The Corrosion Monitoring and Mitigation Handbook

Creating a Balanced and Effective Program for Downstream Processes

SENTRY

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Introduction

Corrosion can create deterioration within refinery pipes and systems that compromises their integrity. In the best case, unchecked corrosion can lead to process failures and downtime. In the worst case, it can be the cause of catastrophic events that endanger human health and the environment.

As crude oil types have diversified in recent years, new corrosive contaminants have entered the process. Yet many refineries have failed to update their corrosion monitoring programs to account for these changes.

This e-book presents an overview of the major factors that contribute to corrosion in refineries, the various technologies to monitor for corrosion and take corrective action when required, and best practices for establishing a balanced and effective program for continually combating corrosion.

Corrosion is the hidden enemy within refineries, silently and invisibly eating away at the interior of flowlines, transportation pipelines, vessels, water systems, boilers, vacuum towers, cooling systems, amine systems, and crude oil systems.

The Risk Is Growing

The potential for corrosion is baked into the refinery process. Unprocessed crude oil contains hydrogen sulfide (H_2S), carbon dioxide (CO_2), oxygen (O_2), water (H_2O), and microbial organisms that interact with the metals inside refinery systems to create corrosion. The excessive temperatures of some refinery processes further enhance conditions for corrosion to occur.

Changes in feedstock resulting from new extraction processes can exacerbate problems associated with corrosion. U.S. refineries are increasingly using light-tight oils (LTOs) that rely on chemically rich fracking fluids. These chemicals can end up in the crude oil stock and increase the risk of corrosion.

Another issue that can accelerate corrosion is extended operating windows and design envelopes as they can overload capacity in critical equipment, such as desalters and heat exchangers. These systems generate wastewater containing hydrogen sulfide, carbon dioxide, and chlorides, all corrosive compounds.

Corrosion has always been a problem in refineries, but current operating practices may be increasing the places in which it is occurring and accelerating its rate.

Disrupting Processes, Endangering Plants

The cost of corrosion to refineries is difficult to calculate, as many cases go unreported. However, according to a National Association of Corrosion Engineers (NACE) International study, "The global cost of corrosion is estimated to be $2.5 trillion, which was equivalent to 3.4 percent of the global GDP in 2013. By using available corrosion control practices, it is estimated that savings of between 15 and 35 percent of the cost of corrosion could be realized."

Worse than the high cost of disruption and maintenance related to corrosion is the potential for a catastrophic event. Following a 2019 refinery explosion in Philadelphia, Chemical Safety Board investigators traced the cause back to the failure of an elbow pipe that allowed flammable process fluid to escape and form a vapor cloud that then triggered multiple explosions. The elbow pipe was found to be so corroded that it was just 0.12 inches thick – about half the thickness of a credit card.

Maintaining Compliance

Regulatory requirements around corrosion in refineries are covered in the Mechanical Integrity section of OSHA's Process Safety Management (PSM) standard.

This standard requires employers to create written procedures to maintain the ongoing integrity of process equipment, train for process maintenance activities, inspect and test process equipment, correct equipment deficiencies, and perform quality assurance. Mechanical Integrity programs must address pressure vessels, storage tanks, piping systems, pumps, relief and vent systems and devices, emergency shutdown systems, and controls, including monitoring devices and sensors.

In an analysis of compliance with the Process Safety Management standard in refineries conducted in 2017, OSHA identified mechanical integrity issues in inspection, testing, and maintenance procedures and ensuring site-specific inspection and testing.

Building the Foundation

Corrosion can occur within multiple systems across the refinery and have different causes in different areas. Ensuring safe and reliable refinery operation requires a holistic approach to corrosion mitigation that identifies the places across the facility where corrosion could occur and then implements appropriate monitoring and mitigation strategies.

