULTS AND DISCUSSION

Pull-Off Strength

The pull-off strength of the conditioned coated samples that were not exposed to the cyclic testing was measured using a pull-off adhesion tester. In addition to the recorded strength, the tests were identified as total coating failure (where the failed coating exposed the steel substrate), partial coating failure (due to cohesive failure of the coating system) or failure of the glue used to attach the mechanical dolly to the coated sample. The results of testing are presented in Figure 1.

The majority of tests resulted in pull-off failure of the two coatings even at the low and ambient relative humidity conditions

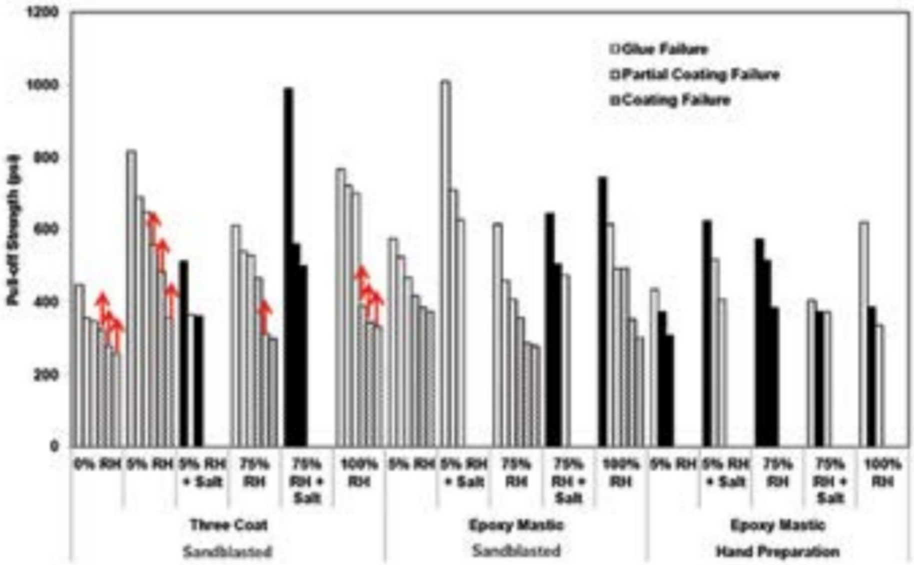

Fig. 1: Coating pull-off strength in as-received condition. Figures courtesy of the authors.

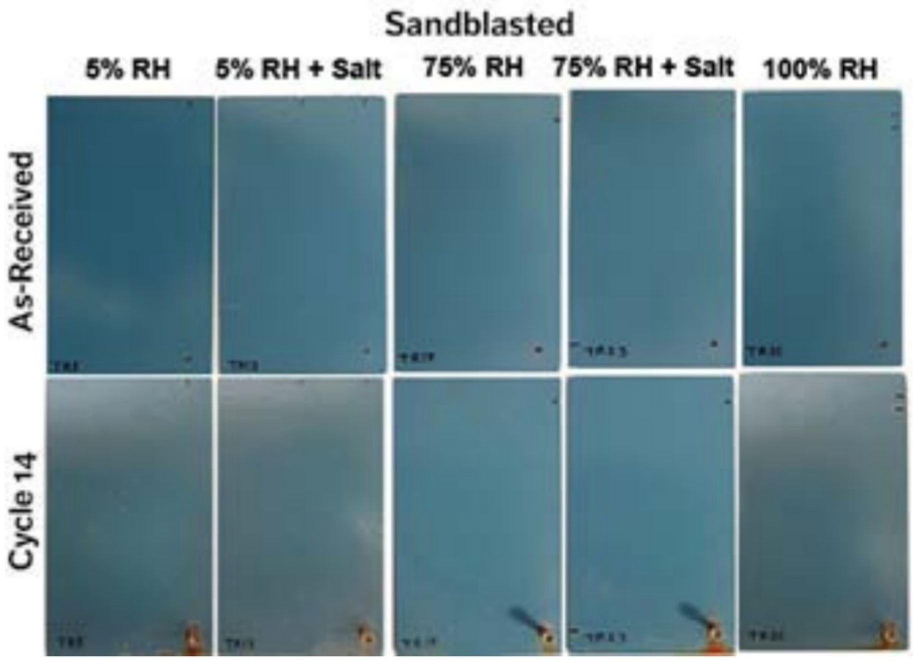

Fig. 2: Typical condition of three-coat-system samples after exposure.

