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JPCL
JOURNAL OF PROTECTIVE COATINGS & LININGS
The Voice of SSPC: The Society for Protective Coatings

SSPC The Society For Protective Coatings

Cover: istockphoto

Also this month

From the Offices of SSPC The Society For Protective Coatings

SSPC recently launched an all-new sspc.org! For quick access, use your smart phone to capture this barcode.

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Messages from the Outgoing and Incoming Presidents

It has been my pleasure to serve as the SSPC President for the past year, where I have been able to represent a first-class society at numerous functions and meetings. In my capacity as President, I have also had the privilege of serving as the chairman of the SSPC Board of Governors. I know many of the past Presidents have said this before, but I want to reiterate that it has been an absolute pleasure being around such a dedicated group of individuals whose focus is, most importantly, serving the coatings industry while enhancing the scope and mission of SSPC. With the Board's guidance and the staff's hard work, it has been amazing how SSPC has weathered our uncertain economy these last few years. We have the premiere coatings society that is financially sound, is relevant, and continues to serve the coatings industry. However, members' continued support and involvement are crucial to the continued success of SSPC.

Training and individual certifications have continued to be the bell weather source of revenue for the association, accounting for 34% of revenue last year. It is well known that owners are requiring workers and companies to meet stringent requirements right now, and the outlook is for these requirements to become more demanding in the years ahead. SSPC is poised to fill that requirement. I was also fortunate to be President when SSPC returned to having its own conference. In this case, it was SSPC 2011. The conference attracted more attendees and more booths than expected. It was rewarding to preside over an SSPC-only event that concentrated on fulfilling the needs of our members. The results validated the Board's decision to hold our own conference. I also want to note that membership has increased over the last year, and SSPC has continued to build its name recognition overseas. Because of that increased visibility, the Board added an International Member, Gunnar Ackx, from Belgium, who is already making great contributions. Increased membership and more visibility are both significant considering the paths of many other associations. I also want to let you know that SSPC awarded three $2,500 scholarships to deserving students from North Dakota State University and the University of Southern Mississippi who are pursuing careers in biochemistry and chemistry. The generosity of SSPC members was so evident in the recent Japanese relief campaign. Bill wrote about this in his last editorial, but I just wanted to pass along my thanks from the Board of Governors.

I also want to thank the other members of the Board of Governors and the staff for their unwavering support. I cannot say enough about the staff who keep the organization moving along the path set by the Board of Governors. Lastly, and most importantly, I would like to thank the members for their support of SSPC.

Russ Brown
Immediate Past President

It is a privilege to serve SSPC as its President for 2011-2012. I am honored that the Board has selected me to follow Russ and be their chairman for the next year, and I must add that I am the first Canadian to serve as President of SSPC. I have been a member of SSPC for over 20 years and have been in this industry for over 28 years. I have lived and worked overseas, and I see a need for the products and services SSPC has to offer around the world. SSPC has always been my association of choice to help me do my job. On a few occasions, I have heard that a certain member was upset with SSPC for the way the staff conducts business or was upset over a certain policy. If you have a suggestion for improving what we do, let a member of the Board of Governors or staff know. We want to be member- and customer-friendly and have more owner/specifier involvement. Owners are key in this industry because they decide what coatings system will be used to satisfy their long term needs. From that decision, other elements in this industry fall into place. If you want to change something, I ask that you get involved. Changes and advancements require communication and participation. By getting involved, you may also learn something from your colleagues that will help you do your job. Come to SSPC 2012 in Tampa, go to a chapter meeting, attend an SSPC training course, or participate in a committee. All are welcome, and you never know what follow-on benefit you will receive.

I am eager to continue working with the other members of the Board and the outstanding staff toward our mutual goal of moving this organization forward. I hope to see everyone in Tampa at SSPC 2012 where we can have a great dialogue on how to better serve the members' needs.

Robert P. McMurdy
SSPC President

Ikenberry Will Give Webinar on Creating a Contractor Safety Program

Robert Ikenberry, winner of the SSPC Outstanding Paper Award in 2011, will present the webinar, "Creating a Contractor Safety Program That Works," on Wednesday, Sept. 14, 2011, from 11:00 a.m. to noon.

The safety program presentation is an SSPC/*JPCL* Education Series Webinar designed to provide relevant education for SSPC recertifications as well as general education to coatings specialists.

Robert Ikenberry

Ikenberry is a corporate safety director and project manager for California Engineering Contractors and is an SSPC-certified Protective Coating Specialist.

In his webinar, he will provide guidance for industrial painting contractors who have to develop a company safety program. He will describe both good safety practices and regulatory requirements germane to contractor operations, including the current OSHA guidelines for a company safety program.

SSPC is an accredited training provider for the Florida Board of Professional Engineers (FBPE). Professional engineers in Florida can now submit SSPC Webinar Exam CEUs to the FBPE. If interested in submitting Webinar Exam CEUs, you must download the FBPE CEU form and successfully pass the Webinar Exam. The CEU form can be found online at the SSPC Marketplace at www.sspc.org/marketplace.

Participation in the webinar is free, but for those who wish to receive continuing education credits from SSPC, the cost of the exam is $25.

Larson Electronics will sponsor the webinar.

SSPC/*JPCL* Plan to Expand Webinar Program in 2012

Due to increasing popularity, the SSPC/*JPCL* Education Series Webinar program plans to expand from one webinar a month to approximately one webinar per week in 2012. This will provide industry professionals with ample opportunities to earn CEUs, in addition to keeping up with the latest information available on dozens of topics within the industrial and marine coatings and linings industry.

Stay tuned as *JPCL* and SSPC schedule expert instructors to provide you with what is sure to be a valuable educational experience.

As it becomes available, information on future webinars can be found at www.paintsquare.com/education.

Two Bulletins for QP-Certified Contractors Issued

SSPC recently issued two bulletins for QP-certified contractors.

The first bulletin updates the Disciplinary Action Criteria (DAC) Special Provision on Reporting Fatalities. Key changes include

- contractors must notify SSPC in writing and by phone within five days of a fatal accident and confirm receipt;
- contractors must notify SSPC of OSHA or other governmental investigations and citations issued in relation to the incident; and
- contractors must file the preliminary correction action plans (CAPs) and the final CAPs after investigations are complete; CAP must be approved by key managers and Certified Safety Professionals (CSP).

The update also clarifies incidents that qualify for an exemption from disciplinary action lists and the procedures for requesting an exemption. The appeals process when exemption requests are denied is also defined.

The second bulletin discusses upcoming requirements and changes for Coating Application Specialists (CAS) and SSPC-QP 1-certified contractors.

As of Jan. 1, 2013, there should be at least one CAS certified craftsperson on eligible industrial painting job sites, which includes blast cleaning and spray-painting projects on metal surfaces with a contract amount for coating work exceeding $50,000. Exempt jobs are specified by the owner. Exempt projects and tasks include water cleaning, chemical stripping, or hand and power tool cleaning; brush, roller, or mitt coating application; coating of concrete or other non-metallic surfaces; and commercial/architectural coating projects.

Getting applicators CAS certified will require at least 2,000 hours of documented practical experience and a minimum of 150 hours of classroom training for Track One of the "Interim" Level II certification. Track two will require at least 3,000 hours of documented practical experience and no formal classroom

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Getting applicators CAS certified will require at least 2,000 hours of documented practical experience and a minimum of 150 hours of classroom training for Track One of the "Interim" Level II certification. Track two will require at least 3,000 hours of documented practical experience and no formal classroom training. The certification exam will include a written, closed-book, 100-question, multiple-choice test and hands-on skill assessment in blast cleaning and spray-painting.

Special Hotel Rates Now Available for SSPC 2012 in Tampa

SSPC 2012 featuring GreenCOAT will take place in Tampa, FL, at the Tampa Convention Center from Jan. 30, 2012, to Feb. 2, 2012. SSPC has reserved rooms at the Tampa Marriott Waterside and the Embassy Suites Downtown. To take advantage of the special rates, book a reservation by Jan. 3, 2012.

Reservations can be made after Jan. 3, through Jan. 23; however, SSPC cannot guarantee a discount or availability at the conference hotels.

Reservation requests must be sent directly to the SSPC Housing Bureau through Jan. 23, 2012. Sending housing forms directly to the conference hotels or SSPC Headquarters will delay the request.

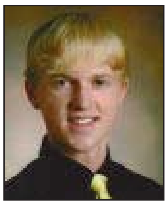
A list of prices and a hotel reservation form can be found on SSPC's web site at www.sspc.org/sspc-events. Forms can be emailed to housing@visittampabay.com; faxed to 813-218-3369; or mailed to SSPC Housing Bureau, 401 East Jackson St., Ste. 2100, Tampa, FL 33602.

A credit card guarantee of one night's room and tax is required with each request. Forms received without valid credit card information will be returned and will not be processed. Credit cards must be valid through Feb. 29, 2012. Cash and check deposits will not be accepted.

Reservations will be processed on a first come, first served basis.

SSPC Chooses Scholarship Recipients

In the March 2011 *JPCL*, it was reported that the SSPC Board of Governors had approved $2,500 scholarships for college students who are pursuing an education in the coatings field for the upcoming 2011-2012 school year.

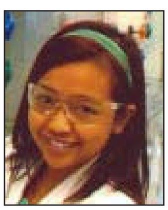


Tyler Brown

According to SSPC, the following individuals will receive scholarships.

- Tyler Brown; Major: Biochemistry & Polymer Science
- Teluka Pasan Galhenage; Major: Chemistry
- Adlina Paramarta; Major: Chemistry

Teluka Pasan Galhenage



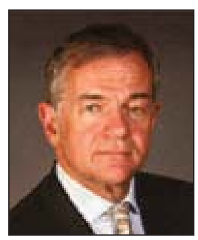
Adlina Paramarta

The SSPC Board Scholarship Task Group, which consisted of three SSPC members designated by the Board, chose the scholarship recipients.

PPG Revamps Global Coatings Leadership

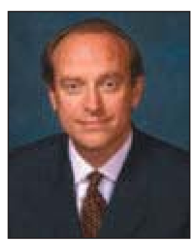
PPG Industries has announced new global leadership for its protective and marine, industrial, aerospace, and architectural coatings businesses. Personnel changes take effect on Sept. 1.

Pierre-Marie De Leener, PPG executive vice president, will lead PPG's global protective and marine coatings, aerospace, and automotive refinish businesses. De Leener will also assume executive leadership responsibility for the Latin America region. He will retain responsibility for PPG's global information technology function.



Pierre-Marie De Leener

Viktoras R. Sekmakas, PPG senior vice president for industrial coatings and president of PPG Asia/Pacific, will become senior vice president for industrial coatings and president of PPG Europe. Sekmakas will assume leadership responsibility for the EMEA region in addition to leading the global industrial coatings and packaging coatings businesses.



Viktoras R. Sekmakas

J. Rich Alexander, PPG executive vice president, will lead all of PPG's architectural coatings businesses. In this role, he will direct the integration of PPG's architectural coatings businesses in EMEA, the Americas, and Asia/Pacific. Alexander will also assume executive leadership responsibility for the Asia/Pacific region and will retain responsibility for PPG's fiberglass and flat glass businesses, purchasing and distribution, and corporate marketing.

J. Rich Alexander

Michael Horton

Michael Horton, vice president of Asia/Pacific coatings and general manager of automotive refinish and architectural coatings in Asia/Pacific, will be named president of PPG Asia/Pacific and vice president of automotive refinish and architectural coatings Asia/Pacific.

Visit www.paintsquare.com or www.ppg.com to read about leadership changes at PPG.

For instant industry news, register at www.paintsquare.com/psn/, or use your smartphone to capture the barcode.

On the Cleanliness of Compressed Air for Blasting

This Month's Question: How clean must the compressed air be for abrasive blasting? How is cleanliness determined?

From Patti Roman
Clemco Industries

One of the most critical elements of a successful abrasive blast operation is the compressed air that energizes the system. Moisture and oil are the enemies. They cause abrasives to form clumps, which can clog metering valves, hoses, and nozzles. If moisture reaches the surface being cleaned, it can cause steel to rust; oil can cause coating adhesion problems and blistering, resulting in coating failure.

A 40–50 micron air filter, installed at the blast machine's air inlet, is typical for removing particulate matter from compressed air for abrasive blasting. This filter will remove moisture that has condensed but will not remove water vapor. In high-humidity areas, additional drying is often needed. Aftercoolers or air dryers are needed to prevent abrasive bridging, which means the air channels through the abrasive in the machine but the abrasive does not flow. Some abrasives are more moisture-tolerant than others. Finer mesh materials will be more susceptible to moisture problems. And some abrasives manufacturers treat their material to enhance flow.

When a blast operator blows down the surface following blasting, it is important that the air is dry. If it is not, and moisture hits the freshly blasted surface, water spotting can occur. Water spotting can affect the coating application.

Compressed air is used to power abrasive blast machines as well as to provide breathing air for blast operators. For blasting, removing moisture and oil assists abrasive flow and prevents oil contamination on the blasted surface. These types of contamination are visible and obvious, and can be identified using methods described in ASTM D4285, "Standard Test Method for Indicating Oil or Water in Compressed Air."

When compressed air is used for breathing air, the term cleanliness takes on new meaning. OSHA regulations state that breathing air must meet the specification for Grade D, as established by the Compressed Gas Association. Grade D defines minimum and maximum limits on oxygen and other gases. Breathing contaminated air can be deadly, so this serious discussion should be the topic of another PSF.

From Gary Mabry

T & G Services

It is critical that the compressed air supply for abrasive blasting is not contaminated with oil or water. To ensure that the air is dry and clean, conduct a blotter test prior to starting each work shift and at reasonable intervals throughout the day. If contaminants are evident on the blotter test, all filters and driers that should be present in the supply line must be opened and blown out until the air is clean and passes the blotter test. If you can't achieve a passing test, added filters can be used, or the air source should be replaced.

From Lee Edelman

CW Technical

The air supply must be free of oil, water, and other contaminants. Cleanliness is checked by doing a blotter test at the air manifold. The air supply should have moisture traps in-line and a proper aftercooler system.

From Carl Havemann

www.corrosioneducation.co.za

There are two contaminants to test for, oil and moisture. Check for oil using proper proprietary oil mist test equipment. The acceptance criterion is that no oil is allowed. To check for moisture, blow the compressed air onto clear glass for 30-60 seconds; then check for condensation. The acceptance criterion is that no moisture allowed. (A five-minute test is too long, in my opinion.)

JPCL

Editor's Note: *The above Problem Solving Forum (PSF) question was posted on the free daily electronic newsletter,* PaintSquare News (PSN), *on behalf of* JPCL. *PSF responses submitted through* PSN *as well as those sent directly to* JPCL *are selected and edited to conform to* JPCL *style and space limitations.* JPCL *invites additional responses to the question; you may send your answer directly to Karen Kapsanis, editor,* JPCL, *kkapsanis@protective-coatings.com.*

The Case of the Gasoline Storage Tank Linings

By Kenneth B. Tator, P.E., KTA-Tator, Inc.
Richard Burgess, Series Editor, KTA-Tator, Inc.

This case involved the investigation of alleged failures related to a large class-action lawsuit between a gasoline refinery and a number of gasoline service station owners. The service station owners claimed that the refinery had not suitably removed contaminants from the gasoline they sold after crude oil refining.

Fig. 1: Typical lined steel underground gasoline tanks removed from service stations and kept in a storage yard. Photos courtesy of KTA-Tator, Inc.

Background

Crude oil contains chemical compounds of carbon and hydrogen that provide the energy component of fuels. Along with these hydrocarbon compounds, there are other ingredients, such as sulfur, hydrogen sulfide, disulfides, and salts. When the sulfur-containing crude oil is heated in the presence of air during distillation to separate hydrocarbon fractions, an oxidation reaction of sulfur produces by-products such as sulfites (SO_3^-), sulfates (SO_4^{-2}), thiosulfates ($S_20_3^{-2}$), polysulfides (-S-S-), and mercaptans (HS^-). The crude oil must undergo further refining to remove these and other deleterious materials, thus purifying the hydrocarbon portion of the fuel. The refinery used a stabilized caustic emulsion solution, consisting principally of sodium hydroxide, to remove residual sulfur and sulfur by-products.

The service station owners contended that the sodium hydroxide emulsion was not completely removed from the refined gasoline and that residual sulfur was present, principally in the form of mercaptans. The station owners contended that these contaminants, along with the excess caustic emulsions used to remove them during refining, attacked the epoxy and polyester linings of older underground steel storage tanks and the polyester resin of newer fiberglass underground storage tanks. While the linings and fiberglass would otherwise be resistant to properly refined gasoline, contamination from the insufficiently removed contaminants and the excess sodium hydroxide in the gasoline caused aggressive deterioration of the lining and fiberglass underground tanks.

Fig. 2: Typical fiberglass underground gasoline tanks in the storage yard.