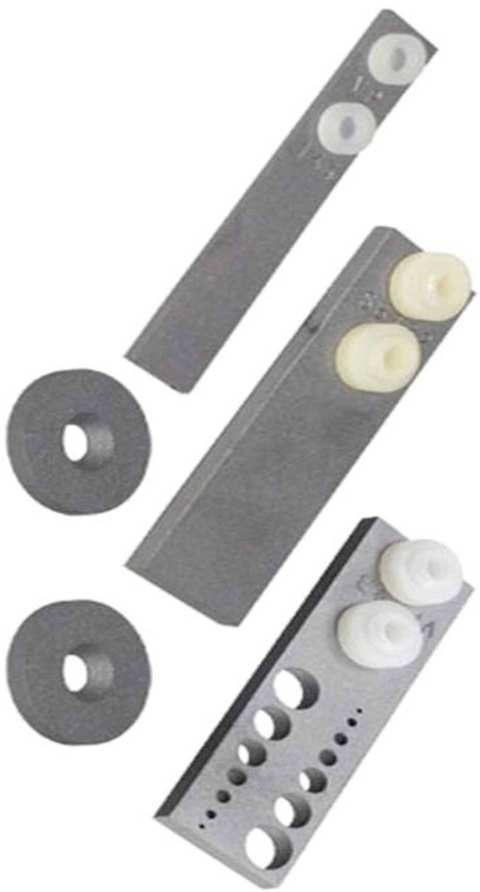
Before you develop a program, there are three important steps that must be taken to ensure its ongoing effectiveness:

1. Identify an internal champion
Corrosion is an issue that cuts across multiple departments within the typical refinery, including safety, quality, compliance, and maintenance. That can sometimes mean no single department is responsible for corrosion and the issue gets neglected. Having a strong internal champion who takes responsibility for the program is essential to establishing and maintaining an effective program.

2. Choose a qualified partner
Few organizations have the resources and expertise to handle corrosion monitoring and mitigation internally. Choose a partner that combines deep understanding of refinery processes, familiarity with the range of corrosion monitoring and mitigation strategies and technologies, and a service-oriented culture capable of working hand in hand with your organization.

3. Audit the process
Your process isn't static, so where and at what rate corrosion occurs isn't either. Subtle process changes can create changes in which corrosion risks increase or decrease. A process audit can be used to identify all of the possible locations corrosion could occur.

Corrosion Monitoring Systems



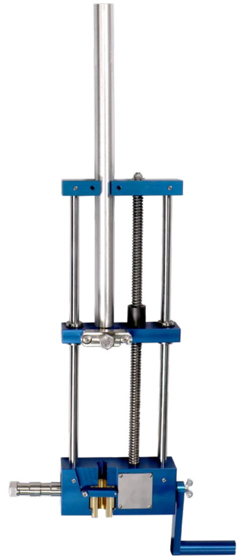
The first step in mitigating corrosion risk is a balanced monitoring program. It is typically necessary to utilize multiple monitoring technologies to support a comprehensive mitigation program. A review of available approaches follows:

Corrosion Coupons

Corrosion within a pipeline or vessel can be measured using a corrosion coupon. A weighed sample or "coupon" of the metal or alloy being measured is introduced into the system and then removed after a set time interval. The coupon is cleaned of corrosion residue and reweighed. The weight loss is converted to a corrosion rate (CR) or metal loss (ML) rate, also stated as mills per year (MPY). This process can help identify where and why corrosion may have occurred, as well as the type and rate of corrosion.

Coupons are an effective and relatively simple method for measuring corrosion within refinery pipes and systems. The requirements are an appropriate type of coupon, a corrosion coupon holder, and a reliable means of removing the corrosion residue without disrupting the metal substrate. This residue is often examined for evidence of microbiologically influenced corrosion (MIC).

Coupon holder



Insertion tool

The best corrosion coupon holders are easily insertable and retractable under pressure to allow systems to be monitored while under normal operating conditions. Corrosion coupons are also capable of monitoring for erosion, scale, paraffin, and microbial organisms.

Corrosion coupon holders generally can accommodate flat rectangular, EM style rod, disc, or flush mount style coupons. A sample probe, quill or drip pot assembly can also be incorporated with the holder to collect samples of the process product at the same point where the coupon is staged. Coupon holders should make insertion and retraction under pressure safe, easy, quick, and cost-effective. Ideally, only one insertion tool should be needed for multiple systems, and the tool should be designed to be operated by one person. They can be hand-insertable or mechanically insertable.

