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CORROSION CONTROL OF ABOVEGROUND AND UNDERGROUND STORAGE TANKS

Tank and Containment Linings

New U.S. Underground Storage Tank Rules

Materials Selection for a Bulk Chemical Handling Facility

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Storage Tank Corrosion—An Introduction

Leaking storage tanks, whether above or below the ground, can pollute the environment, threaten public health, and lead to billions of dollars in direct and indirect costs. One main reason for storage tank failure is corrosion. Fortunately, corrosion prevention technology exists that can protect storage tanks and keep them structurally sound for years to come.

Government and the public understand the extent to which leaking tanks can damage the environment and threaten public health. To prevent environmental contamination, U.S. federal regulations require those who own or operate underground tanks and the connected piping to have spill, overfill, and corrosion protection mechanisms in place, and many U.S. states have additional tank protection requirements. The owners/operators of tanks who fail to comply with these regulations can be subject to both civil and criminal penalties.

Why Do Storage Tanks Corrode?

Corrosion is the deterioration of a material, usually a metal, that results from a chemical or electrochemical reaction with its environment. Without implementation of appropriate corrosion-control measures, storage tanks will deteriorate. Most tanks are made of steel, a material highly susceptible to corrosion. Corrosion-related damage is accelerated by factors including the tank's interaction with interconnected components, corrosive environmental conditions, and stray electric currents. Over time, uncontrolled corrosion can weaken or destroy components of the tank system, resulting in holes or possible structural failure, and release of stored products into the environment.

How Do We Control Corrosion in Storage Tanks?

Modern corrosion control combines historically proven methods with state-of-the-art technology to prevent tanks from deteriorating. Corrosion-control strategies are used individually or in combination with one another. Common strategies include corrosion-resistant materials, application of coatings and/or linings as a barrier to the environment, various forms of cathodic protection to prevent deterioration of tank components in contact with the soil, and use of inhibiting chemicals in stored substances to control corrosion of the tank interior.

Planning and Training Are the Keys to Success

Corrosion control can protect storage tanks, the environment, and the bottom line of owners and operators. It must be an integral part of a storage tank owners'/operators' long-term planning. Tank owner support of corrosion control is vital, but comprises only half of the solution. Long-term planning for corrosion control must include ongoing education and training for persons responsible for operating tank systems. These individuals must be able to recognize the early signs of corrosion and effectively prevent it. Owners and operators must also dedicate the resources required to monitor and maintain these corrosion protection systems to ensure the effective protection of the environment and their economic interests.

Corrosion is a leading cause of storage tank failure. Fortunately, there are many ways to prevent this problem.

Conclusions

Above- and underground storage tanks could leak hazardous substances into the environment that contaminate our soil and water. Often, corrosion is to blame; however, corrosion is not a mystery—it can be prevented and controlled. By implementing comprehensive corrosion control for storage tanks, the environment can be protected cost-effectively while billions of dollars are saved each year.

Source: NACE International web site: www.nace.org. MP

Materials Selection for a Bulk Chemical Handling Facility—A Case Study

New tanks and associated piping at the Wafra Oilfield's bulk chemical handling facility were constructed with Type 316 and Type 316L SS.

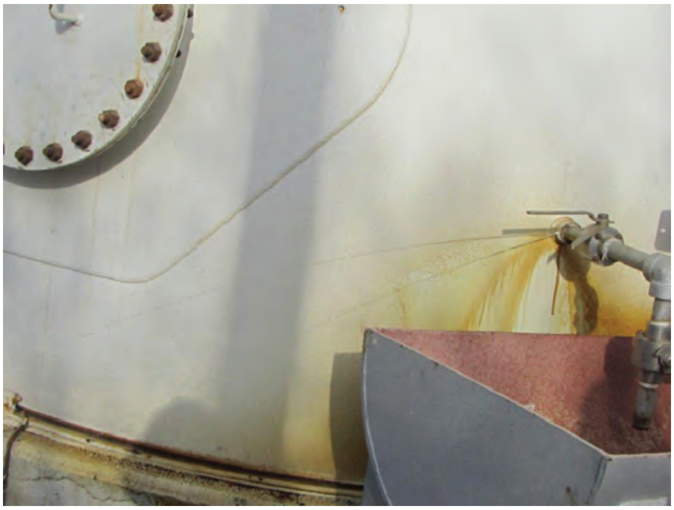
The joint operation bulk chemical handling facility at Wafra Oil Field, located in the Partitioned Neutral Zone area between the Kingdom of Saudi Arabia and the State of Kuwait, was experiencing frequent leaks during storage and transfer of integrity products. The bulk chemical facility's tanks, pumps, and connected piping were constructed with internally coated carbon steel (CS) components to meet cost reduction requirements. An engineering assessment determined that incompatibilities between chemicals used as well as long-term corrosion resistance of tanks and piping should have played a more important role in material selection prior to the facility's construction.

According to a review[1] of the corrosion issues encountered at the facility, authored by NACE International members Tariq Kamshad, Manickavasagan Sabesan, Siriki Ravi Shankar, and their colleague A/Rahman Al-Ghamdi from Joint Operations-Wafra (Saudi Arabia Chevron—Kuwait Gulf Oil Co.), the bulk chemical facility was constructed in 2001 to provide bulk storage of integrity and production chemicals to control corrosion and emulsion issues in the oil field's production wells, process facility, and water handling unit. The bulk facility consisted of eight tanks, transfer piping, a centrifugal pump, and instrumentation items. The storage tanks were constructed of ASTM SA 283 Grade C CS and the piping was constructed of ASTM SA 106 Grade B CS. The tanks, inlet and outlet piping, and drain lines were lined with a phenolic epoxy or fiberglass coating since prolonged storage in bare CS may cause the properties of the stored products to change.

The integrity chemicals used for corrosion control of the oil field's water process are a water-based corrosion inhibitor, biocide, and scale inhibitor, and each has a low pH—in the of range of 2.5 to 5.5. A common manifold is used to transfer these water-based chemicals. Generally, the corrosion inhibitor should be compatible with other chemicals because incompatibilities between chemicals are intensified if they are mixed in the same transfer line. To avoid this, a water-washing cleaning process was developed; however, the CS piping is not always properly drained or cleaned after each use. As a result, neat chemical residuals accumulate in low spots, which cannot be avoided.

The engineering evaluation determined that improper selection of materials and components caused corrosion of the structures, which led to poor containment reliability, increased maintenance activities, and additional safety and environmental concerns due to chemical spills. The accumulation and increased concentration of the neat chemicals in the manifold led to integrity chemical leaks, which caused a dramatic increase in the volume of pipeline maintenance and replacement work. Also, the linings in the CS delivery piping and storage tanks were found to have peeled and blistered.

Since the pH of the integrity chemicals is relatively low, the authors note in the review that materials such as CS should not have been used for the bulk storage facility. Chemicals with low pH can increase corrosion risks, promote internal pitting, and escalate elastomer degradation. They comment that CS piping was found to be experiencing severe corrosion with localized holes. Field experience indicated that most of the piping leaks were due to integrity chemicals in contact with the piping, and over 80% of all piping leaks since 2001 are attributed to accelerated corrosion attack. Lining CS tanks and piping for bulk storage of chemicals is not recommended, because any single holiday in the coating could cause product contami-


Chemical leaked at the welding joint on the tank sampling point.


Chemical spillage around the periphery of the tank.

nation and also lead to blistering and peeling of the coating.

Based on the experience at the Wafra Oilfield, CS was deemed an unsuitable material for construction of the bulk chemical facility as it led to excessive maintenance, operational disturbance, frequent leaks and unnecessary loss of chemicals, and environmental damage.

Generally, the authors say, materials selection for any project requires careful review, testing, and control so all materials can be stipulated as "fit-for-purpose" when used in chemical service. In the review, they recommend a material compatibility protocol that consists of two stages: laboratory testing for material compatibility conducted per NACE/ASTM TM0169 G0031 12A,[2] and field experience documentation. The laboratory test conditions should mimic the field application parameters (temperature, pressure, environment, etc.). Based on the laboratory results, technically unacceptable materials should be rejected and technically acceptable materials should undergo a cost review. Although the most economical material can be selected, the limitation with this approach is that the lowest-cost materials are not always the most economical over the field life of the component (i.e., small savings at the project stage can lead to high costs during the operational stage).

In terms of appropriate field service materials, Type 316 (UNS S31600) stainless steel (SS) as a material for integrity chemicals, which has a broader range of resistance to neat chemicals than CS, was successfully used at the Wafra Oil Field bulk chemical handling facility. All the chemical injection systems in the facility use Type 316 SS quills, which were found to be in satisfactory condition. Additionally, production and integrity chemicals—specifically, the potential use of aromatic solvents, amines, acids, and alkalis—should also be actively considered when selecting elastomeric seals. The best qualification for any seal or seal material is the behavior of actual working seals exposed to the chemicals under field conditions.