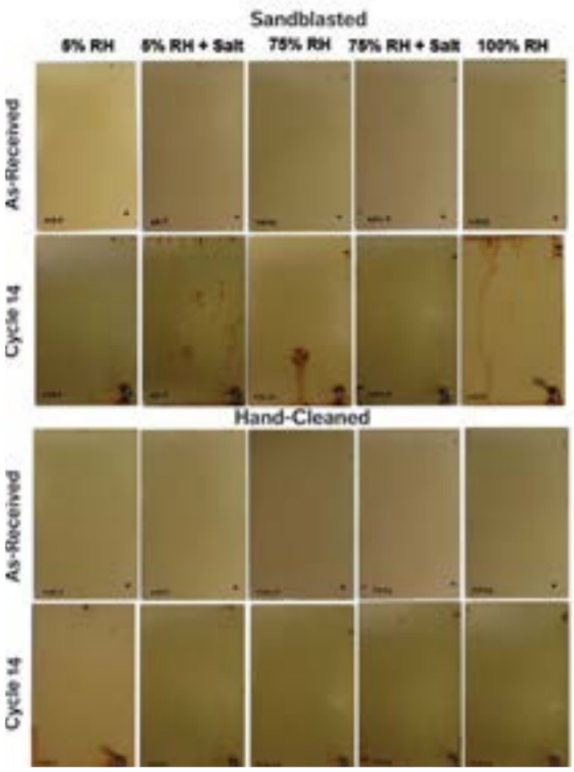

Fig. 3: Typical condition of epoxy mastic samples after exposure.

(generally partial coating failure). Results from earlier testing of the three-coat system applied in ideal environmental and shop conditions also showed partial coating failure at low strengths (~350 psi). This would indicate that other factors are involved in the resiliency of the coating cohesion. However, the test results did not elucidate clear differentiation in performance when exposed at the various levels of RH. Generally, the results showed that the coatings that were sandblasted had similar behavior. For both materials, the results of the pull-off tests indicated distinctly poorer coating mechanical behavior when exposed to salt. For the two coatings, full coating failure was observed predominantly in the ambient RH salt condition. Total coating failure was observed for the three-coat system at 5-percent RH salt condition as well. In a like manner, the mastic coating that was abraded showed distinctly poorer performance as indicated by the total coating failure but that failure occurred regardless of the environmental conditioning. Comparison of sandblasted and abraded epoxy mastic samples distinctly showed poorer performance in the latter regardless of environmental conditioning.

Visual Coating Degradation

Photo documentation was done of coated samples in the as-received condition and after each exposure cycle. Representative photos of coated samples in the as-received condition and after 14 cycles (four months) of exposure are presented in Figures 2 (p. 37) and 3. No major coating deterioration was observed on three-coat samples during the

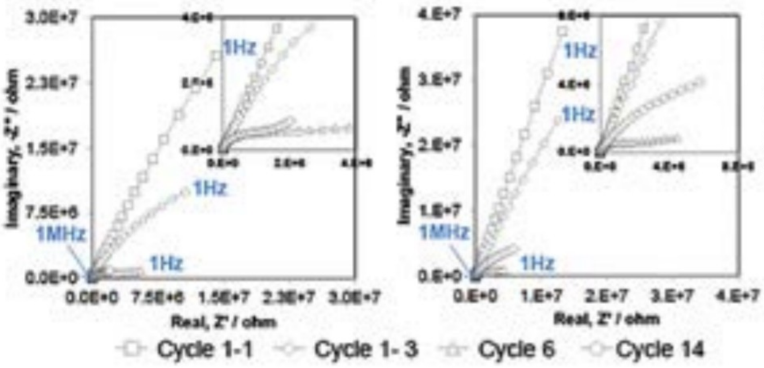

Fig. 4: Typical Nyquist plot of three coat system 5-percent RH (left) and 5-percent RH plus salt (right).