Mechanically inserted corrosion coupon holders should be used in high-pressure systems. They require insertion tools to easily place them into and remove them from the system without interruption of the process. To save on time and manpower, certain tool models are designed to be left in place in the pressurized system.

Electrical resistance probes

Ultrasonic probes

Real-Time Monitoring

A variety of technologies can be used to provide real-time monitoring of corrosion within refinery pipes and systems. These include ultrasonic, electrical resistance, and linear polarization. In each case, a probe is inserted into the pipe or system to support the technology. Probes may be installed permanently to provide continuous information or may be portable to gather periodic data from several locations.

Ultrasonic (UT):
UT probes use corrosion coupons but eliminate the need to remove the coupon for analysis. The probe uses a transducer to measure the thickness of the coupon. The transducer generates an ultrasonic pulse through the coupon. The resulting wavelength changes as the coupon loses metal through the corrosion process.

UT probes may be installed permanently to provide continuous information or may be portable to gather periodic data from several locations. An external data logger and interpretation software are required.

UT arrays are also available. They consist of sensors wrapped around pipes and vessels to map the wall thicknesses through an external data logger and software.

Electrical Resistance (ER)
An ER probe uses electrical resistance to measure both electrochemical and mechanical corrosion and is suited to corrosive environments with either poor or non-continuous electrolytes, such as vapors, gases, wet hydrocarbons, and nonaqueous liquids.

Linear Polarization Resistance (LPR)
An LPR probe measures only electrochemical corrosion and is most effective in aqueous solutions, providing almost instant measurement of the corrosion rate. This allows an operator to evaluate changes or monitor the effectiveness of a chemical program and make adjustments quickly based on the probe readings.

Corrosion Sampling

Sampling of process fluids for analysis of corrosive elements can be collected using a drip pot assembly or performed using stand-alone corrosion sampling panels that enable the collection and quantification of corrosion products circulating in the secondary piping of refineries.

The drip pot assembly includes a container with a corrosive resistant interior reservoir for receiving a liquid sample, and a valve assembly coupled to the drip pot. Drip pots incorporate a bleeder valve on the main chamber to relieve process pressure so the sample then can be drawn safely from the sample valve. A corrosion coupon is attached to the bottom of the assembly with a fixed corrosion coupon holder for simultaneous corrosion analysis and sample collection.

Drip pot assembly

Deploying Corrosion Monitoring Technology

A balanced corrosion monitoring program often includes corrosion coupons and real-time monitoring through probes and sampling. The key is determining the right areas to monitor while using the right technology within each area. Your corrosion partner can help you develop your specific program.

Process for Determining Monitoring Locations

1. **Do a Check with a Drip Pot**
   If you're not sure if you have internal corrosion, you can perform a quick check by creating a low spot on your system with a drip pot assembly. The drip pot will collect a composite sample of all liquids in the system, as well as a corrosion coupon and a bacteria collection device. This is also a great method for proving the effectiveness of your chemical corrosion inhibitor program.

2. **Choose Your Internal Monitoring Methods**
   Work with your corrosion partner to determine the monitoring methods that are best suited to the processes where corrosion is occurring, considering coupons, probes, and sampling.

3. **Identify Locations to Monitor for Corrosion**
   One way to identify monitoring locations is through process flow profiling. Flow profiling is used to predict where water might travel and settle out of the process fluids. Water generally accumulates lower in the system and is swept upward with the process fluids. The sweeping is velocity dependent. Therefore, profiling where the velocity will change, such as pipe diameter changes and direction of flow changes, can determine where you should monitor.