The service station owners declared that the refinery's lack of control over its refining process ultimately required removal and replacement of underground gasoline tanks at a large number of service stations, with an estimated cost of approximately $250,000 per service station. Moreover, the service station owners believed that they were potentially liable for damage to the automobile engines of customers who purchased contaminated gasoline from their service stations and were suing for a substantial sum of money to be set aside for that possibility.

The refinery admitted that there had been some malfunctions and shutdowns to the refinery process equipment, and occasionally, some contaminants were not removed from the gasoline. However, refinery reps stated that the gasoline refined during these problem times had been isolated and did

Continued

Fig. 3: Disbonding of epoxy lining from a steel tank interior. Note the blast cleaned steel beneath the delaminated epoxy lining.

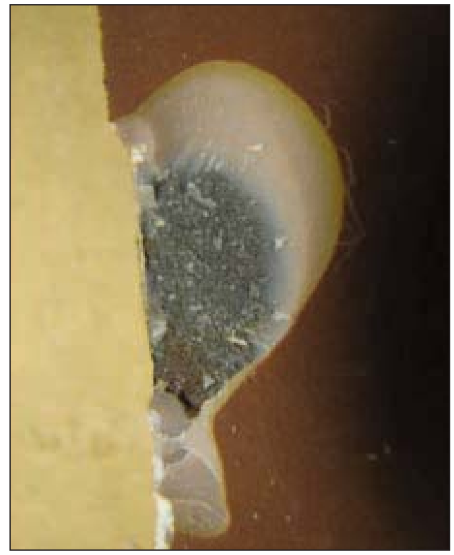


Fig. 4: A close-up (5X) photo of the blast-cleaned steel beneath an epoxy lining in another tank. Adhesion was excellent.

not get into distribution pipelines or the supply system.

Both steel and fiberglass underground tanks had been removed from a number of the service stations and kept in a storage yard (Figs. 1 and 2). Those tanks were available for examination, sampling, and testing.

Field Inspection

Some steel tanks were lined with an epoxy lining, while other tanks were said to have an isophthalic polyester lining. Upon inspecting a number of the steel tanks, it was evident that disbonding of the epoxy lining had occurred at localized areas on all of them, with delamination occurring in some areas from what appeared to be a properly blast cleaned substrate (Fig. 3). In some tanks, a black layer appeared beneath the marginally adherent lining. In other areas of these tanks, the epoxy lining was tightly adhered and could be removed only with a hammer and chisel (Fig. 4). The epoxy lining showed loss of adhesion and loss of gloss and staining, with a thickness between 35–200+ mils.

The application of the epoxy lining was extremely uneven. There was evidence of severe curtaining, pinholing, and dry spray. Pinholing was mostly evident in areas where the lining was relatively thin. Often, the thinner areas were located between heavier areas on the same panel, indicating a severely uneven application. There was often rust bleed from the pinholes.

The application of the polyester linings was more uniform, with little evidence of poor surface preparation, excessive or deficient thickness, or other application irregularities. Adhesion was excellent in all areas when tested with a hammer and chisel. The polyester lining thickness ranged between 95 and 120 mils and averaged 110 mils.

The fiberglass tanks were filament-wound using an isophthalic polyester resin and blended with a limited amount of a vinyl ester resin. The matrix was reinforced with a chopped strand, randomly oriented C-glass fibers, and glass filaments. The inner tank wall surface was a resin-only (no glass fibers) layer about 0.2–0.4 inches thick to prevent the tank contents from “wicking” into the fiberglass reinforcement.


Fig. 5: Sample marked for cutout. All samples were marked in this fashion. This sample was taken from a fiberglass-lined steel tank. Adhesion was excellent.

Dark staining and a loss of gloss were evident on all tanks in immersed areas, but not present or as evident at the non-immersed areas. Cracking and disbonding appeared in portions of the epoxy and polyester linings. Neither disbonding nor perforation of the fiberglass tanks was observed. Barcol hardness of the polyester lining averaged 76–83 with readings approximately the same in areas of immersion (the bottom of the tanks) and non-immersion (the top of the tanks). Hardness of the epoxy lining averaged 63–83, with little difference between the bottom and tops of the tanks.

The appearance and loss of adhesion, gloss, and hardness were independent of whether the steel or fiberglass tank stored diesel fuel or regular, mid-grade, or premium-grade unleaded gasoline.

Areas on several steel and fiberglass tanks were photographed, marked for cutout removal, and shipped to the laboratory for testing (Fig. 5). Fortunately, documentation established that a small number of lined steel and fiberglass tanks had never stored any contaminated gasoline. Samples were also removed from these tanks.

Continued

Effect of Caustic Exposure on Epoxy and Polyester Resins

Caustic Exposure—Epoxy

Epoxy resins are condensation polymers formed by the reaction of epichlorohydrin with bisphenol. The reaction forms a linear polymer with two reactive groups, hydroxyl and the epoxide ring. When reacted with an amino resin, notably an amine, polyamine, and/or amine adduct, the resultant molecule consists of stable benzene rings, carbon-to-carbon linkages, and ether linkages. These highly stable molecular linkages account for the high degree of chemical resistance of the resin and any linings made using the epoxy resin. In particular, these chemical linkages are most resistant to hydrolysis and alkaline saponification, and such cross-linked epoxies are widely used as alkali-resistant lining materials.

In the FTIR analysis of the materials used as tank linings, no evidence of a copolymer was found. This indicates that a condensation reaction between the epoxy resin and an amino curing agent, as described above, occurred. Accordingly, the resultant resin would have been highly resistant to alkali attack, such as that occurring from caustic soda or sodium hydroxide. When formulated with alkaline-resistant pigments such as calcium carbonate and other carbonates, epoxies are widely used as linings in immersion environments where alkaline attack is expected. Such epoxy linings are resistant to both dilute and concentrated (70%) sodium hydroxide at temperatures up to 200 F. Additionally, epoxy linings are resistant to aromatic and aliphatic hydrocarbons as found in gasoline and diesel fuel (*Coatings and Linings for Immersion Service:* TPC-Publication No.2: 1972, NACE, Houston, TX).

Caustic Exposure—Polyester

Isophthalic polyester resins are made from a saturated polybasic isophthalic acid and a di- or polyhydric alcohol. The properties of the specific isophthalic polyester depend on the alcohol used in its synthesis.

In general, the unsaturated isophthalic polyester resin (of whatever specific composition) is dissolved in a reactive styrene monomer and immediately, prior to application, mixed with a MEK-peroxide type catalyst (and sometimes with a naphthenate promoter) to induce and promote cross-linking. Since styrene reacts with oxygen, for ambient temperature cured polyesters small amounts of wax are often added to the formulation. The wax floats to the air-lining surface, sealing it and preventing oxidation of the styrene. If there is a significant reaction of styrene with oxygen, the isophthalic polyester surface will be insufficiently cross-linked. Plural component spray systems can also be used to promote fast cross-linking to reduce surface styrene oxidation. Polyester resins are strengthened with chopped fiberglass and/or woven glass roving to form a lining, which can then be spray applied or hand-laid-up to the tank. The resin encapsulates this glass reinforcement, effectively protecting it from exposure to the tank contents.

The resultant polyester lining, if properly mixed and applied, has excellent moisture and solvent resistance (including excellent resistance to aliphatic and aromatic hydrocarbons found in gasoline and diesel fuels). Isophthalic polyesters have moderate alkali resistance. While prolonged exposure to concentrated alkalis are not recommended, intermittent exposure to alkalis (including sodium hydroxide) up to 25% concentration at ambient temperature may not deteriorate the resin. The isophthalic polyester linings will resist lower (5%) concentrations up to 150 F (*Coatings and Linings for Immersion Service*: TPC-Publication No.2: 1972, NACE, Houston, TX). The addition of a vinyl ester resin, blended with the isophthalic polyester, will increase both temperature and acid/alkali resistance of the resultant copolymer resin.

Laboratory Investigation

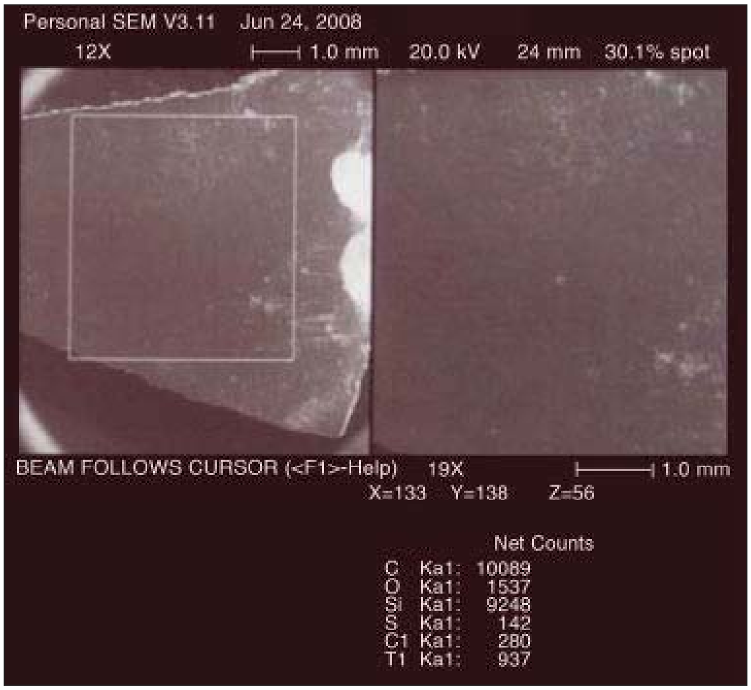
The laboratory investigation consisted of visual and microscopic examinations, infrared spectroscopy (FTIR), and scanning electron microscopy-energy dispersive x-ray spectroscopy (SEM-EDS). FTIR and SEM-EDS was used to analyze the surface of the steel tank linings and the fiberglass tanks at the surface, approximately halfway through the cross-section, and near the bottom. If an element was detected by EDS, a net count was performed to compare the relative quantity of the elements.

The goal was to determine if any element constituents of either the gasoline or the caustic used during refining had penetrated the lining. Sulfur was used as the tracer element for the gasoline, and sodium was used to determine any penetration of caustic.

Epoxy Lining Test Results

The outer surface (approximately 1–2 mils in depth) of every epoxy sample showed evidence of discoloration and oxidation of the lining. The oxidation is associated with aging of the epoxy and production of phenoxy radicals. However, the lining immediately beneath the surface layer and at points halfway and three-quarters of the way through the film cross-section exhibited no evidence of any oxidation. There was no correlation between surface oxidation and type of gasoline (i.e., oxidation of the surface of the lining was present in all types of gasoline, including that from the tank that had not been exposed to contaminated gasoline). The discoloration and oxidation also occurred in all areas of the tanks, both immersed and non-immersed.

The analysis revealed the presence of some or all of the following elements in the samples from the tanks: oxygen, aluminum, silicon, sulfur, chlorine, calcium, titanium, and iron. Several of the elements were present on the surface, at half depth, and/or at three-quarters cross-sectional depth (Fig. 6).



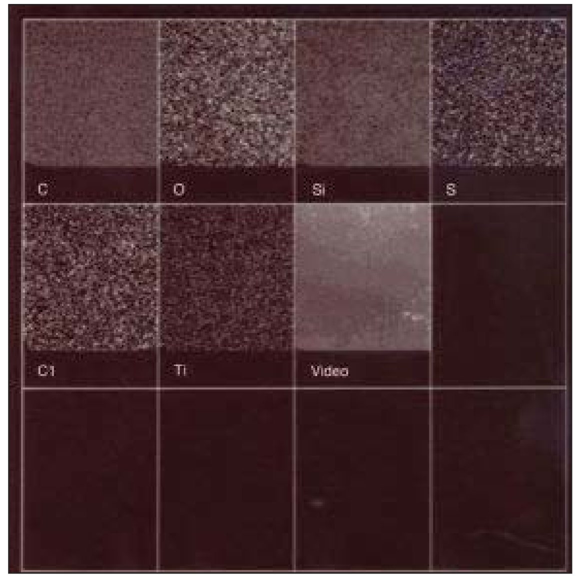


Fig. 6: (Left) SEM-EDS photo (12 and 15 X) of the surface of an epoxy lining. (Right) EM-EDS of the elemental mapping of that surface. Top row, L-R: carbon, oxygen, silicon, sulfur. Bottom row L-R: chlorine, titanium, photo of the area analyzed. (Images not to scale)

Aluminum, calcium, and titanium and their oxides are believed to be constituents of the lining. The others were found only on the surface.

Iron was present on the surface of some of the samples and appeared to coincide with the presence of rust staining on the film.

To investigate whether any significant exposure to sodium hydroxide occurred, the element sodium was used as a tracer. Sodium was not detected in any of the samples, either on the surface or within the cross-sectional body of the epoxy lining. This indicated that the sodium hydroxide emulsifier used by the refinery had not penetrated the lining and likely had not been present in the gasoline.

Sulfur, a gasoline constituent, was used as a tracer to determine whether gasoline penetrated the lining. Sulfur was detected on the surface of all of the samples. Sulfur was not detected through the cross-section of the lining, with the exception of one sample; a trace of sulfur was detected at the half- depth cross-section of a sample from the bottom of a tank. The lining was poorly adhered to the steel with corrosion and mill scale on the surface. It is likely that the gasoline penetrated the epoxy lining by virtue of its poor adhesion and through cracks and voids. Except for this one sample, gasoline had not penetrated the epoxy

Continued

lining. The results were comparable, whether the lining was exposed to allegedly contaminated gasoline or uncontaminated gasoline.

Polyester Lining Test Results

The outer surface of every sample examined exhibited discoloration. The discolored layer was approximately 1–4 mils thick on all of the samples.

The outer surface (approximately 1–2 mils in depth) of the polyester lining samples showed evidence of styrene depletion and degradation of the polyester resin. However, the lining immediately beneath the surface layer and at points halfway and three-quarters through the film cross-section exhibited no evidence of these effects.

There was no correlation between the above findings and type of gasoline. Styrene depletion and degradation of the polyester resin were also present on the surface of the lining in the uncontaminated gasoline tank.

The outer surface (approximately 5 mils in depth) of some of the polyester lining samples showed evidence of carboxylic acid salts, suggesting possible contact of the surface with sodium hydroxide. The carboxylic acid salts were limited to the outer surface of the lining sample. The lining beneath the surface layer of these samples showed no evidence of the carboxylic acid salts. Other samples did not show any carboxylic acid salts, even on the surface.

Cleaning the linings within the tanks is often done periodically by service station owners (usually using a contract cleaning service). If a caustic cleaner or detergent was used on the lining in the past and it was not thoroughly rinsed from the surface, it would be detected. This is the likely cause of the carboxylic acid salts because phosphorous, a component of phosphate detergent, was also detected on the surface layer of the samples where the carboxylic acids were found.

The elemental analysis revealed the presence of some or all of the following elements in the samples: oxygen, sodium, magnesium, aluminum, silicon, sulfur, calcium, phosphorous, and iron. Several of the elements were present on the surface, at half-depth, and/or at three-quarters depth.

Calcium and silicon were present in every sample and were likely constituents of the coating. Iron was present on the surface of some of the samples and appeared to coincide with the presence of rust staining on the film.

The sodium tracer, indicative of caustic contamination in the refinery, was detected on the outer surface of one sample but at no locations on any of the samples from the other tanks. It was determined that contamination from the sodium hydroxide emulsifier had not occurred.

The sulfur tracer was detected on the surface (top few mils) of all samples, with a trace at the half-depth of half of the samples. It was not detected below the half-depth on any of the samples regardless of exposure. Thus, while some gasoline permeation did occur through some of the polyester lining, there was no evidence of penetration of fuel through the lining on any of the samples, regardless of the type of gasoline exposure. The cross-section of the uncontaminated lining also showed a trace of some gasoline penetration.

Fiberglass Tank Test Results

Surface discoloration of the resin on the fiberglass tank interior was observed, similar to that in the steel tanks. However, there was no evidence of styrene depletion or carboxylic acid salts on the resin surface. Elemental analysis disclosed oxygen, sodium, magnesium, aluminum, silicon, sulfur, calcium, and phosphorous on the surface, but no sodium or sulfur within the cross-section of the resin layer. There was no evident effect, visually or analytically, on the resin except on the surface layer (approximately 2 mils). Below that, the resin composition was unchanged from resin that was deeper in the cross-section of the coating. The "deeper" resin would have been unaffected by any contaminants. It was believed factory controls during application and cure of the resin to the tank interior, as well as the addition of a limited amount of a vinyl ester to the isophthalic polyester, enhanced the resistance of the tank to any gasoline or contaminant penetration. There was no evidence of any problem with the fiberglass tanks except for the staining and discoloration at the resin surface.