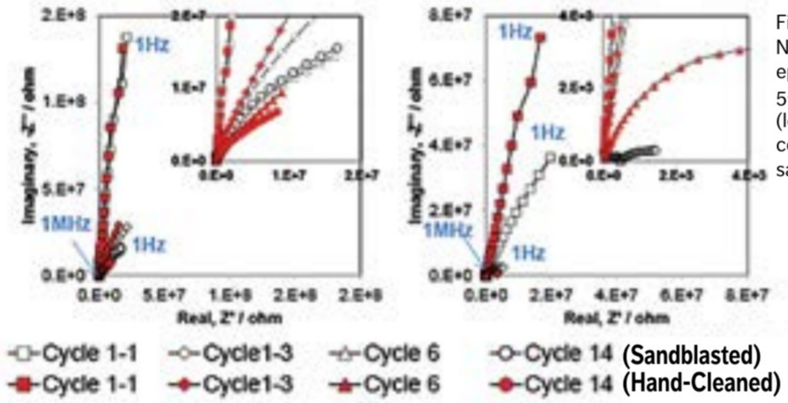

Fig. 5: Typical Nyquist plot of epoxy mastic 5-percent RH (left) and 5-percent RH plus salt (right).

exposure but minor surface roughening and discoloration was observed. Local corrosion spots and coating blistering developed on some of the sandblasted and abraded epoxy mastic samples (likely due to the detected local coating holidays) but was more severe on the former. Some zinc pigments from the original coating layer were retained on the steel substrate on the abraded samples. This residual zinc was apparently providing some beneficial galvanic coupling to the steel substrate. Further discussion is made in the presentation of the results of electrochemical corrosion testing.

Electrochemical Impedance Spectroscopy

Typical EIS results presented in Nyquist plots are presented in Figures 4 and 5 for the three-coat and epoxy mastic coatings. The Nyquist plots show a decrease in the high-frequency loop indicating a degradation of the coating barrier property. On first approach for a general assessment of coating

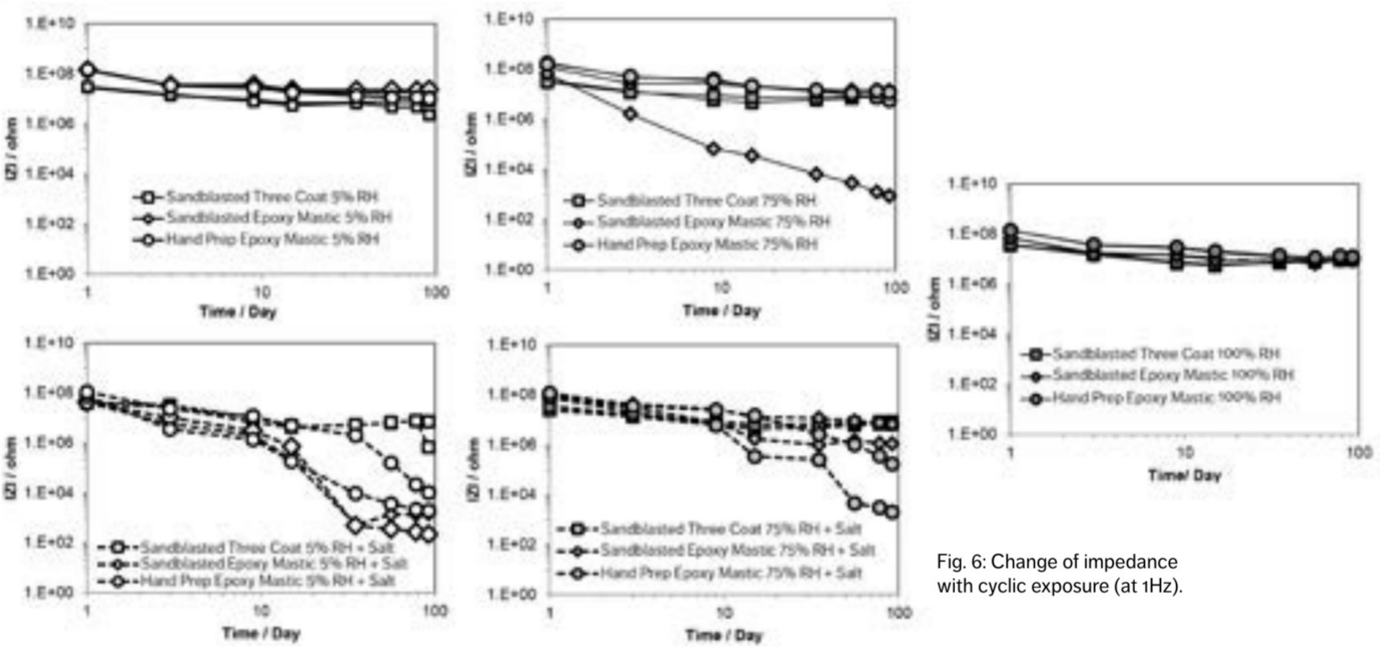

Fig. 6: Change of impedance with cyclic exposure (at 1Hz).

