White Paper

Digitally Transform Corrosion Monitoring in Refining Applications

EMERSON

In This White Paper

Uncontrolled corrosion causes loss of containment events, forcing operators to implement more conservative production regimes and costly mitigation programs. Advanced instrumentation can ensure operators have access to valuable corrosion risk data for increased plant availability, safety and profitability.

The price of fuels and other refined hydrocarbon products is a constant concern in every economy in the world, and in the recent years, refineries are being pushed into an aggressive competitive environment – where besides the price battles – the plant must ensure its profitability. To remain profitable, most refineries are studying ways to reduce costs and boost production to increase the plant margin, and one of the first points of focus is certainly the feedstock cost, which by far is the largest share of the plant expenditure. So-called opportunity crudes are often the answer to this matter; however, behind the attractive lower price, these crude types have undesirable chemical characteristics, such as high total acid number (TAN) and high sulfur content that are a threat to the plant equipment and pipework.

Processing feedstocks based on a higher concentration of opportunity crudes leads to operational challenges that must be monitored closely, especially in regard to potential corrosion. The corrosion threat increases exponentially depending on the production regime that can, in many times, change the crude diet significantly within days or hours. In those cases, traditional corrosion monitoring techniques are insufficient to ensure the operator's confidence around the integrity of the asset and often result in excessive mitigation programs and overdosing of chemical treatments.

Corrosion Risk and Impact

Corrosion can be monitored by two different basic methods: monitoring the **risk** of corrosion using sensors that will evaluate the corrosivity of the process fluid and monitoring the **impact** of corrosion by measuring the wall thickness of the plant equipment and pipework. In a comprehensive corrosion monitoring system both methods are used to complement each other, providing thorough insight of the plant health and condition of the flowing processes.

Monitoring Corrosion Risk Using Traditional Techniques

Corrosion risk can be monitored by using inline, also known as intrusive, techniques such as electrical resistance (ER) corrosion probes and linear polarization resistance (LPR) corrosion probes. These techniques are well known and have been widely used in the industry for more than fifty years. However, many operators are still following an outdated concept: offline systems, where the probe is connected to a datalogger unit positioned close by, or in some cases without any electronics. In both scenarios the operator must retrieve the data manually, which creates challenges related to exposure to hazardous conditions and additional operational cost to retrieve data. In regard to data availability, the operator can only access historical data, directly affected by the retrievable operation consistency, which sometimes is limited due to the device being located in a difficult to reach area.

Another traditional technique used to monitor corrosion risk is weight loss coupons. Weight loss coupons share some of the challenges experienced by offline probes, especially related to retrieval operations and access, along with exposing personnel to process fluid, which in most cases is at a high temperature when the coupon is being removed from inside of the pipework. The data provided by this technique is often scattered and extremely sensitive to exposure intervals consistency. It is important to note that coupons can provide additional information related to different corrosion mechanisms, therefore its use is still recommended in addition and parallel to corrosion probes as a long-term integrity tool that can be retracted after longer exposure periods to evaluate other corrosion data besides general corrosion.

Figure 1 provides an example of a corrosion risk monitoring position using a traditional technique with data retrieval interval of three months.