Investigation Results

The results of the investigation revealed that the epoxy lining failed due to poor application. When properly applied, no failure of the epoxy lining was evident, and no permeation of either gasoline or any caustic contaminant occurred. Similarly, for the polyester lining, while there was evidence of surface styrene loss and trace indication of gasoline permeation into the lining cross-section, no caustic attack of the lining was evident. The polyester filament wound tanks did not show any caustic attack or gasoline permeation, except at the surface.

Accordingly, the class-action lawsuit was not certified and did not proceed further, although the refinery did settle with some of the service station owners.

Ken Tator of KTA-Tator, Inc. has been chairman of the SSPC Research Committee and numerous other SSPC and NACE committees; a member of SSPC's first Board of Directors; Director of NACE; and writer for *JPCL*, SSPC, NACE, and ASM.

Self-Healing Systems for Industrial and Marine Protective Coatings

By Dr. Gerald O. Wilson and Dr. H. Magnus Andersson
Autonomic Materials, Inc.

Fig. 1: Technical concept: Self-healing polymer coatings based on microencapsulation of healing agents.

Self-healing polymers are a new class of smart materials that have the capability of autonomically repairing themselves after damage, without the need for detection or repair by manual intervention. Building on recent breakthrough technology in the design of microencapsulation-based self-healing systems, we are developing self-healing coating systems for extended corrosion protection of steel substrates (Fig. 1). A self-healing coating based on this technology would not only extend the lifetime of the corrosion protection system but would also reduce the cost of labor associated with corrective and preventive maintenance.

The self-healing polymer system described by White et al. in 2001[1] was based on the Grubbs' catalyst-initiated ring opening metathesis polymerization (ROMP) of dicyclopentadiene (DCPD) in the site of damage, thus healing the damage and restoring structural continuity. While a successful demonstration of microcapsule-based self-healing technology, this approach was not deemed viable for commercial applications due to the chemical stability and cost of the catalyst. New chemistries have since been developed for applications in elastomers,[2] coatings,[3] and composites.[4] This article evaluates the application of polydimethylsiloxane (PDMS)-based chemistries in the development of self-healing coatings for heavy-duty industrial and marine applications.

Self-Healing System for Thermosetting Coatings

Thermosetting coatings such as epoxy and epoxy vinyl ester coatings are typically used in aggressive industrial and marine applications due to their chemical and corrosion resistance. However, when these coatings are eventually compromised by environmental factors and heavy usage, the substrate is exposed, leading to the rapid onset of corrosion. Significant corrosion ultimately leads to the need to take the equipment off line for maintenance. A PDMS-based self-healing system that gives a material the ability to autonomically repair mechanical damage has been demonstrated.[3]

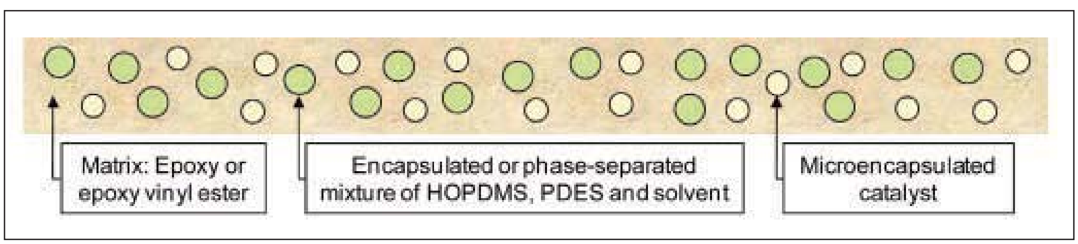


Fig. 2: Silanol condensation-based self-healing system. The mixture of HOPDMS, PDES and solvent is either encapsulated or phase-separated. The catalyst is encapsulated in polyurethane microcapsules. Damage through the matrix ruptures the microcapsules and their contents mix in the crack plane initiating a polymerization that seals the crack.

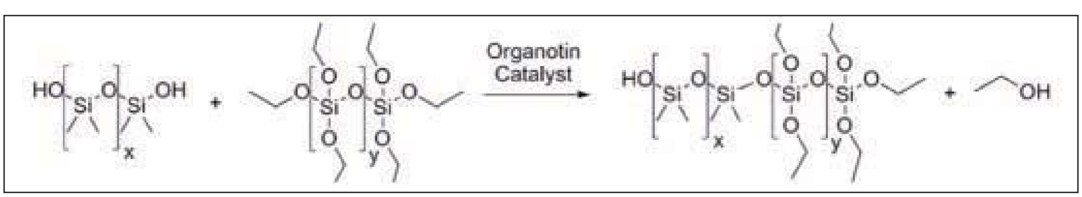


Fig. 3: Silanol polycondensation. A hydroxyl-terminated PDMS reacts with the ethoxy siloxane (PDES) in the presence of an organotin catalyst. The reaction results in a crosslinked network and releases ethanol as a condensation product.

The self-healing system, depicted in Fig. 2, is comprised of two varieties of microcapsules. The first type of microcapsule contains a mixture of hydroxyl-terminated PDMS and polydiethoxysiloxane (PDES) and an appropriate solvent, which was added for the purpose of viscosity modification. The second type of microcapsule contains a tin catalyst encapsulated in a solvent medium. Damage to the resulting coating ruptures the microcapsules, releasing their contents into the site of damage where they mix, react, and polymerize to repair the damage. Figure 3 exhibits the healing reaction that occurs in the site of damage.

A preliminary demonstration of the performance of this self-healing system is shown in Fig. 4. Four versions of the same epoxy vinyl ester coating were prepared and applied to cold-rolled steel substrates. The first version (Fig. 4a) was a basic control sample containing no self-healing additives. The second version (Fig. 4b) was a complete self-healing system with both the resin capsules (containing HOPDMS and PDES) and the catalyst capsules (containing the organotin catalyst). The third version (Fig. 4c) contained only the resin capsules, while the final version (Fig. 4d) contained only the catalyst capsules. All samples were scribed using a 50-micron scribe tool and allowed to heal at 50 C for 24 hours (h) before immersion in a salt solution for 120 h.

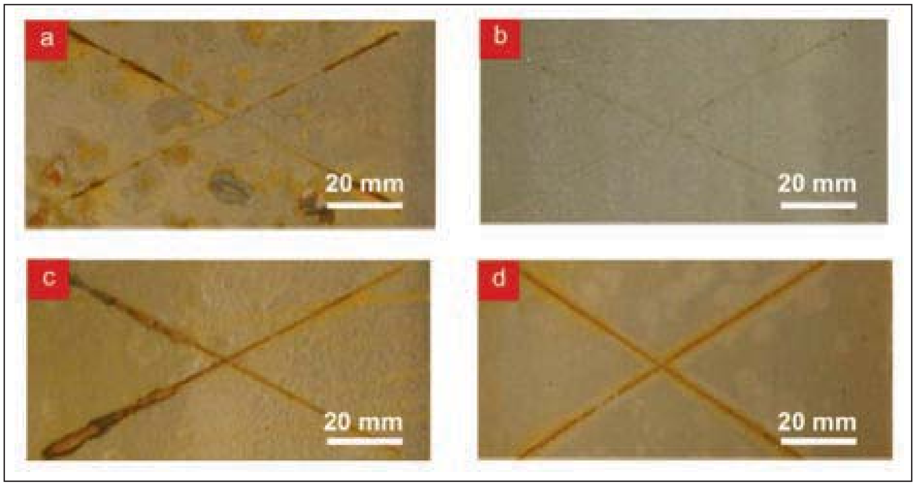


Fig. 4: Vinyl ester resin coating containing (a) only adhesion promoter (control sample); (b) the complete self-healing system including HOPDMS, PDES, catalyst microcapsules and adhesion promoter; (c) HOPDMS, PDES and adhesion promoter; (d) catalyst microcapsules and adhesion promoter. All samples were healed at 50 C (5).

The resulting samples reveal two important observations. First, the addition of a complete self-healing system upgrades a basic traditional coating to a fully functional self-healing coating. Second, self-healing depends on restoring of barrier properties to the damage site as a result of the formation of new polymeric material due to the reaction of the contents of both varieties of microcapsules. Similar observations were made with commercial epoxy and epoxy vinyl ester coatings.

Self-Healing System for Elastomeric Coatings

We have also demonstrated self-healing functionality in elastomeric coatings such as silicones. Building on the work of Keller et al.,[2] we have developed a different PDMS-based self-healing system for application in silicones and other soft coatings. This system is based on the Pt-catalyzed hydrosilylation of vinyl-terminated PDMS. As was the case for the system described in the section above, the resin and curing agent components of the polymer system were microencapsulated in two varieties of microcapsules and added to the coating prior application on the substrate (Fig. 5). Damage to the

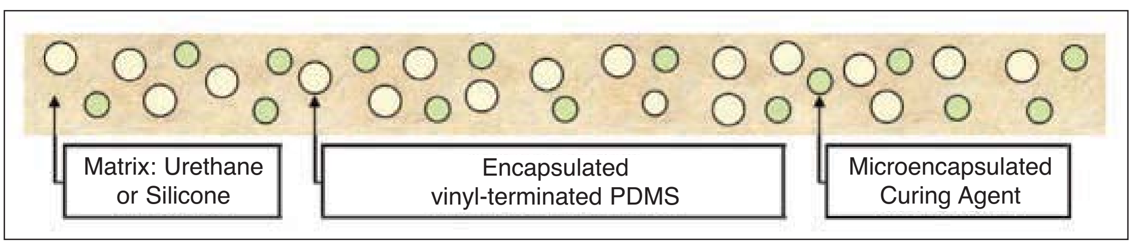


Fig. 5: Hydrosilylation-based self-healing system. The mixture of PDMS resin and solvent is encapsulated in one set of capsules while the curing agent/catalyst blend is encapsulated in a second set of microcapsules. Both varieties of microcapsules were prepared using polyoxymethylene urea microencapsulation procedure. Damage through the matrix ruptures the microcapsules and their contents mix in the crack plane initiating a polymerization that seals the crack.

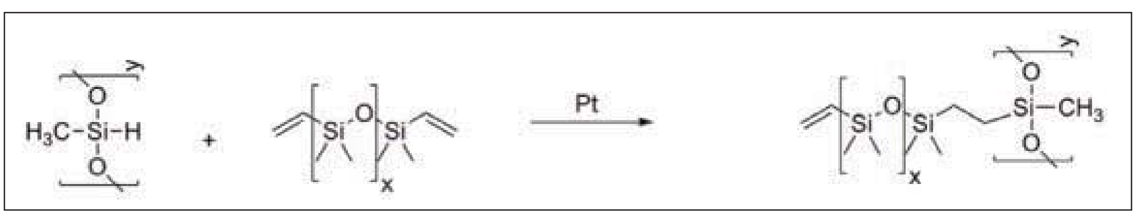


Fig. 6: Hydrosilylation of vinyl-terminated PDMS. The vinyl-terminated PDMS resin reacts with an active methylhydrosiloxane in the presence of a platinum catalyst to yield a crosslinked network.

Continued

resulting coating ruptures the microcapsules, releasing the contents to the site of damage where they mix, react, and polymerize. See Fig. 6 for a schematic of the reaction.

This self-healing system was evaluated in a commercially available silicone coating, marketed as a corrosion-resistant coating. Two versions of the same coating were applied to cold-rolled steel substrates (Fig. 7). The control sample was applied as received from the manufacturer, while microcapsules containing the self-healing agents were added to the self-healing sample. Both samples were scribed using a 50-micron scribe tool, allowed to heal at room temperature for 24 h, and then exposed to salt fog (ASTM B117) for 120 h. As expected, the control sample was observed to rust within and around the scribed region. Blisters were also observed around the scribed region of the control sample. The scribe on the self-healing sample was observed to heal, extending the protection of the substrate. No rusting or blistering was observed anywhere on the sample (Fig. 7).

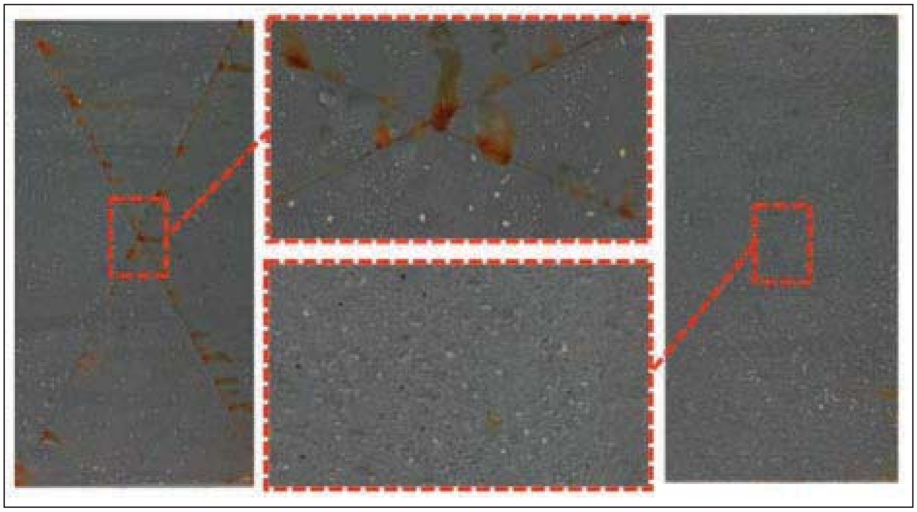


Fig. 7: Results from salt fog corrosion tests after 120 hours according to ASTM B117 of cold-rolled steel samples coated with a silicone coating containing no self-healing additives (control sample: left and top center) and with the self-healing additives included (self-healing sample: right and bottom center).

Conclusions

We have demonstrated the successful translation of self-healing technology originally designed for polymerized resins and reinforced polymer composites to coatings. Two different PDMS-based chemistries were used to achieve self-healing functionality in commercial thermosetting and elastomeric coatings. The samples exhibited in this article were prepared by drawing down coatings containing self-healing microcapsule additives. However, we have demonstrated the ability to apply similar coatings using siphon feed spray guns and high-solids static mixing spray systems, and we confirmed the survival of the microcapsules through this application process.

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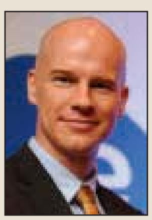

Dr. Magnus Andersson is the Vice-President for Business Development at Autonomic Materials, Inc. (AMI). He has over 7 years of experience designing and characterizing various self-healing materials. Before joining AMI in 2007, he was a Research Scientist in the Autonomous Materials Systems group at the Beckman Institute, University of Illinois at Urbana-Champaign. He earned his Ph.D. in fluid mechanics from Luleå University of Technology, Sweden.

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Coating Aged Concrete Fuel Storage Tanks Succeeds

Eric Hernandez, NAVFAC ESC, Port Hueneme, CA, and Sean Massey, P.E., Shaw Environmental, San Diego, CA

After 60 years of service, three previously uncoated 50,000-barrel (Bbl) underground storage tanks (USTs) were repaired. Constructed in the 1940s to store fuel, the tanks are made of reinforced concrete with no steel lining. Each tank has a diameter of 135 ft and an inside wall height of 20 ft. Over the past 60 years, the tanks have stored various fuels, including bunker fuel and JP-5 as well as JP-8 jet fuel. Over time, fuel has penetrated porous areas of the concrete substrate, creating a challenging coating application. The coating would serve as a primary containment system in the tanks. Traditional guidelines from SSPC: The Society for Protective Coatings (SSPC) for coating concrete did not apply.

Through work with industry experts, specifications and procedures were developed to address the unique coating application. The scope included surface evaluation, surface preparation, concrete sealer application, and coating application. During April 2010 through June 2010, the tank repairs were performed at Defense Fuel Support Point (DFSP) in San Pedro, CA. A two-part modified epoxy novolac polysulfide coating was applied.

Before the coating could be applied, numerous joint repairs were required to improve the hydraulic integrity of the tanks. The joints included a roof-to-wall joint, floor-to-wall joint, offset joint, 18 vertical cold joint (expansion joints) and pipe penetration joints. Since the tanks are located in a Seismic Zone 4 area, the joint repairs were designed to allow slight movement. This article will focus on the abrasive blasting coating project for the first of the three tanks repaired but will not detail the joint repairs.

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Opposite page: The completed tank. Photos courtesy of the authors

Tank Preparation

Before repair work could start, the tank was defueled, pressure washed with water, and certified gas-free by a Marine Chemist. Following the gas-free certification, the joint repairs began. During joint repairs, the tank wall and floor were allowed to "bleed" fuel that had accumulated in the substrate. The joint repair process was approximately 30 days.

Before abrasive blasting began, concrete areas with trapped hydrocarbons near the surface were addressed by removal with power tools, including jackhammers and drills. Areas where concrete was removed were inspected to assure fuel cavities had been removed.

The coating process then included substrate preparation, sealer coat application, trowel coat application and two final coats of modified epoxy novolac polysulfide.