Because of the experience with CS, two additional chemical storage tanks and associated piping installed at the bulk chemical handling facility were constructed with Type 316 and Type 316L (UNS S31603) SS. Individual manifolds for the tanks were installed to avoid mixing the chemicals. Based on the chemical manufacturers' recommendations, the elastomer pump seal material chosen was ASTM D1418,[3] class FFKM grade (perfluoroelastomers), which is compatible with the integrity chemicals used and found to be more corrosion resistant against aggressive amines. After 18 months in service, no leaks in the new tanks or piping were noticed. A field inspection of an opened inlet line of piping spool for both tanks detected no signs of corrosion.

When determining the most cost-effective materials for a construction project, the authors conclude that it is imperative to carefully consider the use of corrosion-resistant alloys as viable materials alternatives to reduce corrosion problems, which in turn increases operational reliability while lowering maintenance costs.

Additional information on the case study can be found in CORROSION 2017 paper no. 8967, "Case History on the Selection of Materials in a Bulk Handling Chemical Facility at Partitioned Zone (Kingdom of Saudi Arabia and Kuwait)—A Case Study."

References

1 T. Kamshad, A/R. Al-Ghamdi, R.S. Siriki, M. Sabesan, "Case History on the Selection of Materials in a Bulk Handling Chemical Facility at Partitioned Zone (Kingdom of Saudi Arabia and Kuwait)—A Case Study," CORROSION 2017 paper no. 8967 (Houston, TX: NACE International, 2017).

2 NACE/ASTM TM0169 G0031 12A, "Standard Guide for Laboratory Immersion Corrosion Testing of Metals" (Houston, TX: NACE, 2012).

3 ASTM D1418–17, "Standard Practice for Rubber and Rubber Latices—Nomenclature" (West Conshohocken, PA: ASTM, 2017). MP

Cortec Corporation

CorroLogic®: A Logical Solution to Soil-Side Corrosion Challenges on Aboveground Storage Tanks!

Soil-Side Corrosion Problem

Soil-side corrosion is perceived to be a principal cause of storage tank failure and imposes a major environmental and operational challenge worldwide. With thousands of aboveground storage tanks (ASTs) installed, the MENA (Middle East & North Africa) region is a prime example. Ingress of chlorides and other corrosive species from the native soil and groundwater through the tank pad, along with the presence of bacteria such as sulfate-reducing bacteria (SRB), are believed to be the main causes for soil-side corrosion. Airborne chlorides and moisture can seep into the under-tank environment through the chime area, causing annular plates to corrode.

Treatment Methods and Limitations

Several techniques have been adopted to mitigate soil-side corrosion of AST floors, such as bituminous/oily sand, cathodic protection (CP) systems, and coatings. However, total effectiveness of these techniques, standalone or combined, has been questionable. The bituminous layer hardens and cracks as it ages, creating a corrosive environment that traps moisture and corrosive species between the underside of the tank floor and construction pad. Also, the presence of inevitable air gaps below the AST prevents the tank floor from being in direct contact with the sand (electrolyte), consequently blocking CP current at such locations and preventing uniform CP distribution on the underside surface of the tank bottom.

CorroLogic® VpCI® in Action

There is a growing industrial awareness about the advantage of introducing Cortec® Corporation's CorroLogic® vapor phase corrosion inhibitors (VpCIs®) into the tank pad. The unique ability of CorroLogic® VpCIs to protect areas that cannot be reached by traditional CP makes it an ideal treatment to be used in conjunction with CP or by itself when CP is deficient or absent. Utilizing the power of Cortec's VpCIs, CorroLogic® is able to vaporize and disperse through open areas below an AST. When the VpCIs reach a metal surface, they adsorb and form a protective molecular barrier to guard against corrosion, providing an added dimension of protection to under-tank areas.

CorroLogic® can be added to an AST in several different forms, enabling application to new or existing tanks. During construction, CorroLogic® pouches can be placed on an AST's high-density polyethylene (HDPE) liner and left to emit VpCIs below the tank surface. For in-service ASTs, a CorroLogic® Slurry is injected beneath the tank floor through the existing monitoring or leakage detection pipes or through injection pipes post-installed through the concrete ring beam. For out-of-service ASTs, CorroLogic® Powder is fogged through the tank floor into the under-tank area and allowed to diffuse.

Successful Research and Implementation

Since the successful implementation of Cortec's CorroLogic® on a 107-m crude oil tank at a major oil and gas facility in the Arabian Peninsula in 2011, research and successful implementation of CorroLogic® AST solutions have continued across the Gulf Cooperation Council countries. Owing to its flexibility and effectiveness, CorroLogic® will remain a logical choice for protecting ASTs from soil-side corrosion.

For more information on Cortec's innovative CorroLogic® systems, please visit: **www.cortecvci.com/Publications/Brochures/CorroLogic.pdf**.

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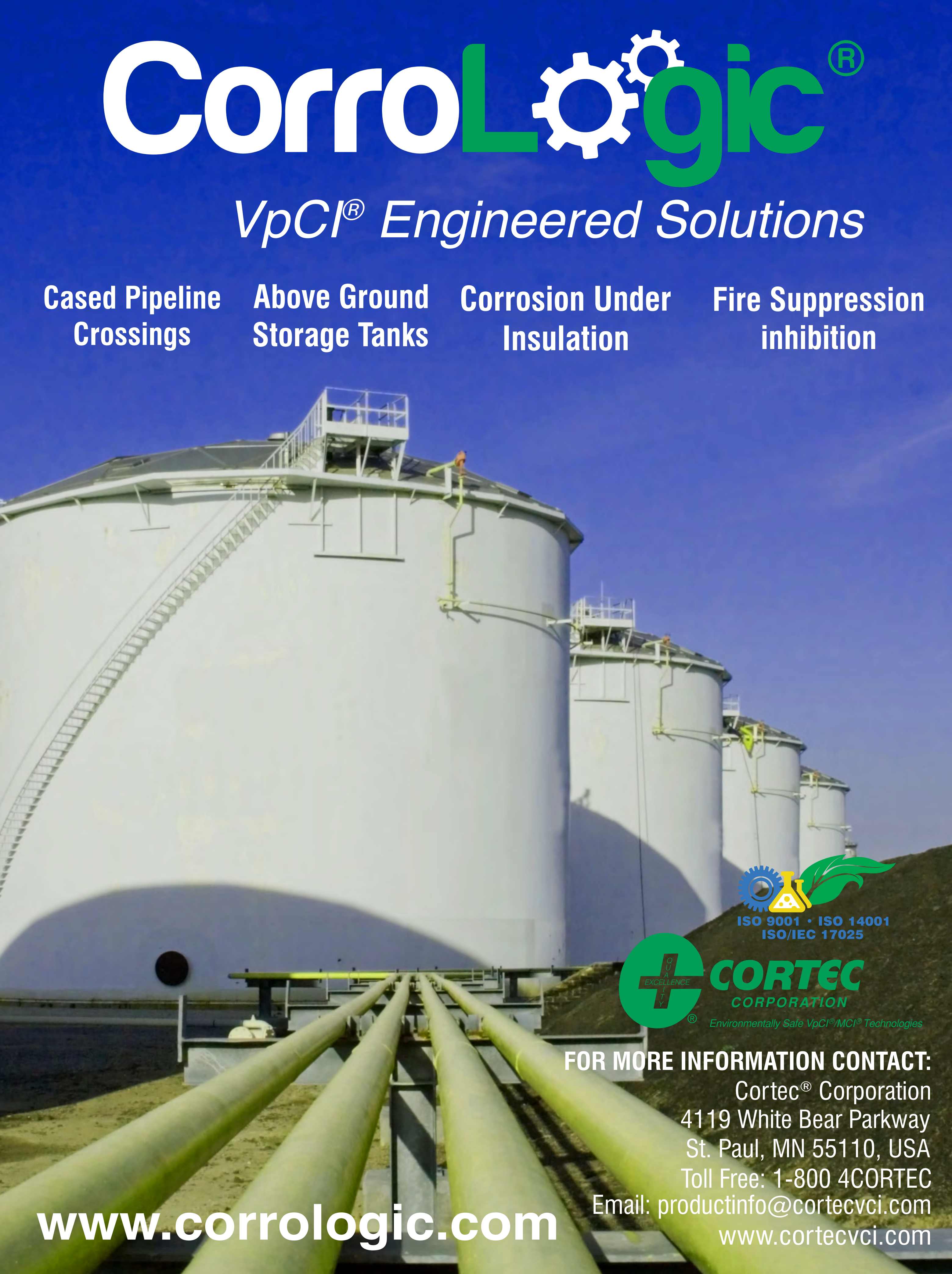
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Pond Chooses De Nora LIDA® Mixed Metal Anodes for Best Performance

Pond is a full-service A-E firm based in Peachtree Corners, Georgia. Through Pond's Energy division, the corrosion control group supports a diverse, global client base that consists of owners of both pipeline and storage assets for liquid petroleum products and natural gas. One of Pond's largest corrosion clients is the U.S. Department of Defense (DoD). In addition, Pond provides corrosion engineering services for power generation, nuclear power, water/wastewater, and the marine industries. As such, Pond's team of NACE International-accredited corrosion professionals is routinely tasked with designing and specifying cathodic protection (CP) solutions for assets where design conditions vary widely including operating environment, electrolyte resistivity, coating quality, and CP current demands. As such, Pond regularly chooses DeNora LIDA® mixed metal oxide (MMO) anodes as our go-to anode material of choice, and LIDA® is a name that we trust.