performance, the total impedance value measured at 1 Hz was used to compare the impedance of the coating systems with the various environmental exposure conditioning and with time of cyclic exposure (Fig. 6). At day one, the impedance for all coated samples was greater than 10 megaohms (Mohm) indicating good initial barrier coating characteristics. Similar to the initial pull-off strength measurements, there was not consistent differentiation of coating degradation with respect to the conditioning at the various RH levels, even after four months of exposure. Only one sample (the sandblasted epoxy mastic) conditioned at 75-percent RH showed a drop in total impedance during the course of the cyclic exposure. The total impedance for epoxy mastic samples (sandblasted and abraded surface preparation) with salt contamination reduced significantly during the exposure, indicating barrier coating degradation, and is consistent with the observation of coating holidays, blistering and corrosion described earlier. The three-coat system appeared to have better performance during the course of the exposure. There is some indication for a drop in total impedance for one sample conditioned in salt and 5-percent RH. Testing continues for these samples.

Electrochemical Corrosion Testing

OCP and I_{corr} results are presented in Figures 7 through 9. Relatively noble potential values obtained in early OCP measurements and in subsequent measurements for some test cases indicate that good coating barrier characteristics remained intact. These samples, in a consistent manner, showed

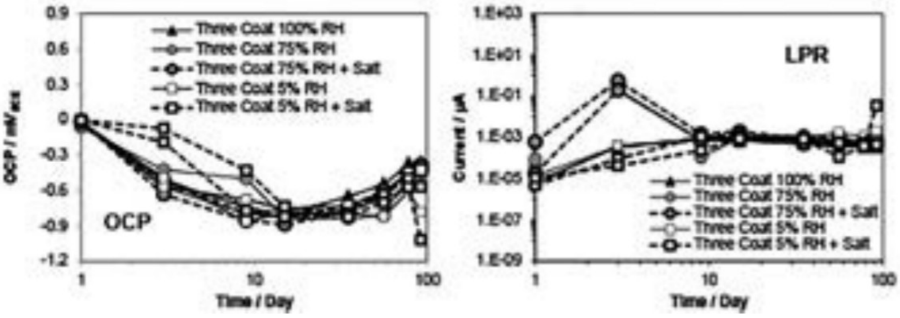

Fig. 7: OCP and LPR evolution of sandblasted three-coat system.

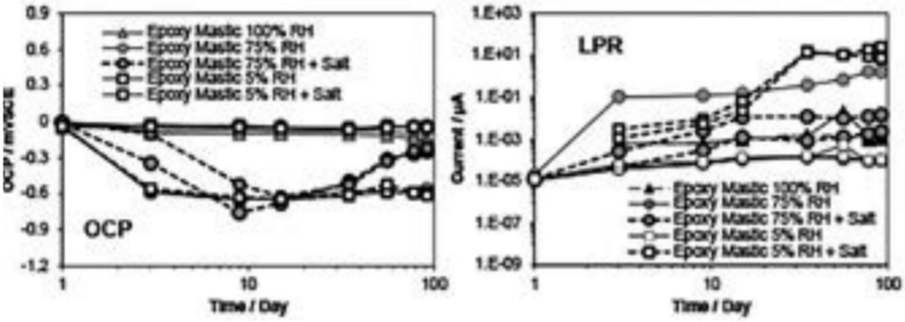

Fig. 8: OCP and LPR evolution of sandblasted epoxy mastic.

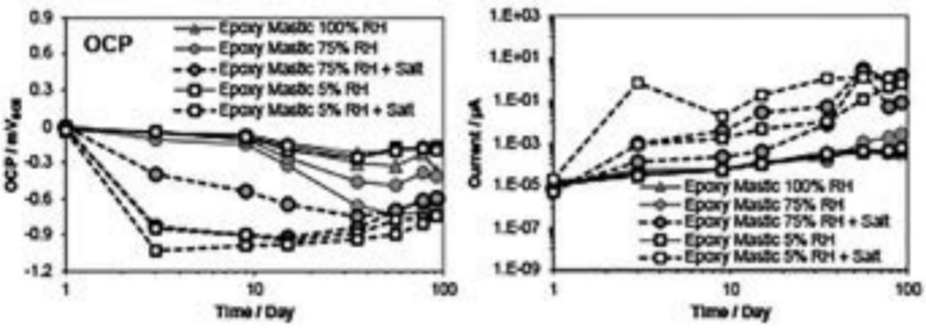

Fig. 9: OCP and LPR evolution of hand-cleaned epoxy mastic.