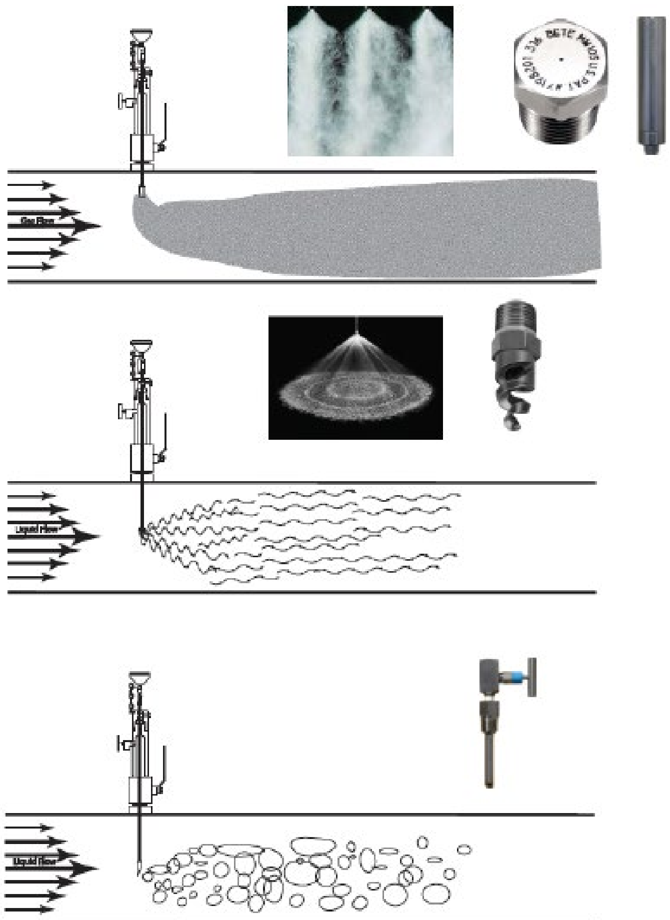
   Locations prone to corrosion that may require monitoring include:
   - Drips
   - Separators
   - Storage
   - Low Spots in the Pipe
   - Headers
   - Dead Legs
   - In Front of Damming System Components (Valves, Regulators, Orifice Plates, etc.)

4. **Determine Monitoring Position**
   Monitoring occurs horizontally or vertically and requires varied methods of measurement and devices to execute.

   Monitoring on a horizontal line requires the measurement element to be positioned close to but never touching the bottom of the line. Water is heavier than hydrocarbons, so it will settle along the bottom of the pipe. Because of this settling, you will want to position ER probes, UT probes, and coupons near the bottom on a horizontal line and mount them from the 12:00 or 6:00 o'clock position regardless of the process type.

   Monitoring on a vertical line, however, will require positioning the measuring element at the center of the flow. This is due to the positive process fluid movement being at the center of the pipe, away from the friction of the pipe walls. It will also account for the sweeping of any water from the last elbow below.

Corrosion Mitigation



While pipelines often use pigging to remove corrosive materials, refineries must rely on chemical mitigation. Once corrosive agents are identified through monitoring, a mix of chemical corrosion inhibitors and scavengers can be tailored to address fluid phases, operating conditions, expected flow rates, and product chemical variations.

These inhibitors are introduced into the process at appropriate locations through inhibitor dispersion/distribution systems that ensure the inhibitors are dispersed into the process in the proper form and in accurate dosages.

Inhibitor dispersion/distribution systems can be hand-insertable for low pressure applications or mechanically insertable for high-pressure systems. Be sure to choose an inhibitor dispersion/distribution system with pressure ratings that match your process requirements. Also ensure your dispersion/distribution system can be mounted in any orientation with extended insertion lengths of up to 20 feet for hard-to-access locations. It's also important to choose a system that includes features that safely and easily secure the shaft within the process in both low- and high-pressure conditions.

Creating a Balanced Corrosion Mitigation Program

Corrosion monitoring is vital to refinery safety and reliability. Determining the right locations, monitoring technologies, and mitigation strategies requires a holistic approach and expertise in refinery processes specifically related to corrosion. Working with a knowledgeable and experienced partner can ensure your corrosion mitigation program is thoughtfully developed and consistently managed.

A Better Solution. A Safer Experience.

Sentry Equipment offers the hydrocarbon processing industry safe, reliable, and effective solutions to corrosion monitoring and mitigation. We offer a range of monitoring technologies, inhibitor dispersion/distribution systems, and insertion and retraction tools that have been designed to the needs of hydrocarbon processing applications. They include unique features that ensure accuracy, safety, and reliability. Sentry also provides corrosion mitigation experts to help you design, implement, and manage an effective corrosion mitigation program.

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