Bryan Evans, Pond's Vice President of Corrosion Control, attests to the quality and value that LIDA® anodes provide for our clients. "In my twenty (20) plus years in the corrosion industry, I have witnessed the industry evolve from graphite and cast-iron anodes, and more to mixed metal oxide anodes in the recent past." Having previously worked for a LIDA® anode distributor, Evans had direct responsibility for overseeing product manufacturing, including the quality control testing associated with each LIDA® anode. "I understand the manufacturing process, and truly feel that the LIDA® products are a superior material. I have a high degree of confidence that the LIDA® anodes will not fail prematurely if manufactured and installed properly."

Pond regularly challenges the design team to provide the most cost-effective corrosion control solution for clients. During the design process, Pond engineers are required to make critical design decisions to ensure specified materials will perform in a variety of environments around the world. Pond's clients rely on the design team to recommend and/or supply products that will perform at a high level in harsh conditions. It is critical to Pond that any materials provide dependable product performance for many years, and yet at the same time are easily installed. Pond finds that LIDA® anodes meet these rigorous project requirements for our clients over and over again.

As an installer, Pond uses LIDA® anodes for their ease of installation, high current output compared to other materials, long life expectancy, and product quality. Pond recently completed a CP installation for the DoD at a remote location outside of the continental U.S. Through the design evaluation, the project team determined a need for a lightweight anode material that would provide high current demands in the very corrosive coastal area. The project materials were transported via container ship from the U.S. to the remote project location. With the product durability that LIDA® MMO anodes provide, Pond was not concerned with a heavy brittle material, and having the anodes show up damaged, which in turn would delay project completion. In addition, the lightweight titanium substrate saved the client a great deal of money in freight costs and eased the installation. The CP system installation was successfully completed on time and ahead of budget with the current output we expected to achieve.

As we look forward, and as the needs for corrosion control within the industries we serve continues to grow, Pond expects our client needs for LIDA® anodes to grow proportionately. Pond looks forward to a long working relationship with DeNora, and the quality and value their products provide to our clients.

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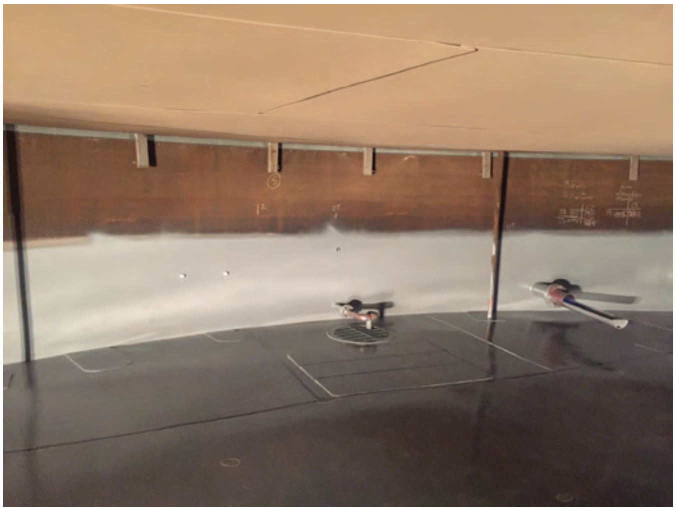

Tank and pipe lining products to protect your tanks inside and out. Archco linings and coatings are designed specifically to protect steel and concrete surfaces from aggressive environments. Denso provides a multitude of tank/pipe lining systems for different temperatures and environments to protect against corrosion for tanks, internal pipe, exchangers, knock-out drums, chime areas, bund areas, pressure valves, pressure vessels, and more. The coatings and linings will protect against crude oil, seawater, waste water, fuels, solvents, lubricants, and acids. In business for over 135 years, Denso is recognized as a global leader in corrosion prevention.

Case History

A large U.S. oil pipeline, storage, and transportation company had been experiencing numerous coating failures with their existing internal tank linings and was looking for a solution. The decision was made to switch to the Denso Archco 400 as a primer and Archco 476P as a topcoat, due to excellent chemical and high-temperature resistance that these linings provide. Other key factors that played into the decision to switch to Denso were the company's success with several other Denso buried pipeline coatings and the valuable technical service provided by Denso.

The internal tank floor and two feet up the sidewall were blasted to a near white finish (NACE No. 2/SSPC SP-10). The Archco 400 primer, which is a two-part epoxy with superior wet-out properties suitable for sealing heavily pitted floors, was easily sprayed with a single leg (68:1) airless spray unit. The following day the Archco 476P was applied using a plural component airless spray unit. This allowed the tank to be returned to service very quickly (8 hours at 75 °F/23 °C). The Archco 476P is a 100% solids, two-part, high-temperature resistant, epoxy phenolic-novolac system designed for internal tank linings. The owners can expect a service life of 20+ years with the Denso Archco Tank & Pipe Lining Systems.

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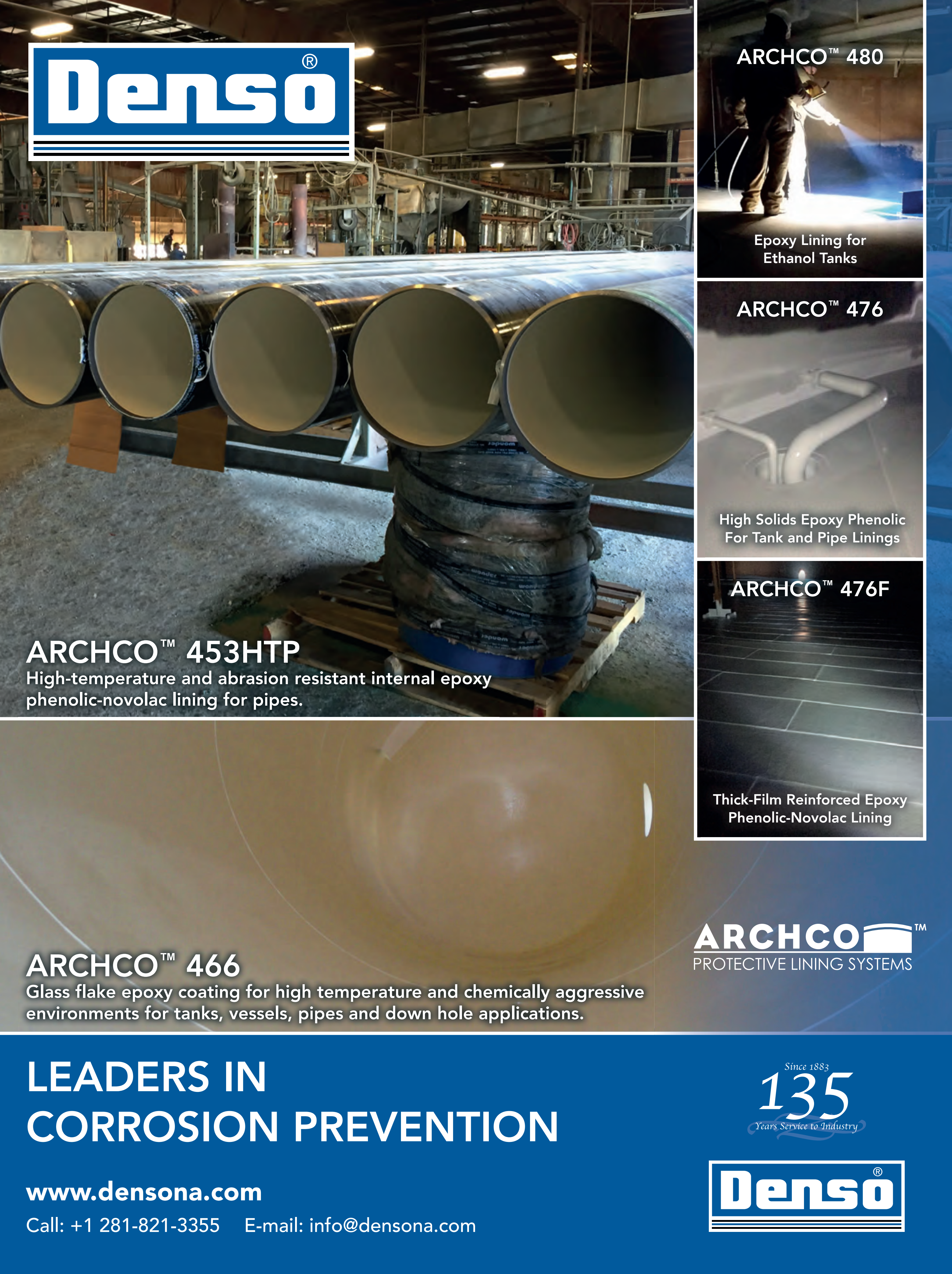
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For People Who Read the Articles