Abrasive Blasting

The abrasive blasting process for the wall involved two 360-degree passes from floor to roof, totaling 8,300 square feet per pass. In addition to the wall, 52, 18-in. diameter floor to roof columns totaling 4,900 square feet were abrasive blasted. The abrasive blasting equipment utilized 30/60 steel grit. Blasters used No. 7 venturi blast nozzles with an application pressure of approximately 100 pounds per square inch gauge (psig). Surface condition was required to conform to SSPC SP-13/NACE No. 6, Surface Preparation of Concrete. Therefore, after bulk grit removal, the 13,600 square foot-floor was abrasive blasted to conform to SSPC SP-13/ NACE No. 6.

Unlike traditional concrete preparation, this application required a sealer coat to be applied to the prepared concrete substrate within 36 hours to prevent "bleed back" of fuel entrained in the concrete substrate. The 36-hour application window was based on field observations and findings; if the concrete was allowed to remain bare for a longer period, fuel would migrate to the surface, resulting in a non-compliant substrate for applying the sealer coat.

Following blasting operations, blow down and vacuum of the entire tank was performed to remove any remaining surface contaminates including dust, grit, and sand.

Sealer Application

To seal the concrete substrate after abrasive blasting and cleaning, a 100% solids, dual-component, surface-tolerant epoxy sealer was applied (Figs. 1 and 2). The epoxy sealer is designed to wet, improve the surface strength, and seal porous concrete surfaces. The sealer application has proven critical for coating previously uncoated concrete fuel storage tanks.

Fig. 1: Substrate after sandblasting and before sealer coat application

Fig. 2: Substrate sealer coat application

The desired coating life for these tanks is 25 years. Failures in coatings have appeared in similar tanks after 8 to 10 years of service. One reason for the premature failures appears to be a lack of sealer, resulting in fuel bleed back and surface contamination. The nature of the failed coatings on similar tanks has been delamination from the concrete, which implies improper sealing that allowed hydrocarbons within the concrete to reach the concrete surface.

For sealing the unique substrate, an application rate of 250 to 350 square feet per gallon (sq ft/gal.) was used. For traditional concrete sealer applications, 450 sq ft/gal. is common. The sealer was applied using 40:1 and 74:1 airless spray pumps with two 250-foot line sets. Inlet air pressure was approximately 80 psig to 90 psig. Spray tips ranging from 17 thousandths to 27 thousandths were used.

The rough concrete surface presented a challenge during the sealer application in that it was difficult to obtain a uniform thickness application and complete coverage. To ensure complete coverage and penetration into surface depressions, a roller was used immediately after the spray application. The application rate was based on test patches performed on various surfaces, including the floor and wall, to determine the adhesion strength and ability to prevent fuel entrained in the concrete from permeating it.

The pull tests performed using this application rate resulted in failures in the concrete surface and not on the concrete to sealer interface. A uniform dry film thickness on the sealer is not possible by the nature of the concrete surface; however, minimum and maximum thicknesses should be as recommended by the sealer manufacturer.

Trowel Application

After the concrete substrate was abrasive blasted and the epoxy sealer was applied and cured, the substrate remained very rough and irregular. The aggregate size varied from ¼ in. to 3 in. Horizontal cold joints (sometimes referred to as lap joints) are common in underground concrete tanks and required additional trowel fill material.

A 100% solids modified epoxy novolac polysulfide trowel coating was used in effort to create a smooth, monolithic surface (Fig. 3). The trowel material had to be compatible with the epoxy sealer and the final coat of modified epoxy novolac polysulfide coating.

The trowel coat was forced into voids and spread evenly using conventional trowels and putty knives. Effort was taken to finish with a smooth surface, free of sharp edges that could have negative effects on the spray coats of modified epoxy novolac polysulfide to be applied next.

Fig. 3: Applying trowel coat to sealed wall

Final Coat Application

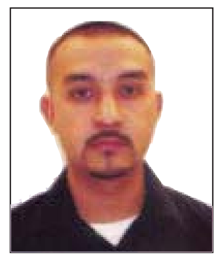
After the recommended curing time of seven days at 70 F for the trowel material, a 100% solids, two-component, modified epoxy novolac polysulfide coating was applied. The required 32-mil dry film thickness was achieved by applying two uniform 16 mil coats. The modified epoxy novolac polysulfide was a preferred material because of its flexibility, strength, and fuel-resistant properties.

For application, a plural-component 68:1 pump and multiple 250-foot line sets were used. The two components were comingled and heated to approximately 120 F. The application pressure was approximately 5,500 psig. The spray tips ranged from 21 thousandths to 33 thousandths.

The tank successfully passed a volumetric test, proving the project was a success.

Conclusion

All three 50,000 Bbl underground concrete tanks were prepared and coated. The coating application required preparing and sealing concrete saturated in fuel. Removing all the contaminated concrete was not an option because the tanks are buried. The abrasive blasting and quick sealer application proved successful to prepare the surface for a two-part modified epoxy novolac polysulfide coating. The repairs were critical to the hydraulic integrity of the tanks.



Eric Hernandez of NAVFAC ESC has experience in petroleum oil and lubrication facilities engineering for the Department of Defense. He has extensive experience with inspecting and repairing storage tanks and pipelines at various military facilities. Hernandez has also specified tank and pipeline repairs, including coating systems, for concrete. He is a certified Engineer-in-Training in the State of California, a certified American Petroleum Institute (API) 570 Piping Inspector, and an API 653 Above Ground Storage Tank Inspector. Mr. Hernandez has earned a bachelor's of science degree in mechanical engineering from California Polytechnic State University of San Luis Obispo, CA.

Sean J. Massey, P.E., of Shaw Environmental, has experience that includes facilities engineering in the jet fuel storage, oil and gas production and waste water treatment industries. Throughout his professional career, he has engineered and specified industrial coating solutions for tanks, pressure vessels, pipelines, concrete and other equipment. Massey is a Registered Professional Engineer in the State of California. He earned a bachelor's of science degree in mechanical engineering from California State University of Long Beach, CA.

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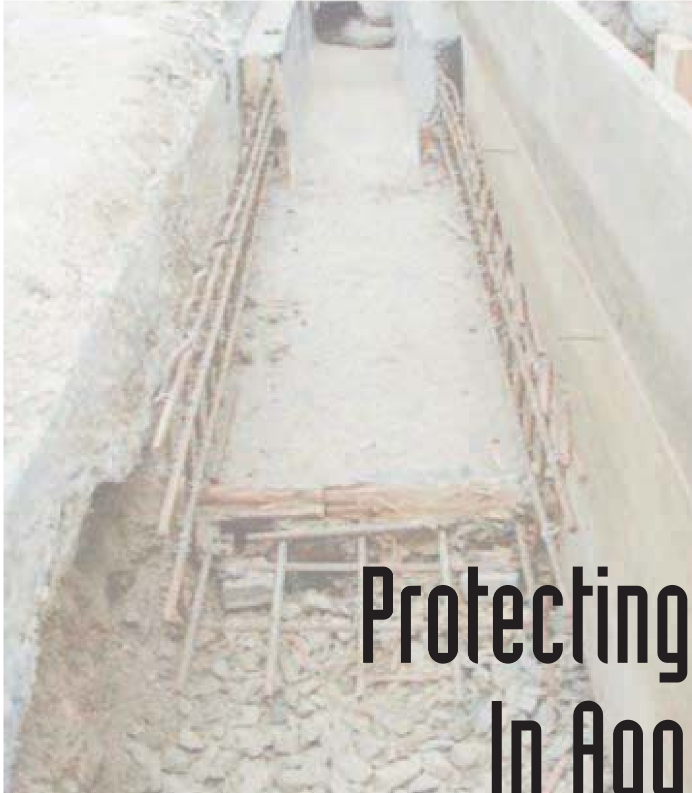
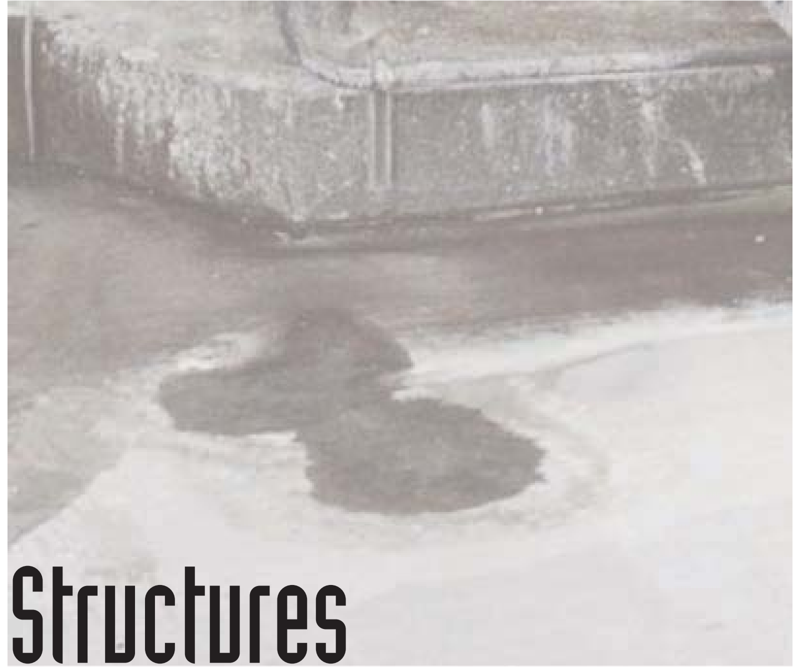




Protecting Structures In Aggressive Chemical Environments:

Where Polymer Concretes Can Help

All photos courtesy of Sauereisen, Inc.

By Gary Hall, Sauereisen, Inc., Pittsburgh, PA

About the Case Histories

Chemical processing industries, including metals processors and refineries, have difficult corrosion problems that require new solutions. Applications include tanks; columns; containment dikes; process areas; and solvent extraction/electrowinning (SX/EW), a process, while not unique to the metal processing and refining industry, is uniquely dominant in this industry.

The use of various polymer concretes in controlling corrosion in a range of chemical and chemical processing industries, including petrochemical, acid handling, and metals processing plants, can be seen from the case studies throughout this article.

The chemical (C) and chemical processing industries (CPI) have some unusually aggressive corrosion environments. These industries are any ones in which a chemical or biochemical reaction occurs, such as petroleum and metals refining, including ferrous and non-ferrous metals; lubricant and biofuel processing; polymer and plastics manufacturing; food and beverage as well as pulp and paper processing; and ceramics manufacturing, including glass. In many aggressive exposures, a variety of polymer concretes can be used successfully, if the properties of the polymer concretes are understood and the correct product is specified.

Simply defined, organic resin polymer concretes are primarily composites of a thermosetting resin or other chemical-resistant binder and selected fillers. Inorganic polymer concretes are made of alkali metal silicates, such as potassium silicate and sodium silicate. Organic polymerics have greater strength than their inorganic analogs and Portland cement-based concrete, along with far superior chemical resistance. Properties such as absorption and freeze-thaw durability are orders of magnitude better than Portland cement concrete. Corrosion resistance varies from one type of resin to another and available chemistries cover a wide range of compounds. Polymer concretes are more expensive than Portland cement-based concrete on a materials basis. When properly designed, specified and installed, however, polymer concretes provide

a value-added solution for some of the most difficult corrosion problems that more than makes up for the higher materials cost. Engineers, architects, plant managers, maintenance personnel and contractors need to have an understanding of their capabilities and limitations to realize the added value and to take advantage of it.

No single polymer concrete is suitable for every aggressive chemical environment. This article outlines several types of polymer concretes and their properties, most notably, their resistance to various aggressive chemical exposures. Several case histories demonstrate where polymer concretes have solved difficult corrosion problems in chemical environments.

Composition

Polymer concretes are resinous materials or ceramic polymers that are filled with selected aggregates. The chemical resistance and physical properties are influenced by both the binder and the fillers.

Fillers are most often siliceous due to low cost; however, other fillers are used, such as carbonaceous, alumina, fused alumina, glass or ceramic beads, zircon, barites and silicon carbide. Each aggregate fills a niche. For example, if the expected exposure included fluorides, the aggregates of choice would be carbon or barites (barium sulfate). Using aluminas, fused aluminas and/or silicon carbide can enhance abrasion resistance. Aggregates can be combined; for example, silica can be used to control cost while silicon carbide can be added to enhance abrasion resistance. Other fillers can be added such as plastic, glass, or metallic fiber to improve crack resistance for extremely dynamic load conditions.

Particle size gradations are important to a properly designed mix. Too many fines limit the placing characteristics and decrease the amount of loading capability, and may increase curing shrinkage. If the mix is gap-graded, maximum physical properties will not be achieved and internal discontinuities in the matrix may result in premature failure, especially in fatigue situations. Gap grading means that the size distribution curve is not smooth and continuous because certain particle sizes are left out or are at a very small percentage. If the mix is deficient in fines, the interstitial spaces between adjacent larger particles will be resin-rich pockets. The resin will respond to applied stresses, such as thermally-induced stress, differently than the aggregate. To avoid these discontinuities and achieve a more isotropic stress response, the interstitial spaces need to be filled with a uniform resin-aggregate mixture.

There is a wide variety of choices for the binder. The specifier has available Bisphenol A epoxy (Bis A), Bis F epoxy, novolac epoxy, Bis A epoxy vinyl ester, novolac epoxy vinyl ester, urethane, poly methyl methacrylate, potassium silicate, polyester, and furan binders. Each binder has its own characteristics, strengths and limitations. Table 1 lists typical physical properties for polymer concretes based on these polymeric classes. Portland cement-based concrete is included for refer-

Table 1: Typical Physical Property Ranges for Polymer Concretes*

Binder	Density	Water Absorption %	Compressive Strength (7 days)	Tensile Strength (7 days)	Flexural Strength (7 days)	Poisson Ratio
Epoxy (includes Bis A & novolacs)	125-140 pcf (2-2.24 g/cm^3)	<0.01-0.5	8,000/21,000 psi (3.8×10^5-1×10^6 pa)	2,000-4,000 psi (9.6×10^4-2.2×10^5 pa)	3,000-4,000 psi (1.4×10^5-2.2×10^5 pa)	0.28-0.31
Vinyl Ester	130-145 pcf (2.08-2.32 g/cm^3)	<0.02-0.5	12,000-18,000 psi (5.7×10^5-8.6×10^5 pa)	1,500-4,000 psi (7.2×10^4-1.9×10^5 pa)	3,000-4,000 psi (1.4×10^5-1.9×10^5 pa)	0.15-0.30
Polyester	125-150 pcf (2-2.4 g/cm^3)	0.02-1.0	5,000-10,000 psi (2.4×10^5-4.8×10^5pa)	1,200-3,000 psi (5.7×10^4-1.4×10^5 pa)	2,500-3,500 psi (1.2×10^5-1.7×10^5 pa)	0.15-0.3
Furan	120-150 pcf (1.9-2.4 g/cm^3)	<0.05-0.2	6,000-15,000 psi (2.9×10^5-7.2×10^5 pa)	1,400-4,500 psi (6.7×10^4-2.2×10^5 pa)	1,800-4,000 psi (8.6×10^4-1.9×10^5 pa)	0.15-0.32
Potassium Silicate	120-150 pcf (1.9-2.4 g/cm^3)	2.0-5.0	3,500-5,000 psi (1.7×10^5-2.4×10^5 pa)	450-600 psi (2.1×10^4-2.9×10^4 pa)	800-1,000 psi (3.8×10^4-4.8×10^4 pa)	0.15-0.20
Portland Cement	120-165 pcf (1.9-2.6 g/cm^3)	5-15	3,000-6,000 psi (1.4×10^5-2.9×10^5 pa)	350-700 psi (7.1×10^4-3.4×10^4 pa)	800-2,000 psi (3.8×10^4-9.6×10^4 pa)	0.15-0.20

*Properties will vary dependent upon the binder, fillers and binder/filler ratios. Property ranges are taken from data published by manufacturers.

ence, as is a potassium silicate polymer concrete. Potassium silicates form ceramic “polymers” and have refractory properties as well as outstanding acid resistance, unlike Portland concrete, which has an amorphous structure. Because of the amorphous nature of Portland cement, its response to stress is anisotropic and thus makes a poor refractory binder.

Petrochemical Plant (Novolac Epoxy)

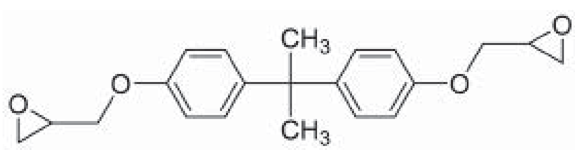
PDVSA/Pequiven, a state-owned refinery in Venezuela, chose a novolac epoxy polymer concrete to form a trench handling sulfuric acid from dilute to 98% concentration and at temperatures up to 200F (93C). Exposure is continuous, but volumes vary from nearly full to a couple of inches. The surrounding floors were also topped with the novolac epoxy polymer concrete. The trench lining was reinforced with steel rebar and cast at a thickness of 4 in. (10.2 cm). The floors were capped with a 2-inch (5.08-centimeter) pour of the polymer concrete. The trench and floor have been maintenance-free since installation in the fall of 2010.