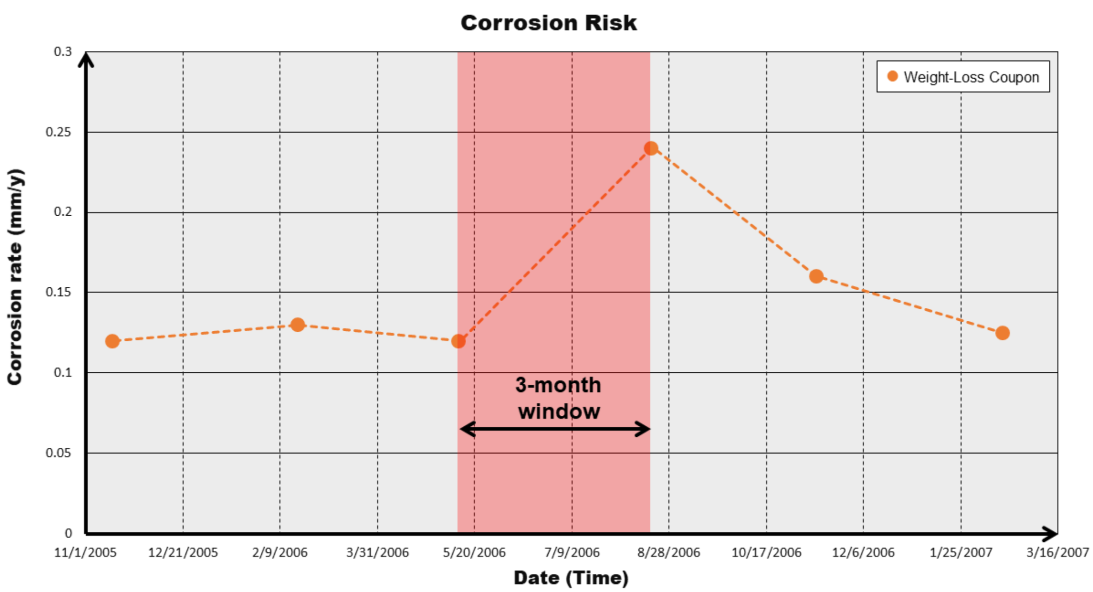

Figure 1. Traditional Corrosion Risk Monitoring

It is possible to observe a sudden increase in the corrosion risk between the third and fourth data retrieval operations, however the operator is unable to link this period of aggressive corrosion to specific feedstocks or process conditions. Unfortunately, proactive actions cannot be performed in a timely manner to prevent the asset lifespan reduction due to such events when a traditional offline monitoring technique is the only tool available to monitor corrosion risk. For such cases, a change is needed to ensure continuous data is available.

Upgrading Corrosion Risk Monitoring Using Modern Instrumentation

The key to effectively monitoring corrosion risk is having data available at the right time. This requires continuous monitoring that can be achieved by using the correct transmitter connected to a corrosion probe (either ER or LPR depending on the application) instead of the traditional dataloggers.
The transmitter will measure and process the corrosion probe electrical signals into valuable data such as metal loss and corrosion rates, then send it continuously to the plant corrosion monitoring application and historian. Due to the application nature, monitoring corrosion risk requires high sensitivity probes, therefore it is recommended to use transmitters with high resolution and digital communication protocols.

The challenge is that most digital communication protocols, such as Modbus® RTU, requires a physical media (wires) to transmit data from field to control room, which means that converting offline probes into online monitoring systems will result in increasing the plant capital expenditure (CAPEX). This is especially true if there is no instrumentation infrastructure available like junction boxes, cable racks, i/o cards, servers or even the minimum required space to run the cables or to install new servers into the control room.

Considering that a medium-size refinery has a potential of more than twenty inline corrosion probe monitoring locations, the effort and cost to make the conversion to a wired system may be high enough to discourage the operator to implement a more sophisticated corrosion risk monitoring system, however such systems can deliver considerably high value by preventing loss of potential revenue as well improving safety as the rounds for downloading data from offline systems is reduced to zero.

Figure 2 adds an online corrosion risk monitoring technique to the previous example, providing a comparison of both solutions.