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- Total corrosion control system design, engineering, installations, and maintenance
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- Underground piping CP system design, engineering, installations, and maintenance
- In-service mitigation of corrosion under insulation (CUI) with Corrologic™ corrosion inhibitor systems
- Real-time corrosion rate monitoring systems

Corrosion Control Solutions Utilizing VpCI®

MESA and Cortec Corp. bring a unique solution to control corrosion of ASTs and other types of assets. Cortec Corp. is the world's leading manufacturer and distributor of VpCI® products and technologies. VpCI® products are used in a wide variety of applications and are environmentally friendly. Various solutions offered by MESA that incorporate VpCI® technology include:

- ASTs of all types, with both in-service and out-of-service systems available
- Real-time corrosion rate monitoring programs
- CUI for pipelines and vessels
- Corrosion control during hydro-testing of pipelines and vessels
- Corrosion preservation of all types of equipment during layup and storage

CorroLogic™ VpCI® System for ASTs

Over 30 years of corrosion inhibitor research, combined with many AST field installations, provide assurance and confidence that the CorroLogic™ Systems for ASTs are effective. The Corrosion Solutions group of MESA is authorized by Cortec Corp. to exclusively provide the CorroLogic™ Systems for ASTs in the United States and Canada. The enclosed interstitial spaces below AST floors provide the perfect environment for effective corrosion mitigation with migrating corrosion inhibitors. MESA offers CorroLogic™ VpCI® systems for ASTs custom-engineered for any type of service.

- **CorroLogic™ Corrosion Inhibitor Packet Strip System**—Cortec VpCI® powder is packaged in Tyvek packets that are connected in 50-foot long strips. These strips are installed under tank floors before the tank pad sand is applied.
- **CorroLogic™ Thru-the-Floor System for Out-of-Service ASTs**—Cortec VpCI® powder is mixed with water and pumped through temporary ports installed in the tank floor. This provides excellent distribution of the corrosion inhibitor under the floor and an aggressive treatment of active soil-side corrosion.
- **CorroLogic™ System for In-Service ASTs**—A special process is used to install a network of perforated PVC pipe through the sand tank pad inside the interstitial space. Cortec VpCI® powder is then mixed into a solution and pumped through the injection pipes for distribution throughout the interstitial space.

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Corrosion Monitoring of Aboveground Storage Tanks

Corrosion related failures in aboveground storage tanks (ASTs) can be catastrophic both environmentally as well as financially.

In order to reduce this risk, a number of solutions can be implemented during construction, including coating, special foundation design, liners, different cushion materials, inhibitors, cathodic protection (CP), etc.

Effective monitoring of the conditions experienced by tank bottoms can highlight risks associated with corrosion and provide an early warning system allowing for preemptive mitigation, while regular monitoring can ensure that preventative measures remain effective.

Monitoring hardware is often only installed in applications where tank bottoms are protected by means of CP and is used for the measurement of tank bottom potential.

However, depending on the environment and other external factors, such as AC interference, potential (ON & OFF/IR-free) alone is not necessarily a good indicator of the likelihood of corrosion (or coating degradation indicated by increased current required to maintain a potential). This is due to the nature of a tank farm environment: it is possible that the conditions under the tank change over time (contamination, new construction, etc.).

As such, measurement of the corrosion rate at a certain potential/current output can be indicative of changes in the environment and can highlight the requirement for additional investigation such as soil sampling to check for contamination, etc.

The corrosion rate at different points under a tank can be used as an early warning system for leaks due to external corrosion. Depending on the product contained and the tank history, the frequency of tank bottom thickness and other surveys may be reduced if an accurate history of corrosion rate is maintained.

The measured corrosion rate is perhaps the most useful parameter in checking the status of a tank bottom "at-a-glance." It can be used in applications with or without any form of corrosion protection (inhibitor, coating, etc.) as an indicator of corrosion risk. It is also a good tool to use in the reporting of the status to non-experts in the field of corrosion/CP as it is a physically relatable measurement and can easily be compared to the tank bottom thickness and the design life of the tank.

Coupling measurement of corrosion rate and other electrical fingerprints (DC & AC potential, DC & AC current densities, spread resistance, and IR-free potential) yields an extremely powerful and versatile tool in the fight against tank bottom and other submerged structure corrosion.

The MetriCorr solution includes WebService presenting and storing data online for the client's exclusive use. Data can be uploaded automatically using remote monitoring devices or manually uploaded. Once on the WebService, data can be viewed, treated, stored, and downloaded using an intuitive, user friendly interface.

Contact MetriCorr for your corrosion monitoring needs.

FRP ASME Section X vs. ASME Section VIII Steel Tank

Why do some equipment design engineers in corrosive environments prefer steel alloys for material of construction over fiberglass reinforced plastic (FRP) for tank and pipe fabrication? This mindset could be attributed to limited education, exposure, and experience by these engineers regarding the benefits of fiberglass composite design and fabrication. Thorpe Plant Services has innovated solutions regarding engineering design build for both atmospheric and pressure tanks using FRP for both short- and long-term economic benefits.

FRP has many benefits vs. steel alloy fabrication. FRP materials offer long-term corrosion resistance both internally and externally. They are terrific in most acid, caustic, brine, chlorine, and wastewater streams. When chlorides are present, the fiberglass composites will outperform any stainless steels from corrosive attack. FRP has excellent tensile strengths, which offer outstanding structural characteristics from a design standpoint. FRP tanks and piping are lightweight in comparison to steel tanks, therefore often allowing engineers to reduce the structural steel support requirements. This can lower overall construction costs and offer cost savings in crane lifts and freight.

Fire retardant resins can be used to meet flame spread and smoke generation requirements. FRP used in outdoor environments are designed using gel coats or UV inhibitors on the exterior layers. This offers excellent performance vs. painting for long-term maintenance performance, when combatting UV and other environmental attack. Finally, all fiberglass composite systems can be easily repaired to extend their life cycles. Results can vary, depending on process conditions, but customers should reasonably expect 20 to 40-plus year life cycles. These types of engineering and economic benefits are being offered by Thorpe Plant Services with 30 to 50% savings vs. other metal alloys.

Thorpe Plant Services is one of only two companies that are dually accredited in both ASME RTP-1 (up to 15 psi) and ASME Section X Class II (up to 250 psi) for FRP vessel fabrication. In fact, Thorpe was the first company in the world to be successfully qualified for ASME Section X Class II fabrication. We have successfully maintained the certifications since 1991. Additionally, in 1975 we developed and patented ring oblation technology that allows for shop fabrication and field erection of vessels up to 57 ft in diameter. This technology is still a widely accepted means of installing high-capacity FRP vessels.

- Thorpe Plant Service—A Leader in Composite Fabrication and Field Services for your Corrosion Environments!
- ASME RTP-1 and ASME Section X Code shop
- 400,000 ft^2 of indoor fabrication at three facilities
- Wide range of tanks sizes from 2 to 100 ft in diameter
- FRP ablated tanks from 18 to 57 ft in diameter
- Large field filament wound FRP tanks up to a 100-ft diameter
- Fiberglass fabrication using both filament wound and contact molded methods
- Fabrication of FRP piping and duct systems
- Dual laminate pipe, duct, and tanks
- Large, safe, skilled work force
- Experienced technical staff: engineers, designers, planners, QA/QC, project managers, and safety team
- Wide range of comprehensive material offering for your most corrosive environments

As a leader in fiberglass composite fabrication for both tank and piping systems, we can offer a "single source" approach with our field services. Please feel free to visit our web site: www.ThorpePME.com for further details on fabrication and field service capabilities. Remember there are three keys for a successful project: 1) proper engineering/design and scheduling, 2) proper material selections, and 3) safe, skilled craftsmen.