Portion of a pre-cast trench made of novolac epoxy polymer concrete, and the same epoxy novolac polymer was installed over the surrounding floors.

Epoxy Binder Characteristics

An epoxy resin is one that contains an epoxide group. These rings undergo ring opening when reacted with curatives and form three-dimensional (3-D), highly cross-linked polymer structures. Three general classes of epoxy resins are used in polymer concretes: Bisphenol A, Bisphenol F and novolac. These react with amines, amides, cycloaliphatic amines, polyamines, and mannic acids.

The type of curative, or hardener, used has a significant effect on chemical resistance and physical properties of the cured polymer binder as the hardener becomes part of the cross-linked polymer. This cross linking occurs at all unhindered epoxide groups. This results in a cross-linked 3-D network.



Bisphenol A Epoxy Resin Backbone

Epoxy-based polymer concretes provide excellent physical properties, with compressive strengths as high as 17,000 psi. They perform well in a wide variety of chemical environments. Chemical resistance is highly dependent on the total formulation, but generally novolacs have the best chemical resistance, followed by Bis F epoxies and Bis A epoxies, in that order. Epoxies work well in acids, alkalis, some hydrocarbons, salts, and aqueous solutions. Many solvents will attack and/or soften them. Ultraviolet light (UV) resistance is the inverse of the above order, i.e., novolacs are less resistant to UV than Bis Fs, which are less resistant than Bis A epoxies.

Thermal limits depend upon the chemical environment. Realistic dry heat limits for epoxies are below.

- **Bis A: 180 F (82.2 C)—200 F (93.3 C)**
- **Bis F: 200 F (93.3 C)—275 F (135 C)**
- **Novolac: 220 F (104.4 C)—300 F (148.8 C)**

The coefficient of thermal expansion (cte) for an epoxy polymer concrete depends on the resin/filler ratio, filler composition, and gradation as well as the resin/hardener combination. Available commercial literature reveals a cte range from 20 x 10^{-6}/F degree (10.96 x 10^{-6}/C degree) to 3.5 x 10^{-6}/ F degree (19.2 x 10^{-6}/C degree).

Vinyl Ester

If we react methacrylic acid with an epoxy, we get a vinyl ester resin. Hence, if we use a Bis A starting resin and react with methacrylic acid, we get a so-called Bis A epoxy vinyl ester. The backbone of the polymer is a Bis A epoxy resin with terminal vinyl groups (CH_2 = CH) at both ends of the polymer. This vinyl ester polymer is dissolved in styrene. These vinyl groups are esters and are the reactive sites for the curative. Vinyl esters cure by reacting with an organic peroxide and a promoter. When the initiator is added, it reacts with the promoter to form free radicals.

R – O – O – R + Dimethyl aniline → + R – O• + R – O• + DMA
Initiator Promoter (DMA) Free radicals

The initiator then starts a chain reaction. The free radicals activate the styrene monomer, forming additional free radicals, which in turn attack the unsaturated ester groups, resulting in a cross-linked 3-D network of vinyl ester polymers, each with an epoxy backbone.

Vinyl ester polymer concretes tend to be more brittle than those based on epoxies. Their physical properties, however, are more than sufficient to allow them to perform in highly demanding situations. Compressive strengths of 17,000 psi or higher are achievable. Flexural strengths are approximately 30% less than epoxies with equivalent moduli of elasticity. Tensile strength is also about 30% lower than that of epoxies.

Vinyl esters can perform at higher temperatures than epoxies because of the vinyl esters' significantly higher glass-transition temperatures (Tg), lower free volume, and higher heat-distortion temperatures (HDT). Typical dry heat limits are shown below.

- **Bis A vinyl ester: 220 F (104.4 C)—270 F (132.2 C)**
- **Novolac vinyl ester: 250 F (121.1 C)—375 F (190.6 C)**

Thermal limits in chemical service vary widely; some limits even exceed the resin's Tg by more than 100 degrees F (55.6 degrees C). For example, in flue gas exposures, novolac epoxy vinyl esters can perform at temperatures as high as 400 F (204.4 C). The coefficient of thermal expansion for any given vinyl ester polymer concrete is highly dependent on the resin/filler ratio, the filler composition, and the filler gradation. A search of available commercial literature revealed a cte range from 9 x 10^{-6}/F degree (4.9 x 10^{-6}/C degree) to 28 x 10^{-6}/F degree (15.4 x 10^{-6}/C degree).

Vinyl esters have good resistance to acids and moderately strong alkalies. They generally perform better in solvents than do epoxies. Vinyl esters are more suited for oxidizing environments than epoxies, e.g., sodium hypochlorite, nitric acid and peroxyacetic acid.

Unsaturated Polyester

Polyester resins cure via a similar reaction as described above for vinyl esters. The difference between polyesters and vinyl esters is that the backbone of the polyester is not an epoxy, but is more related to an alkyd, and, rather than two ester groups in terminal positions as with vinyl esters, polyesters have several reactive ester groups

Zinc Refinery (Epoxy Bis A)

Formed polymer concrete wall and part of cell.

Cells, support beams, floor pad and containment wall all cast from Bis A polymer concrete.

A zinc refinery in the Midwestern part of the United States was experiencing severe deterioration of a concrete pad around and under electrolytic cells due to the dual action of corrosion by sulfuric acid and front end loaders removing waste. The refinery decided upon a polymer concrete made from Bis A epoxy to replace the deteriorated concrete. This pad was poured in 1998 and is in excellent condition with no evidence of chemical attack or physical wear after more than 14 years of service. The sulfuric acid is at 120 F (49 C) and 25% concentration.

along the polymer chain. Each of the unsaturated ester sites provides a potential point of reaction and cross linking.

Polyesters are the lowest cost resin group and, as such, have been used the most. Polyester polymer concrete has good mechanical strength properties, good chemical resistance, and excellent freeze-thaw durability. Polyesters do have a significant drawback that can present serious issues in some applications and that users must take into account. Polyesters tend to shrink significantly during cure; as much as three times the shrinkage of Portland cement concrete can be encountered.

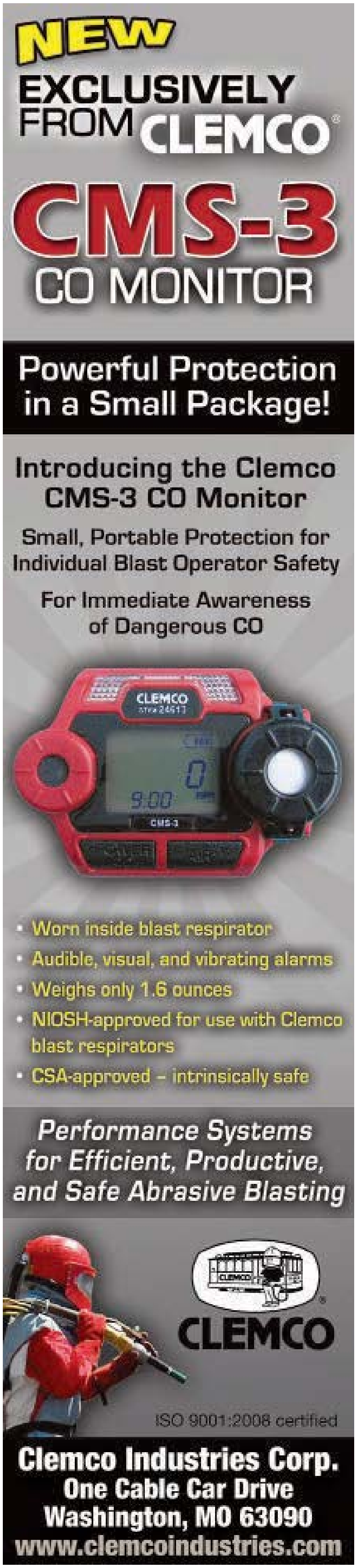
Polyester polymer concretes have thermal limits and coefficients of thermal expansion similar to vinyl esters. As with all other resins, the maximum recommended temperature in chemical service is dependent on the media involved. Like vinyl esters, strong alkalies will attack the ester group. Polyesters can withstand 75% sulfuric acid (H_2SO_4) and higher temperatures than vinyl esters but fare no better in strong hydrochloric acid. In nitric acid and chromic acid, the polyester performs much better than epoxies or vinyl esters.

Furan

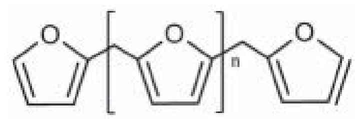
The chemistry of furan resins is the least understood of the resins used for polymer concretes. Furans are based on furfuryl alcohol, a derivative of agricultural wastes such as rice hulls, corncobs, and oat hulls. The furan prepolymer is typically cross linked with furfuryl alcohol, furfuraldehyde, or formaldehyde.

Furan resins are sometimes modified with a phenolic resin or an epoxy resin. Furan resins offer resistance to the widest range of chemicals of all polymer concrete binders. Their most significant shortcoming is low resistance to strong oxidizing media such as nitric acid, chromic acid and hypochlorite bleaches.

Furan polymers can be cross linked by reaction with certain amines or acids. The best chemical resistance and the



highest Tg are obtained from the acid curatives. This presents a potential problem when furans come into contact with Portland cement, which is highly alkaline. The alkalinity of the cement reacts with the acidic curing agent and prevents adhesion to the concrete. If sufficient alkalinity is present, the layer of furan immediately adjacent to the concrete may not fully set. Thus, primers are required for direct contact with concrete.



Furan resin

Furan resins are based on precursors containing the furan ring, which is aromatic. The prepolymers result from partial condensation of furfuryl alcohol with itself. These react with strong acids, such as paratoluene sulfonic and phosphoric acids, which initiate polymerization. When the desired molecular weight is reached, an alkali is added to terminate polymerization.

Furans will withstand significantly higher temperatures than epoxies, vinyl esters, or polyesters, often as high as 350 F (176 C) to 450 F (232 C). As a class, they are resistant to a wider range of compounds than epoxies, vinyl esters or polyesters. They are susceptible to attack by strong oxidizers such as nitric acid, chromic acid, and hypochlorites. The cte for furan polymer concretes ranges from 9 x 10^{-6}/F degree (4.9 x 10^{-6}/C degree) to 40 x 10^{-6}/F degree (21.7 x 10^{-6}/C degree), depending upon the filler(s) and the loading rate of the fillers.

Alkali Silicate

Alkali metal silicates, such as potassium silicate and sodium silicate, have long been used to make polymer concretes. The polymer concretes described heretofore have all been based on organic binders such as epoxies. Alkali silicates are inorganic. Like the other binders described, they form polymers, albeit with shorter chain lengths. This class of materials is best described as being ceramic in nature. They also are refractory or semi-refractory, depending on the reaction mechanism and aggregates used. The alkali silicates, such as potassium silicate, form silicon-oxygen tetrahedra, in which each oxygen atom is shared by two silicon atoms. These tetrahedra form 3-D polymer chains in an aqueous solution. The polymer chain is stabilized by an alkaline solution such as potassium hydroxide.

The addition of an acid or ammonia will cause precipitation of the hydroxide by forming a salt. Once the electrical neutrality is lost, the tetrahedra collapse, gel, and form a cement-like structure upon dehydration. The ceramic polymer thus formed can withstand temperatures from 1,200 F to as high as 3,000 F. This spans the range of both semi-refractories and refractories. Semi-refractories are useful to approximately 1,800 F, whereas refractories are useful up to 3,200 F or higher. Their low thermal expansion and high thermal conductivity enable ceramic polymers to be very resistant to thermal shock. Silicate based polymer concretes can be formulated to be completely resistant to all acids at any concentration, except those that contain fluorine (F). Silicate polymer concretes are also much less costly than their organic counterparts.

Adhesion

Measuring the adhesion of polymer concretes to a substrate is problematic due to the thickness ranges at which they are used, typically greater than one inch. The best method has been found to utilize a property known as “slant shear bond” or “slant shear adhesion.” ASTM C882 affords a realistic and relatively easy means of evaluating adhesion of relatively thick topcoats and polymer concretes to a con-

Copper Refinery (Novolac Epoxy)

An organic polymer concrete was the choice of a large metals refinery operation in the western United States. The plant engineers not only had concrete floors to replace but also had to come up with a liner for the concrete cells. These cells are electrolytic winnowing cells. Large metal panels, weighing more than 800 lbs, are suspended in a 25% H_2SO_4 solution by means of "hanger straps" that are spot welded to the panels. These are then suspended from an electrical bus bar, through which electric current flows into the panel, which then becomes the anode. Occasionally, a hanger strap or its spot weld will fail and the panel, which can be eroded/corroded to something resembling a knife edge, will drop and impact the coated concrete bottom of the cell. These cells sit on concrete pillars and act as the "roof" for a "basement" below.

Frequently the corroded anodes will cut through the protective coating when they fall, exposing the concrete cell to sulfuric acid. Eventually, the acid will destroy the concrete under the damaged coating, resulting in leaking through the deteriorating concrete. As damaged areas developed into leaks, the floor of the "basement" below was severely attacked, as were the bases of support columns for the cells. Spillage from the cells was also a constant problem, which contributed greatly to the corrosion.

Mainly because the polymer concrete eliminated the need for protective coatings, and their maintenance, the metal refinery chose a novolac epoxy polymer concrete to refurbish damaged cells and to protect the basement floor and support columns.

And even if a layer of the polymer concrete was worn or corroded, the underlying newly exposed material would still be the acid-resistant polymer concrete, not Portland concrete. With application thicknesses ranging from 1 in. to 18 in. or more, the epoxy novolacs can provide a long service life.

crete substrate. It describes the general method, but certain modifications are necessary because the polymer concrete is typically bonded directly to the base concrete instead of to a bonding agent. The method is used by several polymer concrete manufacturers.

Applications

Polymer concretes may be used as overlays for Portland cement-based concretes or they may be used as stand-alones in place of concrete. In either case, the polymer concretes should be reinforced. Fortunately, those methods commonly used for Portland concrete also function well for polymer concretes. A review of the literature of commercially available products reveals that polymer concrete manufacturers generally recommend thicknesses of 1 in. (2.54 cm) or more.

Stainless Steel Manufacturer (Novolac Vinyl Ester)

A large manufacturer of stainless steel, located in the eastern U.S., recently decided to encapsulate several of its steel columns in a novolac vinyl ester polymer concrete. The columns, initially encased in brick and mortar, were corroded to the point that the plant determined they needed to make repairs. This facility's corrosion resulted from exposure to hydrochloric acid (HCl), nitric acid (HNO_3), hydrofluoric acid (HF), a mixture of HF and HNO_3, lime, alkaline degreasing solvent, and rinse tanks.

The contractor removed the brick/mortar, cleaned the steel columns, and encapsulated them in a novolac vinyl ester polymer concrete, which could withstand the various corrodents at temperatures up to 150 F. The polymer concrete is expected to give a service life equal to or longer than brick and mortar.

Segments are recommended to be from 10 ft x 10 ft (3.05 m x 3.05 m) up to 15 ft x 15 ft (4.57 m x 4.57 m), depending on the polymer and shrinkage. Compatible expansion/construction joint materials are required between segments and between the polymer concrete and surrounding materials.

The reinforcement should be selected depending on the thickness of the polymer concrete used, shrinkage anticipated, mechanical and thermal loading expected, and the maximum temperature rise anticipated during the cure cycle or in operation. Recommended reinforcements include epoxy coated rebar, fiberglass-reinforced plastic (FRP) rebar, stainless rebar, and galvanized rebar as well as various types of polymeric mesh. The reinforcement must be anchored to the underlying concrete when polymer concretes are used as overlays. When polymer concrete is used in place of concrete, a 10-mil plastic film should be placed under the reinforcing system to protect the polymer concrete from ground water and moisture vapor during cure.

Because polymer concretes will typically cure at a faster rate than Portland cement-based concrete, it is essential that all equipment, forms and reinforcement be ready before mixing. Many polymer concretes liberate heat during cure, and the exothermic reaction can result in shortened working times in large masses. Choosing polymer concretes with the highest possible slump, a measure of its placing characteristics, will reduce the time required to place, consolidate, and finish.