extremely low corrosion currents (~$1x10^{-5}$ µA). After approximately 10 days, the three-coat system showed a drop to potentials that may indicate some level of zinc activation; however, low corrosion currents throughout the cyclic exposure $I_{corr}<1x10^{-3}$ µA were generally maintained. This low level of corrosion is consistent with the lack of visual degradation and the high measured total impedance described earlier.

With the exception of one sandblasted epoxy mastic sample conditioned at 75-percent RH that showed active OCP and I_{corr} (consistent with the earlier description of surface rust and drop in total impedance), similar electrochemical corrosion characteristics were measured for the epoxy mastic except for those with salt contamination. For the salt-contaminated samples with sandblasted and abraded conditions, active potentials developed for the 5-percent and 75-percent-RH salt environmental conditioning shortly after cyclic exposure. Relatively high corrosion currents (greater than 1 µA) developed at the 5-percent-RH salt environmental conditioning for both sandblasted and abraded conditions and also at 75-percent-RH salt environmental conditions for the abraded condition. The high corrosion rates for these cases were also consistent with the visual observations of rust and coating blistering and drop in total impedance.

As presented earlier, the extent of rust development and blistering was somewhat greater on the sandblasted epoxy mastic than the abraded epoxy mastic. This was thought to be partly due to the residual zinc pigments in the latter. Comparison of OCP and I_{corr} between the sandblasted and abraded epoxy mastic indicates more active potentials and earlier development of high corrosion rates in the latter which may substantiate that residual active zinc pigments in coating repairs may provide a beneficial effect. Further evaluation on aluminum epoxy mastic is in progress.

CONCLUSIONS

1. Pull-off strength testing of samples with conditioning of the steel surface at 5-to-100-percent humidity prior to repair did not show clear differentiation in performance. Testing identified lower pull-off strengths on samples with salt contamination on the steel surface prior to repair coating.
2. Significant corrosion can develop on coated steel repaired with epoxy mastic with salt contamination on the steel surface prior to repair.
3. The total impedance at 1 H_z for both three-coat and epoxy mastic coating samples after coating application was greater than 10 Mohm indicating initially good barrier property, regardless of adverse moisture and salt-surface conditioning. The total impedance for epoxy mastic samples (sandblasted and abraded surface preparation) with salt contamination reduced significantly during the exposure indicating barrier coating degradation, consistent with the observation of coating holidays, blistering and corrosion described earlier. The three-coat system appeared to have better performance during the course of the exposure.
4. Inadequate surface preparation (abraded steel) can cause reduced adhesion and result in degraded coating barrier properties.

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COST SAVINGS AND BEST PRACTICES IN AIR ABRASIVE BLASTING

BY GREG BAKER, BLASTONE INTERNATIONAL

Ultimately, the reason that air-powered abrasive blasting is most often specified as the method of surface preparation is that it is currently the most cost-effective way to get large amounts of substrate cleaned quickly. However, learning how to identify costly oversights in the blasting department and discover simple changes or adjustments can lower costs even more. Documenting checks that a group leader should make — at least weekly, learning how to calculate total project costs and how to make incremental changes can all help to improve the bottom line.

There is important criteria to consider when choosing a surface preparation method along with ways to reduce costs associated with this process. When discussing air-powered abrasive blasting, technologies, industry best practices are often overlooked or circumvented in the name of tradition or cost savings, but the results of these choices can be very harmful. This article will focus on taking steps to maintain or increase production, while increasing departmental profits.

IMPROVING AND MAINTAINING PROPER NOZZLE PRESSURE

Proper nozzle pressure means at least 100 psi at the nozzle — 110 psi or higher is better, but the reality is that most jobsites visited by the author don't meet this. Many use below 100, a lot are even below 90, and yes, far too many are still below 80. Why do we care about this and why is it important?

Because, every 1 psi below 100 is costing the user 1.5 percent in productivity. To put this into perspective, if your blaster's nozzle pressure is 90 psi, that means you've left 15 percent of your potential productivity on the table. In a world where costs are being squeezed everywhere, that 15 percent could go a long way.