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Thorpe Plant Services, Inc. is proud to present STRAND® fiberglass reinforced plastic tanks and products. The world's leading manufacturer of custom FRP tanks and products with over 400,000sf of manufacturing space across the USA. Thorpe utilizes state-of-the-art engineering software, materials, equipment, and design principals, as well as industry leading QA/QC procedures, to meet growing process and environmental demands from both public and private industrial clients for the most corrosive environments.

Why FRP Tanks?

- **Major components shop fabricated**
  - *Ring oblation up to 57′ diameters for shipping*
  - *Shop controlled conditions*
- **Economic benefits over field install alloy tanks**
  - *Less freight*
  - *Reduced crane needs*
  - *Faster to erect/install, shorter turnaround*
  - *Minimize field crew size and time on site*
- **Safer to assemble than steel tanks**
  - *Top down construction, minimal elevated work*
  - *Minimize on site chemicals, virtually no VOC's*
  - *Hot work permits are not required*
- **Less maintenance**
  - *Corrosion resistant throughout the FRP structure*
  - *Exterior paint not required – no "UV" derogation*
  - *Easy to repair if damaged*
- **Good insulator on temperature and static electricity**

Thorpe Service and Product Offerings

- **Turnkey FRP Specialists**
  - *Engineering and Design*
  - *Field erect/install*
  - *Manufacture*
- **Developer of oblation technology (Patented 1978)**
- **Dually accredited**
  - *ASME RTP-1*
  - *ASME Section X, Class II*
- **Custom designs**
- **Tanks, pressure vessels, scrubbers, piping, ducts and structural components**
- **Shop and field erected FRP vessels, piping, ducts and equipment**
- **Full line of U.S. made FRP flanges, fittings and accessories**
- **Manufactured with premium grade resins**

www.ThorpePME.com

Preventive Maintenance Can Keep Petroleum Tanks in Service

The bottom plates of petroleum aboveground storage tanks are especially susceptible to corrosion attack because of wear and tear from floating roof legs, floor flexing, or changes in the materials being stored. Taking a tank out of service to replace its flooring is expensive and time consuming, which is why some petroleum facilities are initiating preventive maintenance programs that include the use of long-lasting, high-solids, thick film epoxy liners.

"Replacing a floor is about four times the cost of applying a protective liner," according to Chris Ard, industrial market manager with Tnemec, who has visited several projects where a tank bottom was found pitted and in need of replacement. "These tanks do not have enough steel thickness to get through the next inspection cycle," Ard noted.

One ground storage tank in the Port of Shreveport-Bossier had this very issue. After a new bottom was installed and the lining was applied, the decision was made to reline the facility's remaining tanks under a preventive maintenance program designed to reduce their life cycle costs. "To lose a tank for two months because you have to replace the tank bottom is significant, whereas you can line the same tank in a week or two," added Ard.

Ranging in size from 15,000 barrels to 100,000 barrels, the refinery's tanks were coated with Tnemec's Tank Armor, a fiber-reinforced, self-priming 100% solids epoxy lining. The lining is spray-applied at 30 mils dry film thickness (DFT), then tested for hardness and holidays.

Local Tnemec coating consultant Brandon Lomasney made the coating recommendations. "With a Tank Armor lining, priming isn't necessary," explained Lomasney. "But many tank applicators will apply a holding primer, if desired and/or specified, and stripe-coat welds, bolts, and other potential problem areas."

Interior testing was performed in accordance with the American Petroleum Institute (API) 652 "Linings of Aboveground Petroleum Storage Tank Bottoms," which describes the procedures for achieving effective corrosion control in existing and new storage tanks in hydrocarbon service.

The exterior roofs and shells of each tank were also evaluated as part of the preventive maintenance program, stated Lomasney. "The roofs are exposed to direct sunlight, moisture, and coastal conditions: a very corrosive environment."

Lomasney helped evaluate the existing coatings on the exterior shell of each tank for adhesion, film erosion, and percentage of rusting to see if they were in good enough condition to be overcoated. "In the end, our recommendation was to overcoat tank walls and blast and coat the roofs."

Tnemec's advanced technology acrylic polymer, Series 30 Spra-Saf EN, was specified for use on the roofs and exterior tank

walls. Series 30 is a direct-to-metal, corrosion-inhibiting coating with dry-fall capabilities, built to reduce the potential for overspray problems on buildings and surrounding property.

Ard noted the success of Series 30 around the country. "We've seen Series 30 applied to structural steel, water tanks, pipes, and ground storage tanks, and it can be used on a wide range of substrates over aged coatings."

"Aside from Series 30, Tnemec offers a wide variety of industrial coatings depending on exposure," added Ard. "Our Tank Armor linings and our exterior coating technologies continue to evolve and help our customers protect their investments."

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2018 Deadline Nears for New U.S. Underground Storage Tank Rules

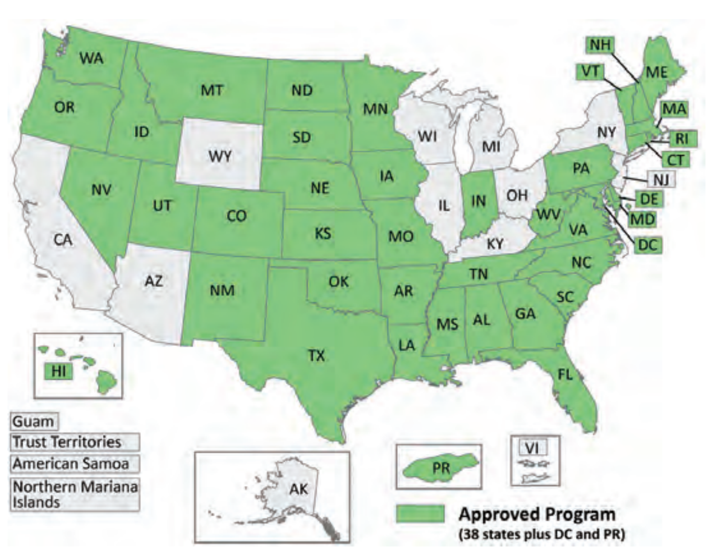
KATHY RIGGS LARSEN AND BEN DUBOSE, *Materials Performance*

The third and final deadline for underground storage tank (UST) owners and operators to meet new federal requirements from the U.S. Environmental Protection Agency (EPA) (Washington, DC, USA) for spill, overfill, and corrosion protection is October 13, 2018. By that date, UST managers must fully comply with the agency's latest UST regulations, which were effective on October 13, 2015. The final deadline of the three-tiered process comes after two prior due dates of October 13, 2015, and April 11, 2016.[1]

The exact steps UST owners and operators must take—and additionally, who they must report to in 2018 as part of the compliance process—vary based on location. In general, EPA says that because of the size and diversity of UST assets, it recognizes that state and local authorities are in the best position to oversee because they are closer to each individual situation and can set appropriate priorities. Once state legislatures enact statutes, and state agencies develop UST regulations in accordance with EPA requirements and put other components of a program in place, states may apply for formal approval, and the EPA must respond within 180 days. Each state plan is approved if it meets a range of criteria, which include the establishment of standards for eight performance criteria that are no less stringent than federal rules; provisions for adequate enforcement; and regulation of at least the same USTs that are regulated under federal standards. Once approved, states have the lead role in UST program enforcement, and UST owners and operators in states with an approved program do not have to deal with two sets of statutes and regulations (state and federal) that may be conflicting. In states without an approved program, EPA works in tandem with state officials in coordinating UST compliance.

As of September 2017, 38 states, the District of Columbia, and the Commonwealth of Puerto Rico have approved state programs. Those states must reapply to retain their approved program status by October 13, 2018. As part of that application process, the state must demonstrate "adequate enforcement" procedures and show how it enforces the technical regulations to any asset owner or operator not in compliance. In those states, UST owners and operators work with state authorities to show compliance for their asset(s). In states and U.S. territories without program approval, owners and operators must work with both state and federal authorities.

In both cases, new requirements that owners and operators must comply with by October 13, 2018 include site assessment records for groundwater and vapor monitoring, along with enhanced operator training. UST owners and operators must also conduct the first test or inspection on areas that include spill prevention equipment, overfill prevention equipment, containment sump testing for sumps used for piping interstitial monitoring, release detection equipment, and walkthrough inspections. Further details on these subject areas and others pertaining to the new UST regulations can be found at the EPA web site, www.epa.gov/ust.