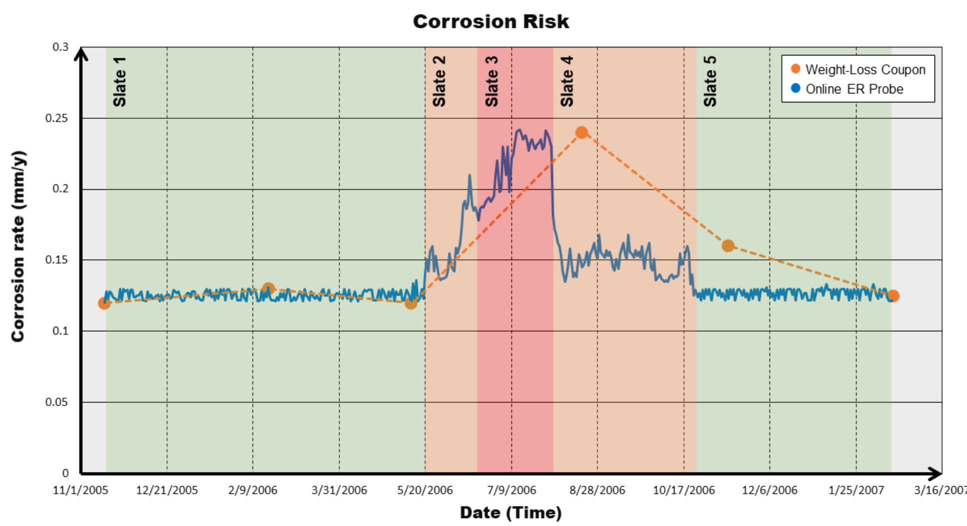

Figure 2. Online Corrosion Risk Monitoring

Previously, when using only the offline technique, the operator was not able to link the sudden increase of corrosion risk between the third and fourth data retrieval rounds to a specific process parameter. But now, looking at the plot with both traditional and online techniques it is possible to identify that different crude diets had a considerable impact on the corrosion risk. This type of insight supports informed decision making and enables proactive mitigation actions to prevent potential damage to the asset.

In this example it is possible to observe that the corrosion rate while running the Slate 1 was under control, and when the feed changed to a different crude diet based on higher concentration of opportunity crudes, it resulted in a rapid increase of corrosion risk that could be mitigated immediately using the online corrosion risk data as a solid justification. Online corrosion risk monitoring techniques also enable valuable insight into each Slate's potential for corrosion and can be used to support strategic decisions on feedstock management. So, how can the operator upgrade the plant's existing traditional monitoring system to an online and modern solution without being limited by the instrumentation infrastructure?

The return on investment delivered by any online solution is often enough to justify the upgrade, however there is a much simpler way to perform the upgrade without spending hundreds of thousands of dollars in building cabling infrastructure. The key is the use of wireless transmitters. (Figure 3). Today's manufacturing landscape is moving toward IIoT technologies, and digital wireless protocols such as *Wireless*HART® are the answer to most challenges related to infrastructure.

*Wireless*HART is a well-established open protocol widely used for monitoring several process parameters such as pressure, temperature, level, and many others. It is not different for corrosion risk monitoring and manufacturers of corrosion monitoring tools are developing transmitters based on wireless protocols to support the upgrade of outdated traditional systems. *Wireless*HART corrosion monitoring transmitters are battery powered and will send data continuously via encrypted radio signals through a mesh network that will automatically adjust the data path, so the monitoring position signal reaches the gateway antenna close to the control room and makes it available to the operator anywhere (locally in the plant or even when working in a home office, given the access to the plant network is guaranteed.)

Figure 3. Corrosion and Erosion Wireless Transmitter

To upgrade a traditional inline corrosion probe monitoring position the operator can simply replace the existing datalogger with a wireless transmitter or replace a weight loss coupon monitoring position with a new inline corrosion probe connected to a wireless transmitter. Figure 4 illustrates a monitoring position upgrade.

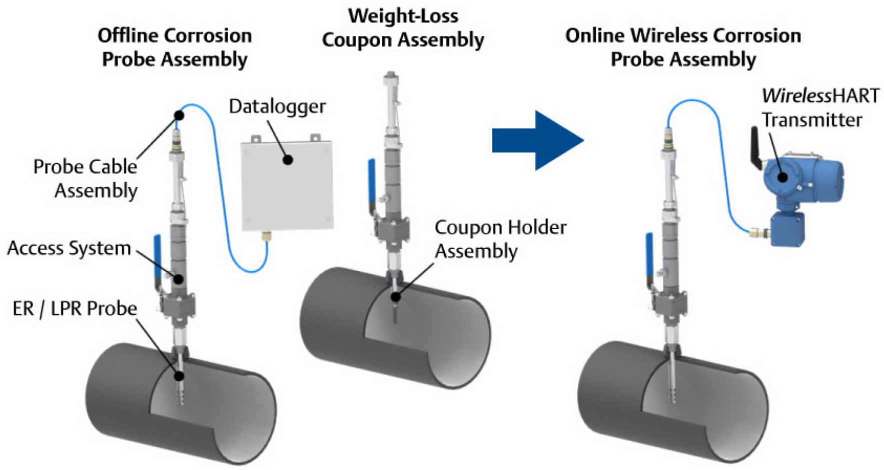

Figure 4. Corrosion Risk Monitoring Upgrade

In most cases the upgrade can be performed during normal operation without the need to shut down plant equipment or pipework given the traditional monitoring is of the retrievable or retractable type. In addition, if the plant already has a *Wireless*HART network, the upgrade is even simpler, as the new corrosion transmitter after commissioned will connect automatically to the network and will start to send data. *Wireless*HART technology is the answer for operators to obtain the maximum value of inline corrosion probes quickly and easily.