Using polymer concretes to pre-cast various structures and appurtenances is becoming increasingly popular. By using precast parts made of polymer concretes, the time required to complete a project can be shortened even more. This use is especially important in rehabilitation work. The contractor can have parts formed and cured before tear-out work begins and have them ready to drop into place. This practice eliminates

Graphite Plant (Novolac Epoxy; Potassium Silicate)

A large graphite producer in the Midwestern United States handles large quantities of sulfuric acid at 24%, hydrochloric acid at 20%, and sodium hydroxide at 50%, all at 140 F (60 C). Process area floors and collection sumps were badly corroded due to the repeated failure of coatings systems. The owner wanted a one-time fix for the facility, with the caveat that the contractor had to do the project after normal business hours and had to be finished with demolition and installation within seven working days. A decision was made to use a potassium silicate polymer concrete in the process area and a novolac epoxy polymer concrete in the collection sump. The project was completed and turned over for use within six days. Installed in the winter of 1995, the polymer concretes in both areas have provided maintenance-free service for more than 16 years at this writing.

The sump seen here is lined with novolac epoxy polymer concrete.

Process area floor nearly done.

the time required for forming in order to cast the polymer concrete in place and the time required for cure. It is also easier to compensate for any shrinkage in this manner than it might be by casting large masses in place. Pre-casting also allows for post curing the parts before placing them in service, if recommended by the polymer concrete manufacturer for a given application. When pre-cast parts are used, they must be joined by an appropriate chemical-resistant mortar or expansion joint.

Using Portland cement-based concrete in the chemical process industries frequently entails protecting the concrete from chemical attack. Such protection can range from a few mils of a corrosion-resistant coating to multiple courses of corrosion-resistant brick and mortar. Whatever protective barri-

Precious Metals Refinery (Potassium Silicate)

A precious metals refinery in the western United States unloads 98% sulfuric acid from railcars for use in its ore digestion process. The concrete around and under the tracks was completely destroyed in many areas. The choice to repair these areas was a polymer concrete based on potassium silicate. The refinery also had rail ties pre-cast from the polymer concrete. The project was completed in 1998; many more years of maintenance-free service life are expected.

Potassium silicate PC being installed under and around railcar unloading pad.

er is chosen, it will eventually need to be replaced. Service life is related to the thickness and the material properties of the barriers. Depending on the corrosive media, removal of degraded barrier systems and any affected underlying concrete may require disposal as hazardous waste. Generally, the thinner the protective barrier, the more often replacement will be required.

Polymer concretes provide a substantial barrier to corrodents in that they are typically applied at thicknesses greater than 1 in. (2.54 cm). If polymer concretes are used as stand-alones, the thickness may be 2 to 6 in. thick (5.08 cm to 15.24

Petroleum Refinery (Potassium Silicate)

Polymer concrete cast in place to form trenches to carry concentrated sulfuric acid to neutralization tank.

Pump pad, floor, and dike wall, all of polymer concrete, are exposed to concentrated sulfuric acid spillage and leaks on a continuous basis.

A sulfuric acid plant located in Argentina was experiencing severe corrosion on its process area floors, in its trenches, and in a concrete pipeline due to concentrated sulfuric acid (H_2SO_4). This H_2SO_4 plant, adjacent to a petroleum refinery, converts elemental sulfur (S) to concentrated H_2SO_4 at 98%+.

In 2009, the petroleum refinery decided to replace a severely corroded section of a concrete pipe with one made of an inorganic polymer concrete. The polymer concrete selected was based upon potassium silicate. Potassium silicates are resistant to all acids and their salts, except those containing fluorine (F), e.g., HF, H_2SiF_6, etc. Potassium silicates are especially recommended for exposure to acidic sulfur-bearing compounds such as H_2SO_4 and H_2S.

At this petroleum refinery, sulfur is removed from the incoming oil through a desulfurization unit and then is sent to an acid plant where elemental sulfur (S) is converted to sulfuric acid, H_2SO_4. The sulfuric acid produced is slightly less than 98% by weight and is at a temperature ranging from 212 F–353 F (100 C–200 C). The final step in the process is the acid drying tower, where the acid is concentrated to 98%+ by weight.

The 98%+ H_2SO_4 is then piped to packaging for re-use in the reformers. During these processes, spillage inevitably occurs. This spillage was flushed to trenches with plant water and from there to the neutralization plant for neutralization and disposal through an unlined concrete pipeline that was leaking badly. The acid had flowed under process area floors and was destroying nearby structural columns and support bases of equipment and buildings.

The plant engineers consulted with several manufacturers of corrosion-resistant coatings and chemical resistant refractories, as well as reviewing the plant's prior practices. After considering protective coatings on new concrete, it was felt that the maximum design life was approximately 10 years with maintenance. Brick/membrane liners were very expensive and required a long outage to install. However, they could be expected to provide more than 25 of years service life with proper maintenance, but maintenance could not be guaranteed. It was suggested to look at polymer concretes.

They chose a potassium silicate based PC, primarily for its extremely high resistance to 98% H_2SO_4, its ease of handling and placement, low permeability, and the long-term economics. It is expected to last more than 18 years. One year after replacing the most severely deteriorated sections of the concrete pipeline, the plant engineers decided to replace the entire pipe with the potassium silicate polymer concrete.

cm) or more. The increased thickness not only provides superior physical properties to coated concrete but also results in a barrier that even the lowest viscosity fluids cannot readily penetrate. The result is a service life many times greater than unprotected concrete. This means far fewer days of downtime and the attendant loss of use of the equipment or area. A simple time-cost calculation will show the value of the additional protection afforded by polymer concretes. Polymer concretes can provide low-maintenance protection for many years, rivaling or even exceeding the service life of brick and mortar. The ease of using polymer concretes makes them much faster and far easier to install than brickwork. Compared to brick, polymer concretes also have improved fracture toughness.

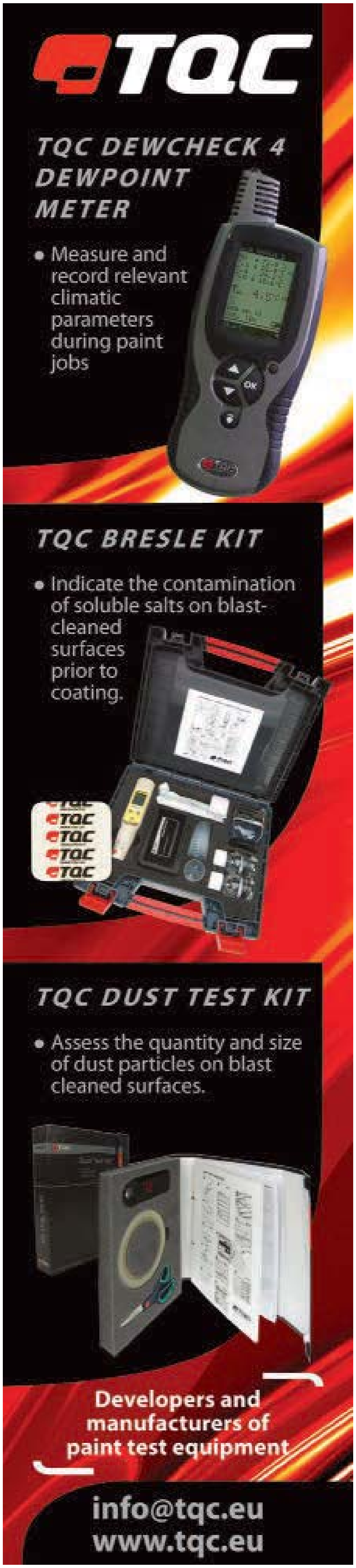
Thin film corrosion barriers, while providing excellent protection, cannot provide the service life of typical polymer concretes. Replacing these thinner materials with polymer concretes reduces the overall cost per year of service.

Table 2 (p. 37) illustrates the relative chemical resistance for polymer concretes, including potassium silicate. The reader is reminded that the fillers also have a significant effect on over-

Table 2: Relative Chemical Resistance for Polymer Concretes Generic Binder Type

Chemical	Bis A Epoxy	Bis F Epoxy	Novolac Epoxy	Bis A Vinyl Ester	Novolac Vinyl Ester	Furan	Polyester	Potassium Silicate	Portland Concrete
10% Acetic	R	R	R	R	R	R	R	R	NR
Glacial Acetic	NR	NR	NR	NR	C	R	NR	R	NR
Acetone	NR	NR	C	NR	NR	R	C	NR	NR
30% Ammonium Hydroxide	R	R	R	C	C	R	C	NR	NR
Benzene	NR	NR	NR	C	C	R	NR	R	R
10% Chromic Acid	C	R	R	C	R	NR	C	R	NR
20% Chromic Acid	NR	C	R	R	R	NR	C	R	NR
Gasoline, Jet Fuel	R	R	R	C	C	R	NR	R	R
10% Hydrochloric Acid	R	R	R	R	R	R	R	R	NR
37% Hydrochloric Acid	R	R	R	C	C	R	C	R	NR
30% Hydrofluoric Acid	R*	R*	R*	R*	R*	R*	C*	NR	NR
Lactic Acid	R	R	R	R	R	R	R	R	NR
Methylene Chloride	NR	NR	NR	NR	NR	C	NR	R	NR
Methanol	C	C	C	C	C	R	NR	R	NR
Ethanol	C	C	C	C	C	R	C	R	NR
MEK	NR	NR	NR	NR	NR	R	NR	R	R
Nitric Acid 10%	C	C	C	R	R	NR	R	R	NR
Nitric Acid 50%	NR	NR	NR	NR	NR	NR	C	R	NR
Phosphoric 80%	C	R	R	R	R	R	R	R	NR
Sodium Hypochlorite 3%	NR	NR	C	C	NR	NR	C	NR	NR
Sodium Hypochlorite 10%	NR	NR	NR	C	R	NR	C	NR	NR
Sodium Hydroxide 50%	R	R	R	R	R	R	C	NR	NR
Sulfuric Acid 10%	R	R	R	R	R	R	R	R	NR
Sulfuric Acid 50%	R	R	R	R	R	R	R	R	NR
Sulfuric Acid 75%	NR	C	R	C	C	R	C	R	NR
Toluene	C	C	C	C	C	R	NR	R	R
Water	R	R	R	R	R	R	R	R	R
Vegetable Oil	R	R	R	R	R	R	R	R	NR
Fats—Animal	C	R	R	R	R	R	C	R	NR

*Must have 100% carbon or barites fillers. R = Recommended NR = Not Recommended C = Conditional, consult manufacturer



Sulfuric Acid Drying Tower (Potassium Silicate)

In 2001, at a metals refinery near Lima, Peru, the acid drying tower had developed several leaks. A polytetrafluoroethylene liner on the interior of the tower had failed, and the concentrated sulfuric acid was leaking through the outside and collecting at the base of the tower. Shutting the operation down and making repairs to the interior was not an attractive option due to cost of repair and even more costly downtime. The owners had considered installing a metallic jacket on the tower's exterior. This would have been a temporary fix because corrosion would have rendered the jacket sacrificial, even if stainless steel was used. The solution chosen was to install a potassium silicate polymer concrete as an external jacket. While the unit was operating, the polymer concrete was cast in place at a thickness of 2 in. (5.08 cm). Forms were removed after a 24-hour cure; the unit has been in continuous operation since Spring 2001 and has, thus far, evidenced no leakage.

all chemical resistance. For example, hydrofluoric acid (HF) requires that a carbon or barite filler be used because silica is readily attacked by HF and other fluoride-containing chemicals. The resin, diluents, and additives used, as well as the curative agent, affect the binder's chemical resistance and physical properties. When used together, different chemicals can act synergistically and do things that neither can do alone. Therefore, a Bis A epoxy polymer concrete made by one manufacturer may not perform the same as one made by another manufacturer. The specifier should always consult the polymer concrete manufacturer for a specific application.

It must also be remembered that chemical compounds often act synergistically in combinations and can do far more damage than any single compound. For this reason, chemical resistance guides may not accurately reflect the degree, or rate, of degradation to be expected. Therefore, the polymer concrete manufacturer must be given an accurate list of chemicals present, the temperature range, and their concentration ranges in order to recommend the best binder/filler for the service.

Also critical to performance is the thermal environment. The rate of reaction of any given chemical environment roughly doubles for each 18-degree F (10-degree C) incremental temperature rise. Therefore, data obtained at room temperature of 72 F (22 C) will not necessarily be predictive of behavior at 212 F (100 C). Cyclical temperatures of sufficient frequency and amplitude to induce thermal shock may result in failure due to cracking and spalling, with an attendant loss of chemical resistance.

Conclusion

From the variety of chemistries and applications described in this article, it is easy to appreciate the added value that correctly understood and specified polymer concretes offer facility owners. The entire mass of a polymer concrete is made of chemical-resistant material. Even if degradation of the top surface occurs, the remaining mass is still corrosion resistant. The thickness, low absorption, and exceptional strength of correctly specified polymer concretes ensure many years of service with little to no maintenance as well as cost savings over the life of the polymer concrete.

Gary Hall is Manager of Research and Development at Sauereisen, Inc. He is responsible for developing new products. He has been with Sauereisen for 43 years and is a graduate chemist from the University of Pittsburgh. He is active in NACE, ASTM, and the American Institute of Chemical Engineers. Hall is also a contributing editor for *JPCL*. He received the SSPC 2006 Outstanding Publication Award and two *JPCL* Editors' Awards.

JPCL

Reducing VOCs in Polyurethanes Takes Two Routes

By Brian Goldie, *JPCL*

Polyurethanes have become an increasingly important, versatile technology for protective coatings. The high solvent resistance, good mechanical properties, and excellent weathering properties of polyurethanes make them suitable as topcoats in a variety of applications. Current environmental regulations to restrict volatile organic compound (VOC) content has meant more challenges for the formulator in developing higher solids or waterborne polyurethane finishes. This article reviews developments in these areas as presented at recent European and U.S. conferences and exhibitions.

Waterborne or High Solids?

In deciding whether to take the high-solids, solvent-borne (or solvent-free) route or use waterborne technologies to meet VOC restrictions, North American and European formulators have tended to go separate ways. Since the 1970 U.S. Clean Air Act, American formulators turned more often to solvents exempt from U.S. VOC regulations to make high-solids systems, rather than adopting waterborne equivalents. European formulators, however, have not had the luxury of using exempt solvents; therefore, most developments in low VOC coatings have tended to be with waterborne systems.

European Coatings Show

A report on the new products on display at the European Coatings Show (ECS, Nuremberg, March 2011), except for developments in polyurethane (PU) systems, was published in the July 2011 *JPCL*. The article noted that the general trend of products on display to meet the lower VOC regulations was related to waterborne technologies, not higher solids, solvent-borne systems. The new products for PU coating technology from a selection of the Show's exhibitors, are no exception.

According to Bayer, PU coatings formulated with its raw materials have a wide range of applications, with the latest developments targeting new functions. For example, waterborne two-component (2K) PU clearcoats and topcoats formulated with the new generation of Bayhydrol® A acrylic dispersions feature outstanding chemical resistance, making graffiti removal easy. They also satisfy exacting requirements for gloss retention and for weathering, UV, and scratch resistance. The specially developed PU dispersions can also be used to formulate waterborne 2K primers with good anti-corrosion and rapid cure properties. Improving on their predecessors, the new products can also be used to formulate coatings with VOC content well below 250 g/L—in some cases even below 100 g/L.

With the introduction of Easaqua™ X L 600, a new modified polyisocyanate, Perstorp has answered coating producers' calls for waterborne PU technology that offers high humidity resistance. With the balance between low viscosity and high NCO content, it helps meet the market's need for low VOC systems. Further, it improves coating adhesion on a wide range of substrates. Thus, it is particularly suitable for direct-to-metal (DTM) applications.

Also to meet the rapidly growing market for aqueous PU dispersions, Croda Coatings & Polymers displayed its bio-based polyester polyols for high-performance waterbornes.

Incorez demonstrated the practical use

(Left) ECS trade fair activity. ©NuernbergMesse

of oxazolidines by case studies showing the enhanced performance of one-pack PU flooring systems and improved performance of aromatic PU sealant prepolymers using oxazolidine latent hardeners; and the benefits of oxazolidine moisture scavengers in wind turbine protective topcoats.

Trends Shifting

There are now, however, signs that, with some exceptions, the dominance of waterborne technologies in Europe is changing, as can be seen from the new studies presented at several important coatings conferences over the past nine months, including the European Coatings Congress that accompanies the ECS, the Advances in Coatings Technology Conference, and SSPC 2011 (SSPC: The Society for Protective Coatings). The main exception to this changing trend was at the FATIPEC Congress, held in conjunction with Eurocoat. The difference may be related to the fact that FATIPEC/Eurocoat targets the architectural market and coating producers in the Mediterranean, where the climate is generally more favorable to waterborne coatings.

European Coatings Congress

While the trend for products on display at the ECS was toward waterborne technology, the PU technical session at the ECS's accompanying European Coatings Congress was primarily focused on developments for high-solids, solvent-borne PU systems.