States in green have UST regulatory programs approved by the EPA. Image courtesy of EPA.

UST Regulatory Background

In the United States, according to the EPA, petroleum or hazardous substances are stored in ~566,000 USTs. These USTs are located at hundreds of thousands of facilities across America. Contamination of groundwater, the drinking water source for almost half of all Americans, is the greatest potential threat from leaking USTs, which are one of the leading sources of groundwater contamination.[2] U.S. UST regulations require owners and operators to design, construct, and properly install UST systems in accordance with industry codes and standards, and according to the manufacturer's instructions. UST owners and operators must follow correct filling practices and protect their USTs from spills, overfills, and corrosion. Additionally, owners and operators must report the existence of new UST systems, suspected releases, UST system closures, and keep records of operation and maintenance.

As part of the 2015 revision, all USTs

installed after December 22, 1988 must meet one of the following performance standards for corrosion protection:[3]

- Tanks and piping are completely made of noncorrodible material, such as fiberglass-reinforced plastic.
- Tanks and piping made of steel have a corrosion-resistant coating and cathodic protection (CP).
- Tanks made of steel are clad with a thick layer of noncorrodible material (this option does not apply to piping).
- Tanks and piping can be installed without additional corrosion protection measures provided that a corrosion expert has determined that the site is not corrosive enough to cause the equipment to have a release due to corrosion during its operating life, and owners or operators must maintain records that demonstrate compliance with this requirement.
- Tanks and piping construction and corrosion protection are determined by the implementing agency to be designed to prevent the release or threatened release of any stored regulated substance in a manner that is no less protective of human health and the environment than the options listed above.

UST systems installed before December 22, 1988 also must be protected from corrosion. These USTs must meet one of the corrosion protection standards listed previously or meet one of the following upgrade options (or be properly closed): interior lining, CP, and internal lining combined with CP. Prior to adding CP, the tank integrity must be ensured using one of the following methods:

- The tank is internally inspected and assessed to ensure that the tank is structurally sound and free of corrosion or holes.
- The tank has been installed for less than 10 years and uses monthly monitoring for releases.
- The tank has been installed for less than 10 years and is assessed for corrosion holes by conducting two tightness tests—the first occurs prior to adding CP and the second occurs three to six months following the first operation of CP.
- Alternative integrity assessment: the tank is assessed for corrosion holes by a method that is determined by the implementing agency to prevent releases in a manner that is no less protective of human health and the environment than those listed previously.

Upgrading bare metal piping is accomplished by adding CP. Metal pipe sections and fittings that have released product due to corrosion or other damage must be replaced. Piping entirely made of (or enclosed in) noncorrodible material does not need CP.

UST regulations in the United States require owners and operators to design, construct, and properly install UST systems in accordance with industry codes and standards, and according to the manufacturer's instructions.

New Rules Seek Better Leak Prevention, Detection

In July 2015, to strengthen federal UST requirements so prevention and detection of petroleum releases from USTs are improved and help ensure all USTs in the United States meet the same release protection standards, the EPA made several revisions to the 1988 UST regulation and the 1988 state program approval (SPA) regulation.[4]

Changes to the regulations include:

- Adding secondary containment requirements for new and replaced tanks and piping
- Adding operator training requirements
- Adding periodic operation and maintenance requirements for UST systems
- Addressing UST systems deferred in the 1988 UST regulation
- Adding new release prevention and detection technologies
- Updating codes of practice
- Updating state program approval requirements to incorporate these new changes

As of April 11, 2016, when installing or replacing tanks and piping, owners and operators must install secondary containment, which means the tank and piping must have an inner and outer barrier with an interstitial space that is monitored for leaks, and includes containment sumps when those sumps are used for interstitial monitoring of the piping. Interstitial monitoring must be used as release detection for these new or replaced tanks and piping. Automatic line leak detectors are still required for new and replaced pressurized piping.[5]

Under-dispenser containment (UDC) for all new dispenser systems must be installed as of April 11, 2016. UDC containment is containment underneath the dispenser system designed to prevent leaks from the dispenser and piping within or above the UDC from reaching soil or groundwater. UDC must be liquid-tight on

The EPA made several revisions to the 1988 UST regulation and the 1988 state program approval (SPA) regulation to help ensure all USTs in the United States meet the same release protection standards.

its sides, bottom, and at any penetrations. It must allow for visual inspection and access to the contained components or be periodically monitored for leaks from the dispenser system.[5]

The docket for the UST regulation is EPA-HQ-UST-2011-0301-0450 and can be accessed at regulations.gov.

Corrosion Protection for USTs: An Overview

According to the EPA,[2] unprotected underground metal components of the UST system—tanks, piping, and metal components such as flexible connectors, swing joints, and turbines—can corrode, and holes caused by corrosion can lead to product releases. Corrosion can begin as pitting on the metal surface, and holes may develop as corrosion continues and pits become deeper. Over time, even a small corrosion hole can release a significant amount of product. All metal UST system components that are in contact with the ground and routinely contain product must be protected from corrosion. The two common methods used for protecting metal components from corrosion are isolating the metal component from the corrosive environment and CP.

Tank Linings

A structurally sound tank interior may be lined with a thick layer of noncorrodible material, as long as the lining material and application method comply with applicable industry codes. The lining used must also meet the same federal requirements as for repaired tanks (40 CFR 280.33). Flexible inner liners (bladders) that fit inside a tank do not meet the tank interior lining requirements. Tanks using only an interior lining for corrosion protection must pass an internal inspection within 10 years and every five years after that to ensure the tank and lining are sound. Records of these inspection results should be kept.

Cathodic Protection

A CP system—either a sacrificial anode or impressed current system—is another option for protecting USTs from corrosion. Sacrificial anodes can be attached to a coated steel UST for corrosion protection; however, the coating must be a suitable dielectric material (i.e., a coating that electrically isolates the UST from its environment and meets applicable industry codes. An asphaltic coating is not considered a suitable dielectric coating). Sacrificial anodes are more electrically active than the steel UST. Because these anodes are more active, the attached anode is sacrificed while the UST is protected. Depleted anodes must be replaced for continued corrosion protection of the UST.

An impressed current CP (ICCP) system uses a rectifier to convert alternating current (AC) to direct current (DC). This current is sent through an insulated wire to the anodes, which are buried in the soil near the UST. The current then flows through the soil to the UST system and returns to the rectifier through an insulated wire attached to the UST. The UST system is protected because the current going to the UST system overcomes the corrosion-causing current normally flowing away from it.

Federal regulations require that the field-installed CP systems installed at UST sites be designed by a corrosion expert. Within six months of installation and at least every three years thereafter, the CP system must be tested by a qualified CP tester. An ICCP system must be inspected every 60 days to verify that the system is operating. Additionally, within six months of a repair to any cathodically protected UST system, the CP system must be tested. The results of the last two tests must be kept to prove that the sacrificial CP system is working. Results of the last three 60-day inspections must be kept to verify the ICCP system is on and operating properly.

Tank Lining Combined with Cathodic Protection

Applying both an interior lining and CP is another option for upgrading existing tanks. Combining the two corrosion protection systems has several advantages: the USTs receive greater corrosion protection and the condition of the interior lining does not require periodic inspection. While these advantages can amount to significant cost savings over using an interior lining alone, the CP system must periodically be tested and inspected to ensure it is working properly. Records of these tests and inspections must be kept.

Source: U.S. Environmental Protection Agency, web site: www.epa.gov.

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Coating Inspection: Great Responsibility with Little Power

JUSTIN RIGBY, PRINCIPAL, Remedy Asset Protection

Photo courtesy of Justin Rigby.

Being a coating inspector is a rewarding career where we can share our experiences and provide the coatings industry with better quality and durability outcomes. This is especially true when we are supported by interested owners who ensure our position has authority and when the description of the work is detailed in specifications.

However, the industries we serve consist of construction and maintenance projects that have many intermediaries and specific time constraints. Often, we find our services being engaged at the last minute when all the project plans and programming have already been fixed. Even more difficult is when our services are engaged as an add-on or afterthought where we must try to catch up to the work schedule while trying to educate the team as to the importance of our role.

Often, in these situations, the project team has not realized the importance of the paint specification. So what are some tricks of the trade to get the job done right?

Authority and Workmanship

You as the coating inspector have very little authority unless you have a communication line directly to an interested asset owner. The best defense is a subtle offense. I will often describe my position as having little authority, meaning I can't stop the job to prevent poor workmanship; however, my report is a reflection of the workmanship performed. Therefore, if the applicator is doing an outstanding job, my report will be a glowing reference of such work. If I encounter many quality problems, my report will be long and descriptive, and it will reflect poorly on the project team.