Monitoring Corrosion Impact Using Traditional Techniques

The most common technique for monitoring corrosion impact is using traditional manual ultrasound measurements to assess the actual wall thickness of the plant equipment and pipework. While this technique is well established, a full set of measurements in a medium-size refinery with more than a couple thousand corrosion monitoring points requires a considerable amount of time and is very labor intensive.

Besides time and effort, this technique presents challenges related to personnel exposure to hazardous conditions during the whole inspection round and requires a considerable amount of pre-work to ensure the inspector will have access to the metal surface intended to be monitored, which includes mounting scaffoldings and disassembling insulation. This situation adds operational costs, and often result in monitoring positions that may only be measured every three to five years, which is not an adequate frequency to measure corrosion impact with any confidence.

This technique also has other disadvantages that impact the data results considerably such as lack of repeatability. It is highly unlikely that the same inspector will be able to take consecutive measurements at the exact same monitoring point. This problem increases over time as different inspectors with different skills using different monitoring equipment can generate variations in the measurement results. Figure 5 provides an example of traditional ultrasound results taken from a nominal monitoring point over time.

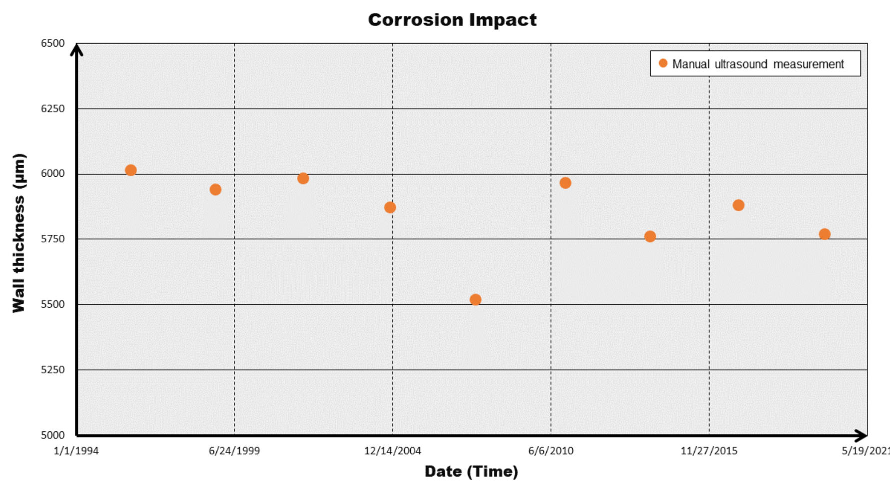

Figure 5. Traditional Corrosion Impact Monitoring

The graph shows a relevant variation between the fourth and fifth measurements, and again between the fifth and sixth measurements, which clearly indicates the level of uncertainty this technique delivers. Considering that the measurements are taken in intervals of approximately three years, the operator of the example above would raise concerns around the pipework integrity, and possibly trigger mitigation programs that may be excessive for the actual asset condition.

Using Wireless Ultrasonic Sensors to Continuously Monitor Corrosion Impact

To increase confidence around plant health status, operators can implement permanently mounted ultrasonic sensors at known hot spot areas to continuously monitor the plant equipment or pipework wall thickness with 1000 times higher frequency than the traditional manual technique. This exponentially increases operator awareness around the actual condition of the asset.

This technology is based in a compact and cost-effective sensor that, depending on the model, can be mounted on top of the monitored surface without the need to remove painting. Other models can be applied on metallic surfaces that operate at temperatures up to 600 °C (1100 °F), making this solution suitable for all critical areas in a refinery. Ultrasonic wireless sensors are battery powered and designed to be mounted in a single spot or arrays with multiple sensors depending on the monitoring needs (Figure 6). A variety of mounting techniques offers quick and easy deployment of large sensor systems, enabling scalable digital transformation.