Fig. 1: A hypodermic needle-style nozzle pressure gauge kit. Images courtesy of the author.

Many production managers make the assumption that their compressor gauge is actually their blasting pressure, when in fact there are a lot of areas of pressure loss throughout an entire system. The nozzle pressure is the only variable that matters when assessing blasting pressure.

So how does one actually test nozzle pressure? This can be accomplished with a new or relatively new hypodermic needle style nozzle pressure gauge kit (Fig 1). There are some very specific places that the pressure should be checked, but the most ideal is directly behind the nozzle holder.

To test nozzle pressure with a pressure gauge kit, you simply follow these three steps while the abrasive flow is open.

1. Place the hypodermic needle onto the nipple at the base of the gauge.
2. Point the needle toward the nozzle at a slight angle. Insert the needle into the blast hose slowly, a few inches back from the nozzle until you get a constant reading. Is your reading at least 100 psi?
3. Record your reading and remove the needle.

You can also use this gauge to test the rest of your system by checking your blasting system right through to find where your pressure losses are located. Test the pressure at both ends of a long length of hose — you'll be amazed to see how much the pressure can drop.

It is recommended to get two pressure test kits, one to test the air going into your blast pot and one to test the air pressure coming out (Fig. 2). If you are losing excessive pressure, it may be related to equipment, accessories or the compressor.

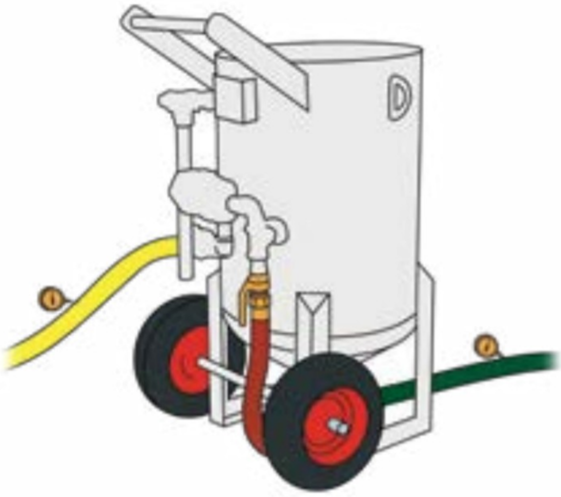

Fig. 2: Two pressure gauge kits are recommended — one to test the air pressure going into your blast pot and one to test the air pressure coming out.

USE AND TESTING OF BLAST NOZZLES

A common misconception is that you are going to save money by hanging on to your old blast nozzles. The reality is that the actual cost of a blast nozzle is extremely small in comparison to the total cost of a painting project, but the performance of a nozzle can significantly affect a total project cost.

A Venturi-style abrasive blast nozzle works like a jet engine. Air is compressed rapidly in a cone, passes through a small orifice and then expands more gradually than it compressed (Fig. 3).

This rapid compression and expansion allows the abrasive in the airstream to pick up speed very quickly. For example, abrasive travels down the blast hose at about 65-to-80 mph, and after this rapid compression and decompression (known as rarefaction) the abrasive is moving at close to the air speed, which can be more than 400 mph.

Fig. 3: A Venturi-style abrasive blasting nozzle works like a jet engine. Air is compressed rapidly in a cone, then passes through a small orifice and then expands at a more gradual rate than it compressed.

Table 1: Air Consumption (CFM) per Blast Nozzle – Using Garnet Abrasive.

Nozzle Size		Nozzle Pressure										
		50 psi	60 psi	70 psi	80 psi	90 psi	100 psi	110 psi	120 psi	130 psi	140 psi	150 psi
No. 2	⅛"	14	17	19	21	24	28	28	30	32	34	37
No. 3	3⁄16"	32	37	42	47	52	62	62	67	72	77	83
No. 4	¼"	57	66	75	84	93	111	111	119	127	136	185
No. 5	5⁄16"	89	103	117	131	145	172	172	186	200	214	229
No. 6	⅜"	129	149	169	189	209	249	249	269	289	309	330
No. 7	7⁄16"	176	203	230	258	285	339	339	367	394	422	451
No. 8	½"	229	265	300	336	371	442	442	478	513	549	586
No. 10	⅝"	356	412	468	524	580	688	688	744	800	856	914
No. 12	¾"	516	596	676	756	836	996	996	1076	1156	1236	1318
Emergency		47%	55%	64%	74%	86%	100%	115%	130%	145%	165%	175%

Fig. 4: A nozzle size analyzer gauge is most frequently used to measure the diameter of a blasting nozzle.