M. Mechtel et al., from Bayer MaterialScience, Germany, noted that in the current economic climate, the search for the effectiveness and efficiency of coatings that maintain quality and environmental compatibility is more important than ever ("Are high coatings performance, efficiency, and environmental compatibility still a contradiction?"). Highly functional aliphatic polyisocyanates enable fast-drying 2K PU topcoats to be formulated. Due to their high cross-linked density, they have excellent durability; however, in many cases, the high viscosity of these polyisocyanates has required high solvent levels and thus reduced their environmental compatibility. The author described a new high functionality, low viscosity aliphatic polyisocyanate (HDI-allophanate) for clear coats and 100% solids coatings.

The effect of the polyol/isocyanate combination in achieving the desired VOC level in high-solids, 2K PUs while keeping good drying and hardness properties was the subject of a study by F. Lucas et al., BASF SE, Germany ("Structure-property relationship of 2K aliphatic polyurethane systems"). The authors found from a study of the drying kinetics of combinations of acrylic/isocyanate that the composition was critical to achieve specifically desired mechanical properties. Although this presentation was biased to automotive topcoats, the reasoning is valid for high-performance protective topcoats.

> **"There are now, however, signs that, with some exceptions, the dominance of waterborne technologies in Europe is changing"**

V. G. Parcios, Universidad de Alicante, Spain, discussed the synthesis of PUs from polycarbonate polyols ("Performance of PU coatings obtained with polycarbonate diol, polyether & polyester polyols"). Parcios demonstrated that the polycarbonate polyols gave better hydrolytic stability, mechanical properties, and low-temperature behavior than coatings made from polyether or polyester polyols. The polycarbonate polyol reduced drying times and improved pencil hardness, gloss, and yellowness index.

Reduced VOC levels were also the subject of a presentation by R. Shain et al., King Industries, U.S. ("Novel polyol modifiers to achieve VOC compliance with improved performance"). The authors described a unique family of polyester reactive modifiers for high-solids, solvent-borne industrial coatings. Several formulations were described to show how other physical and resistance properties were also improved such as flexibility and exterior durability. Despite these reactive modifiers being hydrophobic, they can offer advantages to a waterborne 2K PU: increased impact resistance, good salt spray resistance, and high gloss.

Waterborne technology was not entirely absent from the PU technical session at the Congress. K. Woods et al., Arkema, U.S., described hydroxyl functional PVDF-acrylic hybrid emulsions cross-linked with water-dispersible polyisocyanates to produce coatings with good weatherability and abrasion resistance for wind turbine blades ("Water-based fluoropolymer-urethane hybrid systems for wind turbine blade topcoats"). The authors reported their work on optimizing the binder's fluoropolymer level and the parameters of the resultant coating. These new hybrids combine the excellent weather properties of PVDF resins with good solvent resistance, hardness, toughness, and abrasion resistance from the urethane component.

Waterborne 2K PUs were also the subject of a paper by M. C. Schrinner et al., Bayer MaterialScience, Germany ("Next generation acrylic dispersions for high performance waterborne 2K PU coatings"). Noting that these systems had been gaining success and now have some properties comparable to their solvent-borne counterparts, the authors described a new generation of acrylic polyol dispersions. They have a reduced concentration of organic solvent of the dispersion and a reduced demand for additional solvent in the finished coating formulation. Both properties resulted in lower VOC coatings with good film properties, hardness, and solvent resistance

In addition, two general presentations were also on reducing VOCs in coatings by replacing solvent-borne systems with their equivalent waterborne counterparts.

J. Stubbs et al., DSM NeoResins, U.S., described a range of urethane and other resin monomers that could be combined to give environmentally compliant coatings ("Eco challenge to reduce emissions in high performance coatings"). The authors illustrated the design concepts for zero or low VOC systems.

J. Roper, et al., The Dow Chemical Company, U.S., described the development of a proprietary mechanical dispersion technology for waterborne dispersions ("Waterborne mechanical dispersions to replace solventborne coating binders"). The technology does not need solvent to form the dispersion. The authors demonstrated how the waterborne mechanical dispersions could be used to replace solvent-borne coating binders with waterborne systems, including PUs, to overcome the performance gap.

ACT '10 Conference

At the ACT '10 Conference (Advances in Coatings Technology) held in Katowice, Poland, in November 2010, the following papers described problems in formulating high-solids and waterborne PUs.

How solvents affect the curing and properties of high-solids PU was reported by D. A. Vasilyev, et al., from the Yaroslavl State Technical University, Russia ("The Influence of Solvents on Curing and Properties of 2K-PUR High Solids Coatings"). The authors identified the effect of solvents as one of the challenges facing formulators trying to meet VOC requirements. The authors' work showed a significant difference in the amount of the different solvents needed to produce the required application viscosity for spray-applied PU coatings. They found that using more thermodynamically stable solvents such as MEK, MIBK, and butyl acetate allowed a coating to be formulated with VOC below 420 g/L. However, they also found it necessary to incorporate potentially higher VOC solvents, such as toluene, to maintain coating properties and ease of use.

The problem of increased viscosity of high-solids PUs was also discussed by M. Glennstål et al., of Perstorp, Sweden, who introduced the use of polycaprolactone as a reactive diluent in his paper ("Polycaprolactone as Reactive Diluent in 2K PU Coatings"). Polycaprolactones are

"In the US,…the monopoly of high solids systems seems to be changing with more interest in waterborne technology"

liquid aliphatic polyols with low viscosity, which makes them ideal as co-binders in 2K PUs. The authors found that replacing 25% of a conventional acrylic polyol with polycaprolactone reduced VOC by 13% at the required spray application viscosity. Polycaprolactones also improved drying time, but at the expense of pot life. Other formulation parameters, however, could compensate for the effects on pot life.

S. Easthope, et al., from Incorez Ltd in the UK, discussed the use of oxazolidines as a means of dealing with moisture, which can easily be attracted by the hydroscopic polyols or other ingredients in the PU formulation ("Oxazolidines: A Useful Aid to Solving Polyurethane Formulation Problems"). A side reaction between the isocyanate curing agent and moisture to form CO_2 can affect full cure and cosmetic appearance. Oxazolidines preferentially react with moisture, thus preventing the side reaction with the isocyanate.

FATIPEC

The biennial FATIPEC Congress was held during the Eurocoat exhibition (Genoa, Italy, Nov. 2010). Although the Congress deals mainly with architectural coatings, a few presentations on waterborne PU technology addressed high-performance coatings.

A. Sanderse et al., Nuplex Resins BV, The Netherlands, described the development of a practical waterborne 2K PU that can be brush or roller applied ("New developments on water-borne resins for 2K coatings"). The coating depends on careful selection of binders, solvent, and thixotropic and defoaming additives. The results of the study gave rise to the required VOC-compliant coating with properties comparable to its solvent-borne counterpart. Also from Nuplex Resins, J. Akkermann et al. described the results of an R&D study of the open (workable) time of waterborne gloss topcoats, which resulted in the development of very low VOC paints ("New developments on open time resins for waterborne decorative coatings").

I. Amici-Kroutilova et al., Lamberti SpA, Italy, described a study into chemical modifications of the PU polymer backbone ("New hydrophobic modifications of polyurethane aqueous dispersions for hard substrates coating"). Introducing hydrophobicity to promote adhesion and chemical resistance, the authors identified a range of novel hydrophobic polyols for new PU aqueous dispersions with reduced VOC content.

A new waterborne technology that can produce low VOC coatings without sacrificing hardness, and that can maintain good corrosion resistance and weathering properties, was introduced by L. Procopio et al., The Dow Chemical Company, France ("Protection of Metal with a Novel Waterborne Acrylic/Urethane Hybrid Technology").

Their hybrid technology couples a hard acrylic dominant phase with a soft polyurethane minor phase. The result is a self-crosslinking hybrid polymer with low VOC/fast hardness development and the required corrosion resistance and weatherability in a 1K waterborne system. Corrosion resistance is similar to that of a conventional acrylic.

SSPC 2011 Conference

In the U.S., again the monopoly of high-solids systems seems to be changing with more interest in waterborne technology. This change was in evidence at the SSPC GreenCOAT 2011 Conference. One of three presentations on new developments in PU covered waterborne technology. The other underlying trend was for green developments in raw materials, similar to the trend at Nuremberg.

H. B. Sunkara et al., Dupont, U.S., described a family of poly(trimethylene ether) polyols manufactured in a sustainable process using a raw material derived from agricultural feedstock—corn ("Polyether Polyols: A Renewably Sourced and High Performance Ingredient for Coatings"). These polyols have low viscosity, low melting point, high flexibility, and heat and acid resistance, which make them ideal for PU coatings. The presentation discussed the performance benefits possible in solvent-borne and waterborne PU coatings by using the polyol as a reactive diluent.

L. Ferrnando, Kemwerke Inc., The Philippines, described the performance properties of coconut-based polyol resin used in PU coatings and compared with commercially available PUs, both as primers and topcoats ("Application study on the performance of polyurethane paint as a green coat using biobased coconut polyol resin for protective and marine industrial coatings"). Generally, properties similar to conventional PU coatings were obtained, although the novel coating had better flexibility and a high level of adhesion.

R. Stewart of Bayer MaterialScience, Pittsburgh, U.S., discussed the challenges to the formulator of DTM PU coatings to meet changing market requirements ("One Component Waterborne Resins for Direct-to-Metal Applications"). Stewart focused on the use of oxidatively curing PU dispersions for these applications. He linked the coating performance requirements to the choice of the resin building blocks—polyol, isocyanate, chain extender, and solubilizing agent.

Conclusion

Obviously, there is a lot of interest in polyurethane technology for protective coatings, but whether high-solids or waterborne systems will dominate the low VOC products is anyone's guess. **JPCL**

SSPC Launches PCI Level 3 Coating Inspector Certification

SSPC has announced the release of the next level of its Protective Coatings Inspector (PCI) program, PCI Level 3.

The PCI inspector certification was first introduced to the coatings industry in 2007. Since then, it has been well received by both industry veterans and newcomers as a high-quality and affordable education alternative that effectively teaches both core and advanced concepts of coating inspection. It has also gained the approval of international agencies like ABS (American Bureau of Shipping), Lloyd's Register, and RINA. One of the keys to the program is its flexibility, SSPC reports.

According to SSPC President Bob McMurdy, "When SSPC designed PCI, the goal was to provide a more affordable pathway to certification for independent inspectors and professionals in emerging markets. In our research, we discovered a great thirst for knowledge among groups of highly skilled workers. These groups already had training and experience in coatings and they wanted to be able to put that to work for them in gaining inspector certification. PCI allows them to do that."

PCI Level 3 provides a new goal for the most experienced inspectors, SSPC says. The new level adds one more day to the PCI program for those candidates who choose to take the exam. Candidates must meet certain prerequisites in order to qualify for the exam and must complete the test within a designated time frame. To achieve Level 3, students must score 80% or better.

"SSPC works hard to provide good programs that people want," said Bill Shoup, SSPC Executive Director. He added, "If you're looking to improve your skills and knowledge, you want a return on your training investment. PCI Level 3 will deliver that ROI and prepare inspectors to meet the demands of the toughest specifications and the toughest projects."

The PCI Level 3 exam will be available September 1, 2011. To schedule an exam, contact SSPC at 877-281-SSPC or 412-281-2331.

For more information about PCI or SSPC's other certification programs, visit www.sspc.org and click on "Training."

Preparations for SSPC 2012 in Full Swing

Registration for SSPC 2012 will open on Sept. 1. The conference and exhibition will take place at the Tampa Convention Center on Jan. 29 to Feb. 2.

SSPC 2012 is the industry's only 100% protective, marine, and industrial coatings show. Over the next few months, *JPCL* will highlight different aspects of the show including workshops, training and certification, technical programs, and special events and awards, culminating in a full-scale conference preview and guide in the December issue.

Indulge in a new feature on the SSPC web site—video proceedings of SSPC 2011 presentations. The video proceedings are presented free of charge through the sponsorship of Mascoat and Sherwin-Williams.

To access 20 presentations from four sessions, visit www.sspc.org/sspc-events/sspc-2011-video-proceedings.

The official web site for SSPC 2012 featuring GreenCOAT will launch soon. In the meantime, if you can't wait to start planning your trip to the exhibit hall, a sneak peak of exhibitors that have signed up for SSPC 2012 (as of press time) can be found on the following page.

Continued

SSPC 2012 Exhibitors (at press time)

- Advanced Recycling Systems, Inc.
- Aggreko, LLC
- AIR Systems International
- Arid Dry by CDIMS
- Atlantic Design Inc. (ADI)
- Axxiom Manufacturing Inc.
- BlastPro Mfg.
- Bullard
- Carboline Company
- CESCO / Aqua Miser
- Chlor*Rid International Inc.
- Church & Dwight (ArmaKleen)
- Clemco Industries Corp.
- Clothes Cleaning Systems
- *Coatings Pro* Magazine
- Croda
- CSI Services, Inc.
- Defelsko Corporation
- Dehumidification Technologies, Inc.
- DESCO Manufacturing Co., Inc.
- Detroit Tarp Inc.
- Doosan Portable Power
- DRYCO, LLC
- DUSTNET by EMI
- Eagle Industries
- EcoQuip, Inc.
- Elcometer Instruments Ltd.
- Ervin Industries
- Evonik Degussa Corporation
- Farrow Systems
- Fischer Technology Inc.
- Forecast Sales / Pirate Brand
- GMA Garnet (USA) Corp.
- Graco Inc.
- Greenman-Pedersen, Inc.
- Guzzler Manufacturing Co.
- Hanes Supply Inc.
- Harsco Minerals
- HippWrap Containment
- HoldTight Solutions Inc.
- Hydrex Underwater Technology
- Indian Valley Industries
- Industrial Vacuum
- ITW Industrial Finishing
- JAD Equipment Co.
- KTA-Tator, Inc.
- MARCO
- Mascoat
- Mohawk Garnet, Inc.
- Monarflex by Siplast
- Montipower, Inc.
- NACE
- National Equipment Corp.
- NexTec, Inc./PreTox
- Novatek Corporation
- Novetas Solutions
- Olimag Sand
- Opta Minerals, Inc.
- Painters & Allied Trades
- Paul N. Gardner Co.
- Pinnacle Central Company
- Polygon
- PPG Protective & Marine Coatings
- Ring Power Corporation
- SAFE Systems
- Sanstorm (MMLJ)
- Sauereisen
- Sherwin-Williams Company (The)
- Spider
- Sponge-Jet Inc.
- Surface Prep Supply
- Tarps Manufacturing, Inc.
- Technology Publishing/ PaintSquare
- ThyssenKrupp SAFWAY Services
- Tnemec Company
- Tomoric Technology Inc.
- Tractel Inc. Griphoist Division
- Trimaco, LLC
- TSE-Okulen Americas LLC
- Van Air Systems
- VRSim
- Western Technology
- WIWA LP
- Wooster Brush Co.

SSPC Standards Planned for Revision

SSPC will be revising and reviewing the following standards later on this year and early next year.

SSPC-AB 2 and AB 3

SSPC-AB 2, "Cleanliness of Ferrous Metallic Abrasive Work Mix," and SSPC-AB 3, "Ferrous Metallic Abrasives," are scheduled to begin review and revision later in 2011. For more information on joining the review committee, contact Aimee Beggs at beggs@sspc.org or 412-281-2331 x2223 by Sept. 15.

Tri-Society Thermal Spray Application Standard

There is also a committee forming for the revision of SSPC-CS 23.00/AWS C.2.23/NACE No. 13, "Specification for the Application of Thermal Spray Coatings (Metallizing) of Aluminum, Zinc, and Their Alloys and Composites for the Corrosion Protection of Steel."

A meeting open to committee members from all three associations is planned for Sept. 20, 2011, during NACE Corrosion Technology Week in Las Vegas. The committee also plans to meet during SSPC 2012 in Tampa. If you are interested in participating in the SSPC review committee contact Aimee Beggs by Sept. 15.

Free SSPC Training for DoD, Army, Air Force, Navy

Government personnel can register for approved SSPC coatings training courses and have the cost for the course completely covered by funds authorized by the U.S. Department of Defense.

The pool of funds authorized for coatings training courses was originally announced by SSPC in July 2008. The latest contract was enacted on July 5, 2011, and runs through Sept. 27, 2011.

Courses available under the funding include Fundamentals of Protective Coatings (C1) and the C1 eCourse; Planning and Specifying Industrial Projects (C2) and the C2 eCourse; NAVSEA Basic Paint Inspector (NBPI); Concrete Coating Inspector (CCI) Program Levels and Options; Abrasive Blasting Program (C7); Airless Spray Basics (C12); and Marine Plural Component Program (MPCAC, C14).

For information, contact Jen Merck at 877-281-7772 x2221 or merck@sspc.org.

Hampton Rds to Hold Annual Golf Event

The SSPC Hampton Roads Chapter will hold its Annual Golf Tournament on Oct. 7, 2011, at Sewell's Point Golf Course in Norfolk, VA.

Check in time is 10:30 a.m., and the shotgun start is at noon. Lunch is pro-

Continued

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vided and begins at 10:45 a.m. Dinner will also be provided during the awards ceremony.