Figure 6. Array of Wireless Ultrasonic Sensors

The sensors transmit data via encrypted radio signal to the same gateway that the inline corrosion transmitters are connected to, making an even stronger and robust wireless network. From the gateway, the data is then processed in a specific data management software that translates the raw sensor data (in wall thickness values) and then plots the measurements as a function of time, providing the operator with information on the corrosion impact trend of the specific monitoring location. Figure 7 provides a direct comparison between a traditional ultrasound measurement and the use of wireless ultrasonic sensors.

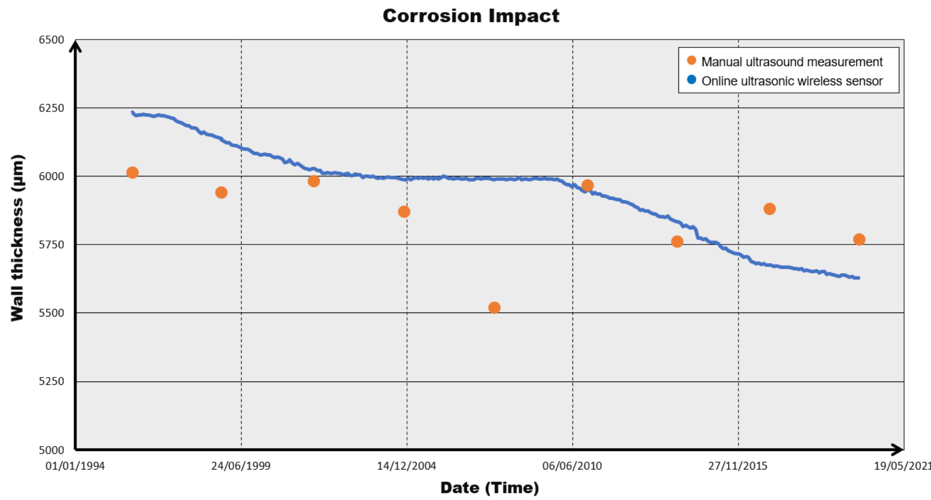

Figure 7. Online Corrosion Impact Monitoring

The graph shows a linear trend for the online ultrasonic monitoring sensor, which clearly represents the great amount of data points delivered by the system. It is worth noting that since the sensor is permanently mounted in the exact same location there is a considerable reduction in measurement variation related to repeatability, which in the case of the online system is limited only to the sensor specification and installation. The amount of data delivered aligned to the processing application provides an unmatched visualization of the wall thickness loss trend, which can be used to supported strategic decisions and enables better planning of long-term interventions.

Corrosion Monitoring Locations in a Refinery

Refineries are complex chemical plants with a range of processes and materials that provide a mixture of corrosion related issues. Therefore, selecting the correct corrosion monitoring locations is not a simple task and the operator must understand the plant particularities and pains when studying potential monitoring positions for both corrosion risk and impact monitoring.

Corrosion Monitoring Upgrade Program Starting Point

It is estimated that 80% of the refineries that have adopted online corrosion monitoring techniques started to implement the system in Crude Oil Distillation Units (CDU) and Vacuum Distillation Units (VDU), where corrosion issues related to high temperature and feedstock contaminants first appear, especially in the column bottom hot circuits and overhead systems. Challenges related to hydrochloric (HCl) acid corrosion, amine hydrochloride salt corrosion, high temperature sulfidation and naphthenic acid corrosion are likely to happen in these essential units.

Figure 8 illustrates common monitoring locations in the CDU and VDU units. Corrosion risk monitoring positions are represented by the symbol “CP” that stands for corrosion probe, while corrosion impact monitoring positions are represented by the symbol “UT” which indicates non-intrusive ultrasonic wall thickness monitoring sensors. Note that a symbol does not necessarily indicate one single monitoring point, especially for UT, where arrays and multiple spot installations may be required for the indicated location.