The two most common liner materials for blast nozzles are tungsten carbide and silicon nitride. These are both very long-wearing materials, but this is an extreme environment, so wear is inevitable.

As you can imagine, the area of fastest wear is the smallest point of the nozzle, called the orifice. This orifice is measured by its ID, in either 1⁄16 of an inch or in millimeters. This size, and this size alone, determines how much compressed air the blasting system will need. Table 1 demonstrates the volume of compressed air that various size nozzles will use at differing pressures.

A nozzle is considered to be worn when it reaches one size larger than its original.

The tool that is most frequently used to measure the diameter of a nozzle is a nozzle size analyzer gauge (Fig. 4).

Use of this gauge involves the following steps.

1. Using a soft marking utensil such as a construction pencil, industrial crayon or marker, mark all sides of the tapered section of the gauge.
2. Holding the round end in hand, insert the gauge into the back of the nozzle until it stops.
3. With the gauge held into the nozzle, rotate the tool two-to-three full turns.
4. Remove the tool and compare the scratch marks on the gauge to the

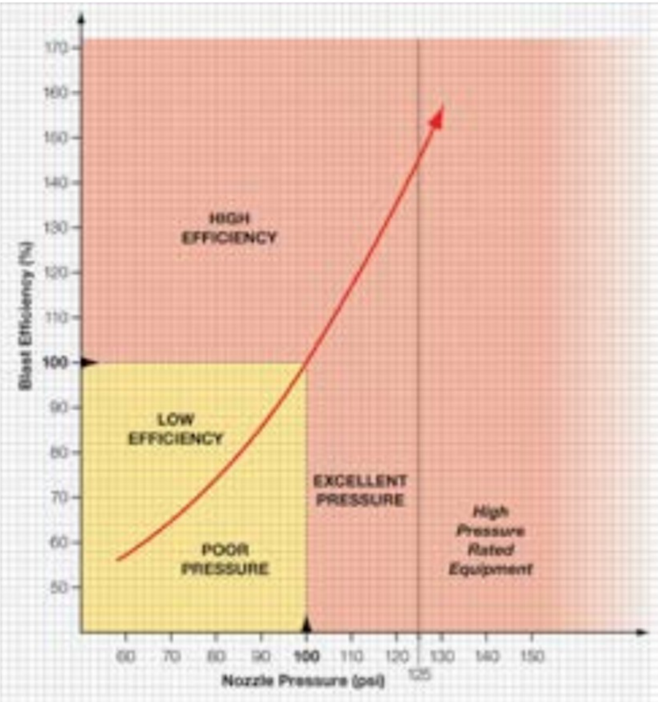

Fig. 5: Having optimized nozzle pressure is of critical importance.

measurements on the flat side of the tool. This scratch marking will indicate the ID of the nozzle orifice.

5. If the size indicated by the test is more than one size larger than is shown on the outside of the nozzle, discard it and replace the nozzle.

SELECTION OF BLAST HOSES

The selection of blast hoses is absolutely critical to setting up a project for success. Failure to select proper hoses will cripple the project and put a successful result in jeopardy by reducing nozzle pressure, which in turn slows production while increasing energy and abrasive consumption.

The primary arguments against using larger blast hoses are that the hoses are more expensive to purchase, are heavier and are harder to move around. However, these factors pale in comparison to the additional cost of using an undersized blast hose, even for a relatively short-term project.

A blast hose that is undersized will increase the internal resistance of the hose, slowing down the air/abrasive mix and in some cases, dramatically decreasing nozzle pressure. Table 2 explains the pressure loss differences between blast hoses.

To put this idea into context, if you are running 150 feet of 1-inch ID blast hose, you will likely lose around 45 psi just across the hose. Or if you have 120 psi in the blast hose when it comes out of the pot, you

Table 2: Differences in Pressure Loss Between Blast Hoses.

ID of Blast Hose	Pressure Loss per 50' section
1" Inside Diameter	15-17 psi
1-¼" Inside Diameter	6-7 psi
1-½" Inside Diameter	2-3 psi

have only 75 psi at the nozzle. By switching to a 1.5-inch ID blast hose, that pressure loss would be as low as only 6 psi, meaning you would be maintaining well in excess of 110 psi at the nozzle.