An example of such a situation was when I was inspecting prefabricated steel panels for tank wall plates. I was performing an inspection of the primer coat while, without notification, the applicator was preparing to apply an intermediate coat over an inorganic zinc (IOZ) silicate. When I realized that he was mixing paint, I performed a test to check the cure of IOZ in accordance with ASTM D4752,[1] "Standard Practice for Measuring MEK Resistance of Ethyl Silicate (Inorganic) Zinc-Rich Primers by Solvent Rub." I found the primer to need further cure.

So with a full kit of epoxy already mixed, the applicator turned to me with a cheeky grin and said, "It will be alright if I just blow this kit out though?" He didn't want to waste the kit and instead wanted to use it by spraying it over the uncured IOZ. My response was simply, "I can't stop you from applying that kit, but it will be recorded in my report as a nonconformance, and the client will need to provide approval." It seems that he must have thought about the barrage of emails and explanations required because in the end he decided to sacrifice the mixed kit.

There are many standards and test methods we are asked to use that don't always ensure good workmanship, and it takes a keen inspector to identify areas of potential for poor-quality outcomes.

I had another project where I was the client's only representative. The applicator was asked to verify surface cleanliness in accordance with ISO 8502-3,[2] "Preparation of Steel Substrates Before Application of Paints and Related Products—Tests for the Assessment of Surface Cleanliness—Part 3: Assessment of Dust on Steel Surfaces Prepared for Painting (Pressure-Sensitive Tape Method)." The test is to be completed every 50 m^2 (538 ft^2); therefore, the applicator supplied four tape samples for a 2,000 m^2 (21,528 ft^2) tank floor. When I performed my inspection, I found a fine powdery layer of spent garnet over a dark-colored holding

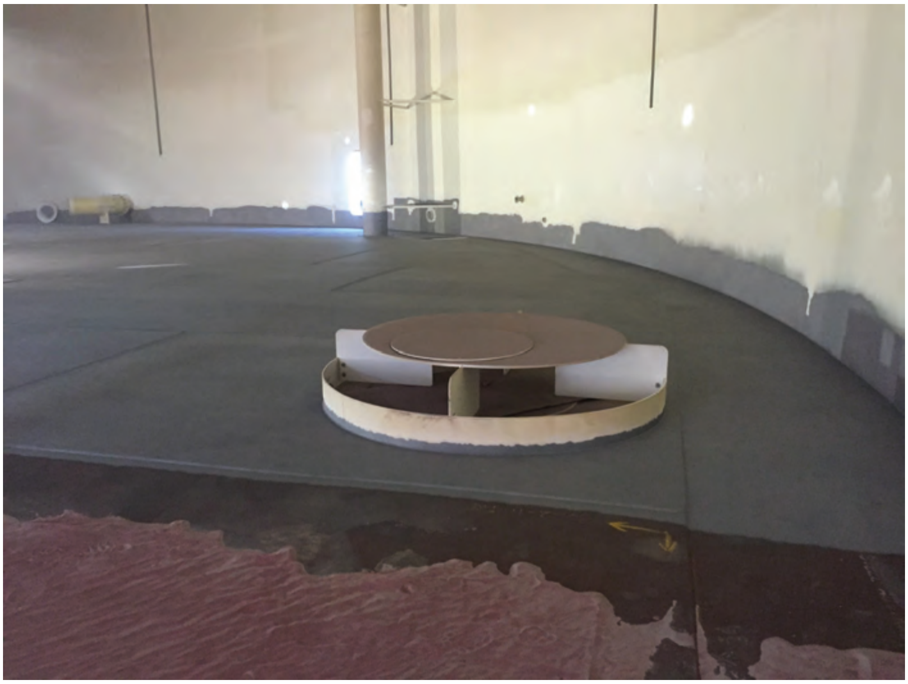

Photo courtesy of Justin Rigby.

primer that was not visible to the eye and could be viewed only when blowing the surface or at the end of each spray pass. This powder presented as fine clouds, mostly visible when crossing natural light. The specification requested a tolerance rating ≥2, which requests removal of visible dust as described in the standard but doesn't deal with nonvisible dust.

This contamination was widespread and presented a significant risk to the coating adhesion. The head contractor along with the applicator said, "The specification says we only need to supply four compliant tape tests, and we have achieved that." This situation was difficult because the client hadn't provided me with authority, and the specification didn't effectively deal with dust contamination.

I first asked the client to provide a site instruction to include the recleaning of any areas of surface dust found to not comply with the specification. Second, I asked the coatings manufacturer if it would endorse application over a powdery dust layer. The coating manufacturer's response hit my inbox before the client could get back to me. Obviously, the answer was a resounding "no." When this was confirmed via email, I forwarded it to all parties and recommended that the coating application be halted until cleanliness was achieved.

During this time, the applicator had applied coatings to 25% of the tank's floor area. I did not have the authority to prevent this work; however, through my effort, the team decided to reclean the remaining floor area.

Strictly speaking, a nonconformance was not applicable; however, all information was captured in my report for future reference, and the client responded by thanking me a few weeks later.

Excellence and Improvement

A coating inspector does not perform surface preparation, provide materials, nor apply coatings. Nor does he or she provide a warranty or guarantee of the coating performance.

Our role as coatings inspectors is to observe, inspect, test, and report. We are, however, requested to observe the project documentation and report compliance and noncompliance in accordance with the specification, standards referenced, manufacturers' data sheets, and written site instructions.

On projects where workmanship is poor, our inspection reports should include twice as much data to describe tasks performed and project difficulties. I recommend that every inspector be vigilant in providing a daily site diary of tasks performed and project difficulties, especially on projects where your authority or the specification is insufficient.

Additionally, an inspector should describe good workmanship—without endorsing coating performance—and highlight practices used to provide high-quality work.

For example, I was engaged by a client who needed to improve the quality of the coating application in order to achieve increased durability. The asset is a network of buried mild steel oil transmission pipelines in Australia. The owner had endured a history of poor applications, including runs and inclusions because the field staff culture believed it would "just get buried anyway." Each dig required the removal of existing coatings, usually coal tar enamel or two-layer polyethylene (yellow jacket), followed by nondestructive material testing of the metal surface. Once the pipe was confirmed fit for AS 2885.3,[3] "Pipelines—Gas and Liquid Petroleum Operation and Maintenance," it was prepared and recoated in accordance with the owner's specification document.

Over the course of two years, there have been 84 digs of this type, and we have been successful in providing on-site inspection of hold points. Each report has a section for "Items of Excellence" and a section for "Items for Improvement."

Items of excellence included:

- Use of canopies for protection during inclement weather
- Use of plyboard panels for flooring in each dig to
  - Keep either mud or dust from contaminating the surface
  - Provide a cleaner work environment for applicators
- Self-inspection by the applicator in between inspection points

- Completion of daily inspection forms by the applicator

Items for improvement included items of defect as well as any nonconformance items.

By providing this information, the client can provide positive feedback to the applicator or issue improvement notices.

Remaining True

Not all projects have difficulty, and even the ones that do have occurred sporadically throughout many years of work.

Regardless of the level of authority that we as inspectors are given on a project, we should aim to be approachable, forthcoming, and helpful when asked for solutions and deviations from the specification.

We must gain the trust of the client, gain respect from the project manager, and have a working relationship with the applicator.

Consider reviewing the documentation and standards before reacting. Try to avoid reacting quickly to situations, and be thoughtful and measured in your responses. Refer to associations and their networks when necessary.

An inspector's role has a great deal of responsibility that requires good people skills. When given little authority, even if you aren't a NACE International Coating Inspector, it's a great goal to remain true to the NACE Attestation, especially, "to pursue your work with fairness, honesty, integrity, and courtesy, ever mindful of the best interests of the public, your employer, and your fellow workers."

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About the Author

Justin Rigby is the principal at Remedy Asset Protection, a consultancy for clients who require specialists in protective coatings to provide expert assistance within their own team structures, including coatings project advisory and coating inspection services. Rigby has 20-plus years of experience and is a NACE Coating Inspector Program lecturer. He serves as chairperson for two of the Australasian Corrosion Association's Technical Groups. For more information, contact: Justin Rigby, info@remedyAP.com.au.

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NACE International Education and Training

NACE International offers comprehensive education, training, and certification programs to grow and enhance the careers of corrosion professionals worldwide. Most of these programs apply to tank and piping corrosion, helping operating companies comply with critical regulations and standards, effectively design and protect assets, and avoid risk to personnel and environmental liability by using trained and certified corrosion professionals. Visit www.nace.org/training-education for complete information on the following programs.