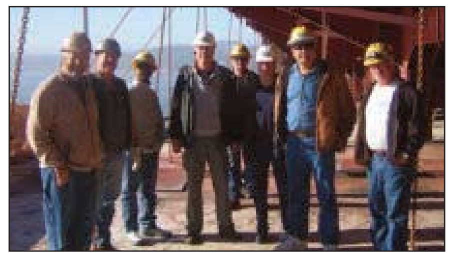
All players and teams must pay their fees prior to the tournament. Payments must be received by Sept. 30. The fee for an individual player (golf and lunch) is $60; teams of four (golf, cart, range balls, lunch, and prizes) pay $260 per team; hole sponsors (looking for 20 sponsors) can get their company name on a sign for $100 per hole; beverage sponsors (need 8) pay $75 each; and gift sponsors (need 25) pay $75 each.

This year, the chapter's goal is to have at least 22 teams of four.

Checks can be made payable to HR Chapter—SSPC. Payments can be sent to Robert Patrick at 1561 Scoonie Pointe Dr., Chesapeake, VA 23322 or Pam Winterling at PPG Industries Inc., 2424 Smith Ave., Chesapeake, VA 23325. Patrick can also be contacted at rpatrick1956@yahoo.com or 757-237-4378 (cell). Winterling can be contacted at winterling@ppg.com or 757-647-1020 (cell).

HRC–SSPC is asking for individuals or companies to provide bag stuffers, including golf tees, golf balls, ball markers, hats, visors, etc. Stuffer donations can be sent to Robert Patrick.

Training Roundup



Golden Gate Bridge personnel take the C3 course. Photos courtesy of SSPC.

In June, Chris Lovelace instructed the SSPC-C3 course for Golden Gate Bridge Highway & Transportation District personnel. All students were Golden Gate Bridge-dedicated personnel. A site visit to the bridge was used to reinforce the classroom concepts.

SSPC holds a new course in CA.

On July 19–20, SSPC held its new Protective Coatings Paperless QA and Digital Data Collection course at YYK Enterprises, Inc. in National City, CA. Six students attended, and the instructors were Phil Parson and Joe Walker.

associations

WaterJet Show Blasts into Houston

The WaterJet Technology Association (WJTA) and the Industrial & Municipal Cleaning Association (IMCA) have planned the 2011 WJTA-IMCA Conference and Expo for Sept. 19–21, 2011, at the George R. Brown Convention Center in Houston, TX.

The conference and exposition focuses on high-pressure waterjet technology and related services, including surface preparation, paint and coating removal, industrial cleaning, waste handling, and more.

According to WJTA-IMCA, the show is the largest global exhibition of waterjet/waterblast equipment, systems, and service providers. Attendees can expect displays including high-pressure and ultra-high-pressure waterjetting systems and accessories, automated equipment, guns, hoses and hose assemblies, valves, fittings, tubing, nozzles, lances, pumps, abrasive cutting systems and abrasives, surface preparation supplies, concrete removal systems, safety gear and supplies, and vacuum trucks.

Education

Educational opportunities during the conference will include paper presentations, a pre-conference workshop, and educational sessions.

Paper presentations will take place on Sept. 20–21. Presentations that might be of interest to the industrial coatings industry include the following.

- "Current Practices in Design Standards and Criteria for High Pressure Waterblasting Tools and System Components," by D. Wright
- "Energy Based Evaluation of Waterjet Peening for Industrial Application," by A. Chillman, M. Hashish, M. Ramulu, C. Lavender, E. Stephens, and Y.C. Chen
- "Influence of De-Painting Method on Substrate Surface Profile," by H. Teimourian, H.V. Tamaddoni, B. Mutabi, and A. Soleimanzadeh
- "Precision Robotic Waterjet and Abrasivejet Industrial Applications," by D. Snider
- "Selecting the Most Effective Waterblast Pressure and Flow for a Given Standoff Distance," by D. Wright
- "Stripping Coatings with High-Frequency Forced Pulsed and Ultra-high Pressure Waterjets: A Comparative Study," by M. Vijay, M. van Wonderen, W. Yan, A. Tieu, and B. Daniels
- "Theoretical and Experimental Basis of Water Pipeline Renovation with High-Pressure WaterJet Technique," by P. Borkowski
- "What's Happening in Surface Preparation Standards for Paint," by L. Frenzel

Downtown Aquarium Dancing Fountains. Photo courtesy of the Greater Houston Convention and Visitors Bureau.

The preliminary schedule for the pre-conference workshop and the educational sessions is as follows (as of press time).

Monday, Sept. 19

"Waterjet Technology—Basics and Beyond" is a workshop designed to provide an applied introduction to the technology and practical applications of waterjets and related equipment. It is intended for anyone with an interest in waterjet technology, from first-time users and new employees to those seeking to increase their level of knowledge.

The workshop is broken into two sections. "The Basics" will take place in the morning, breaking for lunch, and "Beyond the Basics" will take place in the afternoon. The current schedule includes:

- 7:00 a.m. to 8:00 a.m., Registration
- 8:00 a.m. to 8:05 a.m., Welcoming Comments and Introductions
- 8:05 a.m. to 8:30 a.m., "History of Waterjet Technology," by Mike Woodward, Ph.D.

• 8:30 a.m. to 9:00 a.m., "Applications of Waterjet Technology," by Scott Hardy
• 9:00 a.m. to 10:00 a.m., "Equipment Consideration," by Hugh Miller, Ph.D.
• 10:00 a.m. to 10:15 a.m., Break
• 10:15 a.m. to 10:45 a.m., "UHP & Abrasive Cutting Applications," by Mohamed Hashish, Ph.D.
• 10:45 a.m. to 11:45 a.m., "Safety," by Gary Toothe
• 11:45 a.m. to 12:45 p.m., Lunch
• 12:45 p.m. to 1:45 p.m., "Cleaning Applications," by Scott Hardy
• 1:45 p.m. to 2:15 p.m., "Field Cutting Applications," by Bill McClister
• 2:15 p.m. to 2:45 p.m., "Surface Prep," by Lydia Frenzel, Ph.D.
• 2:45 p.m. to 3:00 p.m., Break
• 3:00 p.m. to 5:00 p.m., "Understanding the Power of Vacuum and How Industrial Loaders Work," by Phil Stein

Tuesday, Sept. 20

"Boot Camp" sessions on Sept. 20–21 are designed to cover practical topics. The preliminary schedule follows.

• 10:30 a.m. to 12:30 p.m., "Understanding the Power of Vacuum and How Industrial Vacuum Loaders Work," by Phil Stein, Consultant
• 12:30 p.m. to 1:00 p.m., "Safety in Waterjetting," by Ed Twaddell, TurtleSkin WaterArmor by Warwick
• 1:15 p.m. to 1:45 p.m., "Reduction of Hydro Blasting Manual Labor at Dow Chemical," by Hans Borgt, Dow Benelux, B.V.
• 2:00 p.m. to 3:00 p.m., "Driving to Zero...Together!" by Kathy Krupp, The Dow Chemical Company
• 3:15 p.m. to 3:45 p.m., "Hose Safety," by Paul Webster and James Kim, Parker Hannifin-EPD
• 4:00 p.m. to 4:30 p.m., TBA

Wednesday, Sept. 21

• 10:30 a.m. to 11:00 a.m., "Automated Tube Cleaning," by Todd Shawver, NLB Corporation
• 11:15 a.m. to 11:45 a.m., "Hydro-Excavation," by Brett Hart, Federal Signal
• Noon to 12:30 p.m., "Automated Waterblasting Equipment Benefits and Capabilities," by Scott Hardy, StoneAge
• 12:45 p.m. to 1:15 p.m., "Nozzle Selection," Speaker to be announced
• 1:30 p.m. to 2:00 p.m., "High Pressure Waterblasting," by Gary Toothe, FS Solutions

Visit www.wjta.org for updates on educational sessions and workshops.

Continued

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- GapVax, Inc. 117
- Gardner Denver Water Jetting Systems, Inc.....601
- GMA Garnet (USA) Corp. 1008
- Hammelmann Corp. 309
- HoldTight Solutions, Inc.....729
- LaPlace Equipment Co., Inc.....1013
- NLB Corp.....607
- Parker Hannifin—EPD....807
- SPIR STAR....1011
- StoneAge, Inc.....401
- TurtleSkin WaterArmor by Warwick....229

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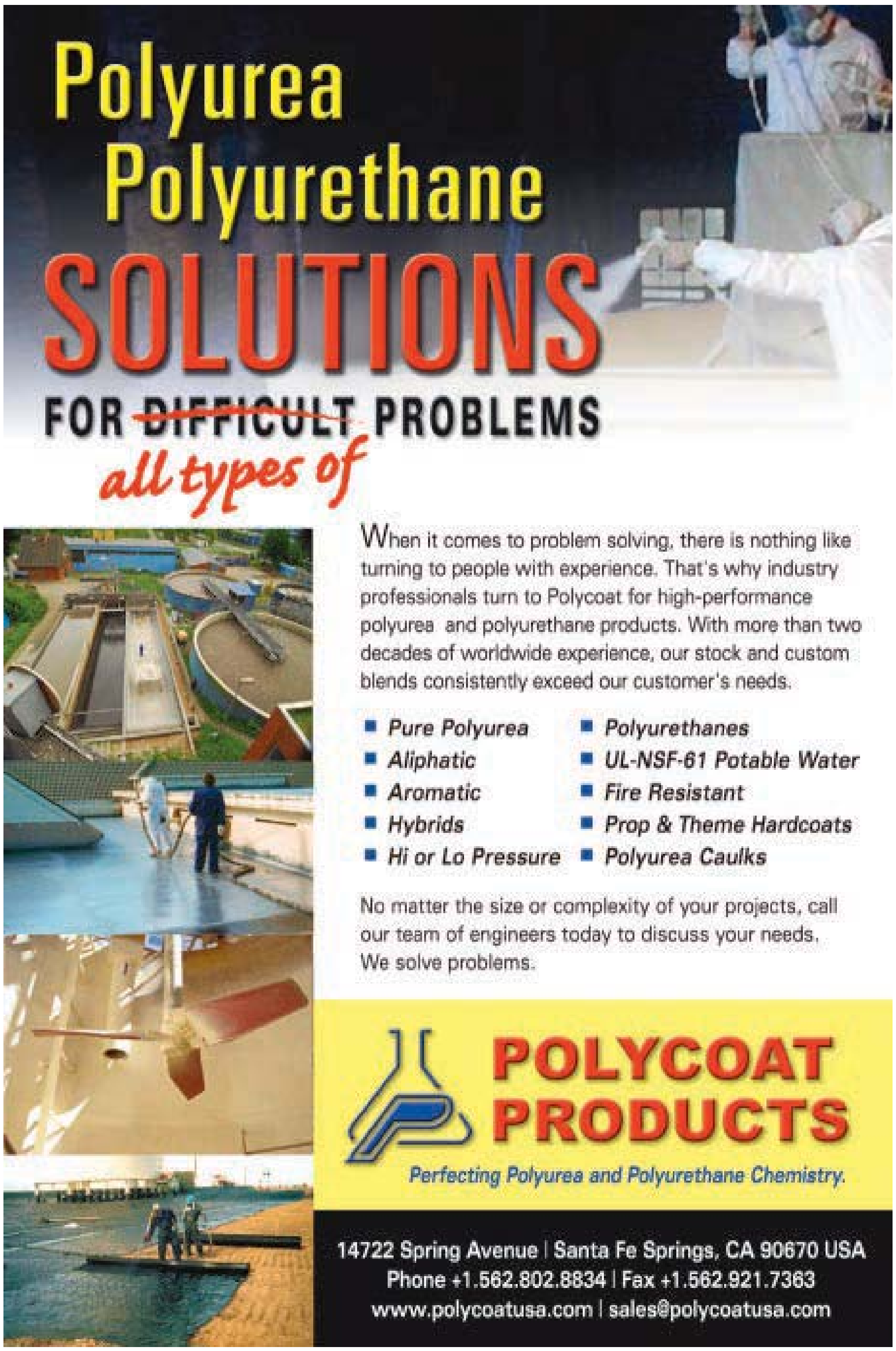

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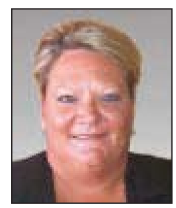

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companies

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Access equipment manufacturer SafeWorks LLC has received ISO 9001:2008 certification for its Seattle production facility, the company has announced.

The certification "reflects SafeWorks' commitment to its rigorous quality management system, continuous process improvement, and to the delivery of the highest level of quality and

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The Performance Coatings segment established a new all-time earnings record, and Industrial Coatings segment earnings matched the previous record, Charles E. Bunch, PPG chairman and CEO said.

The company reported that it ended the quarter with approximately $1.25 billion in cash and short-term investments. During the quarter, the company finalized the acquisitions of Equa-Chlor and Ducol Coatings and announced its agreement to acquire Dyrup A/S.

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refractory coating used to bond, coat and seal refractory fiber boards and other shapes, providing resistance to molten metals and open flames to 3200 F (1760 C), the company says.

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The J5A-30P is driven by an industrial-duty, 5-horsepower electric motor, which requires a single-phase, 230-volt power source. It features a four-cylinder "J" pump with a high compression ratio for producing 19.4 CFM at 100 PSI or 19 CFM at 125 PSI.

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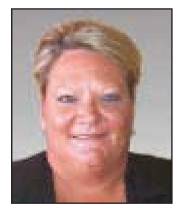
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Abhe & Svoboda Wins Aqueduct Coating Contract

The East Bay Municipal Utility District (Oakland, CA) awarded a contract of $6,183,310 to Abhe & Svoboda, Inc. (Prior Lake, MN) to perform lead abatement and coatings application on the Mokelumne Aqueducts. The contract required SSPC-QP 1 and QP 2 certification. The project involves abrasive blast cleaning and recoating a total of 17,815 linear feet of exterior surfaces on four sections of the aqueduct, a system of three large diameter steel pipelines that transport water approximately 90 miles from the Sierra foothills to treatment facilities and raw water reservoirs. The project includes recoating 6,236 linear feet of 65-inch-diameter piping; 5,581 linear feet of 69-inch-diameter piping; 5,998 linear feet of 89.5-inch-diameter piping; and various supports and appurtenances. The steel piping and supports will be recoated with zinc and zinc-epoxy-polyurethane systems, plus a cementitious mortar finish on one small section. The contract includes erecting Class 1A containment structures (SSPC-Guide 6), as the existing coatings contain lead.

Courtesy of EBMUD

Continued

Project Preview

Washington State DOT Lets Ferry Terminal Maintenance Painting Bid

Washington State Ferries, a division of the Washington State Department of Transportation, awarded a contract of $659,599 to Long Painting Company (Kent, WA), SSPC-QP 1- and QP 2-certified, to perform on-call maintenance painting at various ferry terminals. The contract may include abrasive blast cleaning and recoating transfer spans, wingwalls, overhead loading structures, and other terminal components using epoxy and splash-zone coating systems. The contract also includes testing existing coatings for hazardous content and performing as-needed containment, abatement, and disposal.

Purcell Wins Drawbridge Coating Contract

Courtesy of NOAA

Purcell Painting and Coatings (Tukwila, WA), SSPC-QP 1-, QP 2-, and QS 1-certified, was awarded a contract of $2,082,400 by the city of Seattle, WA, to recoat structural steel and railings on the 295-foot-long bascule section of the Ballard Bridge, a historic 2,854-foot-long bridge over Salmon Bay. The project includes coating 1,200 tons of structural steel, 590 linear feet of railings, and select concrete walls on the double-leaf bascule section of the bridge. The steel will be pressure-washed at 3,500–5,000 psi; spot-cleaned by Commercial blasting (SSPC-SP 6) and Bare Metal power-tooling (SSPC-SP 11); spot-primed; and coated with a moisture-cured urethane system. The contract includes following SSPC-Guide 6 recommendations for containment of the existing coatings, some of which contain lead.

West Virginia DOT Awards Bridge Coating Contract

The West Virginia Department of Transportation let a contract of $5,333,886 to Panther Industrial Painting, LLC (Mishawaka, IN), SSPC-QP 1- and QP 2-certified, to recoat a total of 7,949 tons of structural steel on the main span and approaches of the Arch A. Moore Jr. Bridge. The 14-span, 2,623-foot-long by 59-foot-wide structure spans the Ohio River between Marshall County, WV, and Belmont County, OH. The steel will be abrasive blast cleaned to a Near-White finish (SSPC-SP 10) and recoated with an organic zinc-rich primer, an epoxy intermediate, and a polyurethane finish. The project also includes applying an epoxy mastic coating system to interior arch surfaces and a protective coating to 864 square yards of concrete surfaces. The contract requires containment of the existing lead-bearing coatings.