Using the 1 psi equals 1.5 percent production rule of thumb, that 39 psi difference equals roughly 58 percent productivity.

These figures are too large to be ignored. Evaluating blast hoses for correct sizing should be a top priority; having optimized nozzle pressure is of critical importance (Fig. 5).

SELECTING THE CORRECT ABRASIVE FOR A PROJECT

One big misconception is to immediately look at the price of abrasive, i.e., the price-per-pound or price-per-ton. On a blasting project of any significance, if you actually look at the cost of abrasive compared to the total job cost, it is surprising to notice what a small percentage of a total project the abrasive makes up.

Some abrasives blast faster than others and some abrasives have lower consumption than do others. So, to look at the price of abrasive and choose the lowest thinking you're saving money is a misconception.

In order to determine what abrasive should be selected, the following formula developed by the U.S. Navy to determine the cost per square foot of blasting should be used.

True cost per square foot = $\frac{A(B+C)+D+E}{X}$

A = Abrasive consumed per nozzle, per hour (in pounds).

B = Abrasive cost delivered per pound.

C = Clean up and disposal costs per pound.

D = Labor cost per nozzle, per hour.

E = Equipment running cost per nozzle, per hour.

X = Square feet blast cleaned per nozzle, per hour.

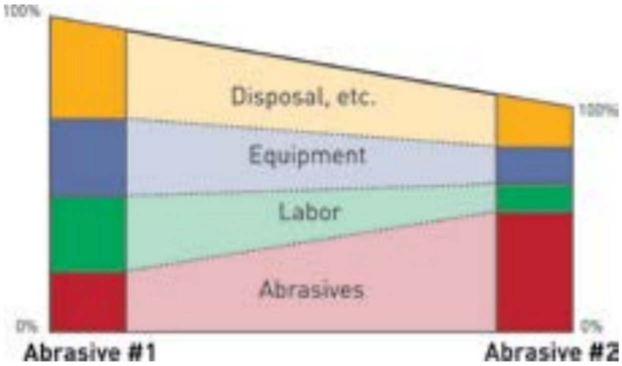

Fig. 6: When used correctly, an abrasive that costs more per pound can yield better overall results.

Using this formula, the evaluation of different abrasives takes on a completely different perspective. Oftentimes, when used correctly, an abrasive that costs more per pound can yield better overall results, an example of which is shown in Figure 6.

Before any abrasive choice is made, the decision maker should ask him or herself two questions.

1. What will my blasting speed be for each abrasive in this specific application?
2. What will my hourly consumption be with each abrasive? (This will affect the material I purchase, pay to get delivered to the site and pay to have disposed of).

SUMMARY

The following points are important to consider and can easily impact the success and cost of a coating project.

- Make sure you get the accurate air pressure at the actual blast nozzle.
- Don't overuse blast nozzles. Throw them away when they wear more than one size.
- Don't hinder production by using small blast hoses. Take a serious look at what size hoses you are currently using.
- Consider both the blasting speed and consumption rate of any abrasive before looking at the price.

ABOUT THE AUTHOR

Greg Baker has in-depth knowledge in best practices and techniques developed in the more than 20 years he has worked in the blasting and protective coatings industry. He has worked at BlastOne International since 2011 in various roles, including technical production consultant and industrial solutions support. ***JPCL***

31 mm²

The measurement area of replica tape, roughly 258 times larger than that of a stylus roughness instrument and approximately 4,400 times larger than that of a depth micrometer.
See page 22.

1.5 percent

The amount of productivity lost with each 1 psi below the minimum proper blasting nozzle pressure of 100 psi.
See page 46.

92

The age of a refurbished Montgomery County, Maryland water tank — the oldest in the inventory of the Washington Suburban Sanitary Commission (WSSC).
See page 28.

71%

Percentage of PaintSquare Poll respondents who believe that states should take bridge conditions more seriously and immediately close and repair bridges that are deemed unsafe.
See page 11.

5%, 75% and 100%

Humidity levels that prepared samples were exposed to — along with surface salt contamination — before coating.
See page 36.

11,800 feet

The elevation at which a 5 MG water storage tank had to be constructed and painted at a ski resort in the mountains of New Mexico, which presented unique challenges.
See page 25.