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These gateway courses are intended for individuals new to the corrosion industry and skill enhancement opportunities for experienced professionals.

- Basic Corrosion
- Basic Corrosion eCourse
- Corrosion & Protection of Concrete Structures & Buildings
- Corrosion Prevention and Control Management eCourse
- Designing for Corrosion Control
- Power Industry Corrosion Concepts eCourse

General Coatings Program

- Marine Coating Technology
- Math for the Coatings Professional
- Nuclear Power Plant Training for Coating Inspectors
- Offshore Corrosion Assessment Training (O-CAT)
- Shipyard Corrosion Assessment Training (S-CAT)
- Pipeline Coating Applicator Training
- Protective Coating Systems (PCS) 1—Basic Principals
- PCS 2—Advanced

Coating Inspector Program

- Coating Inspector Program (CIP) Level 1
- CIP Level 2
- CIP Peer Review
- CIP Bridge eCourse
- Marine Coating Technology
- Nuclear Power Plant Training for Coating Inspectors

Industrial Coating Application

- Industrial Coating Application (ICA) eCourse
  - — Module 1: Safety Codes, Practices, & Standards
  - — Module 2: Process Control
  - — Module 3: Surface Preparation
  - — Module 4: Liquid Coating Application
- Math for the Coating Professional

Cathodic Protection Program

- Cathodic Protection (CP) 1—Cathodic Protection Tester
- CP 2—Cathodic Protection Technician
- CP 2—Cathodic Protection Technician—Maritime
- CP 3—Cathodic Protection Technologist
- CP 4—Cathodic Protection Specialist
- Cathodic Protection Fundamentals: Math & Electricity eCourse
- Coatings in Conjunction with Cathodic Protection
- CP Interference
- Cathodic Protection Virtual Training Simulator

Pipeline Industry Program

- Internal Corrosion for Pipelines—Basic
- Internal Corrosion for Pipelines—Advanced
- Pipeline Corrosion Assessment Field Techniques
- In-Line Inspection
- Direct Assessment
- Pipeline Corrosion Integrity Management

Refining Corrosion

- Corrosion in the Refining Industry

MP

NACE International Standards, Reports, and Books for Corrosion Prevention of Storage Tanks

Corrosion is a leading cause of storage tank and piping failures. Government regulations often require that industry codes and standards be followed (where applicable) to ensure that a storage tank system is properly designed, constructed, installed, and maintained. For example, all U.S. underground storage tank systems must be designed, constructed, and protected from corrosion in accordance with a code of practice developed by a nationally recognized association or independent testing laboratory. Current government regulations should be reviewed to determine if a code of practice is required to be followed in order to meet regulatory requirements.

NACE International Standards

NACE No. 10/SSPC-PA 6, "Fiberglass-Reinforced Plastic (FRP) Linings Applied to Bottoms of Carbon Steel Aboveground Storage Tanks"

SP0169-2013 (formerly RP0169), "Control of External Corrosion on Underground or Submerged Metallic Piping Systems"

SP0177-2014 (formerly RP0177), "Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems"

SP0178-2007 (formerly RP0178), "Design, Fabrication, and Surface Finish Practices for Tanks and Vessels to be Lined for Immersion Service"

SP0187-2017 (formerly RP0178), "Design Considerations for Corrosion Control of Reinforcing Steel in Concrete"

SP0188-2006 (formerly RP0188), "Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates"

SP0193-2016 (formerly RP0193), "External Cathodic Protection of On-Grade Carbon Steel Storage Tank Bottoms"

SP0196-2015 (formerly RP0196), "Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks"

SP0285-2011 (formerly RP0285), "Corrosion Control of Underground Storage Tank Systems by Cathodic Protection"

SP0288-2011 (formerly RP0288), "Inspection of Lining Application in Steel and Concrete Equipment"

SP0294-2006 (formerly RP0294), "Design, Fabrication, and Inspection of Tanks for the Storage of Concentrated Sulfuric Acid and Oleum at Ambient Temperatures"

SP0298-2007 (formerly RP0298), "Sheet Rubber Linings for Abrasion and Corrosion Service"

SP0388-2014 (formerly RP0388), "Impressed Current Cathodic Protection of Internal Submerged Surfaces of Carbon Steel Water Storage Tanks"

SP0391-2016 (formerly RP0391), "Materials for the Handling and Storage of Commercial Concentrated (90 to 100%) Sulfuric Acid at Ambient Temperatures"

NACE International Test Methods

TM0101-2012, "Measurement Techniques Related to Criteria for Cathodic Protection of Underground Storage Tank Systems"

TM0174-2002, "Laboratory Methods for the Evaluation of Protective Coatings and Lining Materials on Metallic Substrates in Immersion Service"

TM0177-2016, "Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H_2S Environments"

TM0187-2011, "Evaluating Elastomeric Materials in Sour Gas Environments"

TM0296-2014, "Evaluating Elastomeric Materials in Sour Liquid Environments"

TM0497-2012, "Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems"

NACE International Reports

NACE Publication 05107, "Report on Corrosion Probes in Soil or Concrete"

NACE Publication 14D194, "Resource Materials and Services for Materials Selection and Corrosion Control in the Cargo Tank Industry"

NACE Publication 6A192/SSPC TR 3, "Dehumidification and Temperature Control During Surface Preparation, Application, and Curing for Coatings/Linings of Steel Tanks, Vessels, and Other Enclosed Spaces"

NACE International Tank-Related Books

Corrosion and Materials Fundamentals for Engineers in Wastewater Treatment Plants & Collection Systems

CorrCompilation: Coatings for Marine Vessels

CorrCompilation: Corrosion Under Insulation

Corrosion Inhibitors

Guidelines for Ballast Tank Coating Systems and Surface Preparation

Tank Linings for Chemical Process Industries

The Marine Coatings User's Handbook MP

NACE International standards and reports are a member benefit of the association. Log in to www.nace.org as a NACE member and download the documents you need at www.nace.org/store. Not a NACE member? Find out more at www.nace.org/membership.

Tank and Containment Linings

Some of the most critical uses of protective coatings involve service conditions that require the use of coatings as linings. They may be the same coatings that are used in atmospheric or underground service, but they are usually specially formulated for three specific purposes:

1) To protect the substrate (steel, aluminum, concrete, or other materials) from attack by the liquid being stored inside the tank or temporarily stored inside a containment structure

2) To protect the liquid being stored from contamination by the substrate

3) To restore structural integrity to an old tank, while meeting the requirements for protection of the substrate from corrosion and the liquid in storage from contamination

All coatings are permeable to some degree. The choice of coatings as tank linings requires a much greater knowledge of the properties of the liquid being stored and the ability of the coating to withstand permeation by that liquid than would typically be required for any coating being applied in atmospheric service.

Choosing a Tank or Containment Lining

Few project managers have an in-depth knowledge of the suitability of various tank linings when placed in immersion of aggressive, penetrating liquids. It is possible to review the product data sheets of several global scope and specialty scope manufacturers to get a general idea of which linings might work in a given situation. However, this approach is risky in that the product data sheets, of necessity, must be quite general in nature. There are three recommended alternatives that will provide choices with better chances of success in a given application:

1) Comparative side-by-side testing of candidate systems in a laboratory program that simulates, to the best extent possible, the service conditions expected in that particular tank. This takes time but can provide very good indications of a lining's resistance to permeation by a particular liquid for a given period of time at a stated storage temperature.

2) If time does not allow for comparative laboratory testing, the candidate coating manufacturers can be requested to provide their chemical suitability tables for the products that are being considered for a particular tank. Although this normally is limited to specific testing for specific time frames such as 30 and 60 days, it often provides reliable guidelines about the performance characteristics of each product. In addition, these suitability tables normally include some very valuable precautions regarding immersion based on the pH, temperature, etc., of the chemicals. Some very valuable information is normally available about cleaning chemicals, procedures, and recovery times between different cargoes.

3) Review selected case histories of tank linings used in similar services. This can be very valuable as it provides longer-term results. However, when doing so, the project tank and containment linings manager must be careful to confirm that the service conditions are truly similar to the expected service conditions. He or she must also be careful to confirm that the product shown in the case history is still formulated the same as it was when that case history was conducted. Volatile organic compound requirements have caused changes in products to achieve higher volume solids that can, and have, drastically altered the chemical resistance of some products.

This article is adapted from The Protective Coating User's Handbook, *Louis D. Vincent (Houston, TX: NACE International, 2010), pp. 147-148.* MP