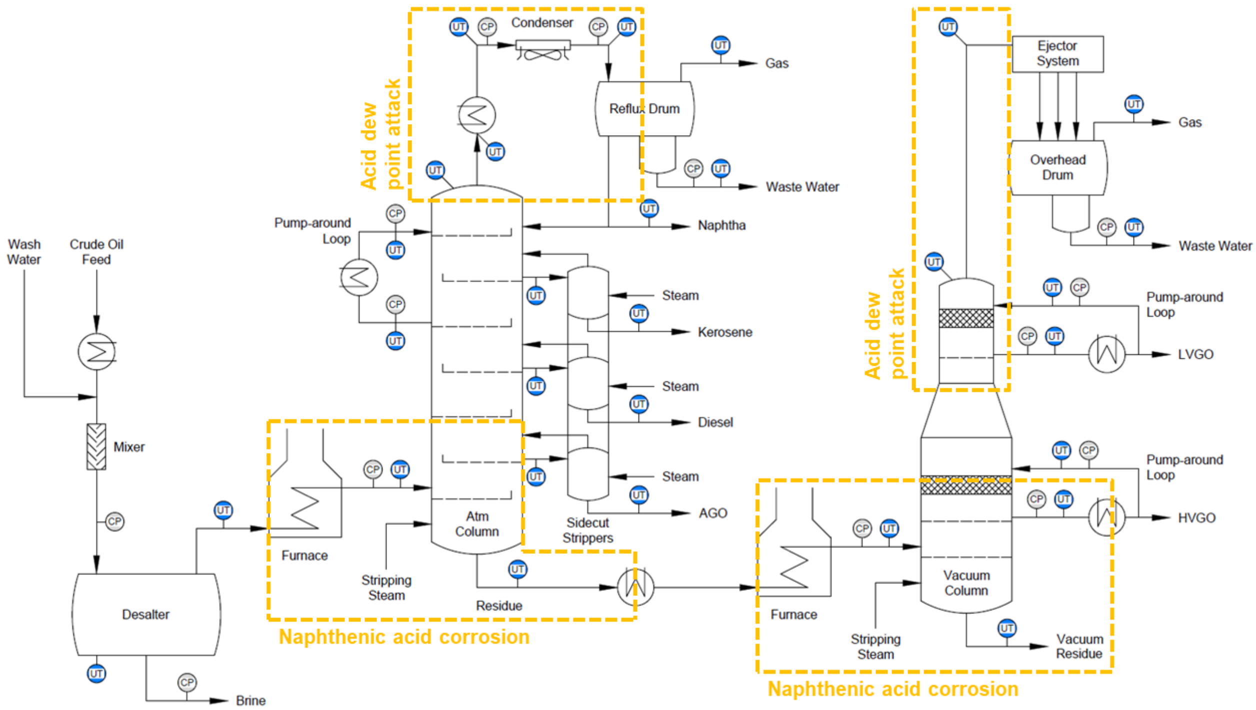

Figure 8. CDU and VDU Monitoring Locations

Some essential monitoring locations can be identified at the furnace outlets, where corrosion risk monitoring provides valuable information on the corrosion potential of different crude diets. Corrosion impact monitoring in the overheads supports the assessment of the desalter performance as corrosion events in the overhead system are greatly impacted by the desalting parameters. In a medium-size refinery’s CDU and VDU units there is a potential for an average of 20 corrosion risk monitoring positions and 300 corrosion impact monitoring points.

CDU Overhead Case Study

In a refinery located in central Europe, severe corrosion attacks in the overhead system pipework of a CDU resulted in loss of containment. As immediate mitigation action, expensive clamps to tap leak points were installed, however further action was required to prevent damages in the overhead air cooled heat exchangers located right after the affected pipework. The operator implemented online corrosion monitoring techniques where before only traditional monitoring was being used, and the continuous data delivered by the new wireless system supported the operator to identify the root cause for the corrosion event.

The data also validated process variables such as chemical injection formulation, flow rates and desalting parameters that resulted in the reduction of carry-over and considerable reduction of corrosion risk and impact, which prevented an estimated four million euros expenditure in reactive maintenance and replacement of the heat exchangers.

Other Corrosion Monitoring Locations in a Refinery

Besides CDU and VDU, there are several other units in a refinery where corrosion is a constant threat. Hydrocarbon processing units such as the hydrocracking unit, alkylation unit, amine unit and even other auxiliary units like tank farms, transfer lines and utilities are locations where corrosion monitoring is highly recommended. The operator should evaluate progressing the corrosion monitoring upgrade program in phases based on some selection criteria such as locations with record of previous corrosion incidents, locations of difficult access where manual measurements are challenging, locations where previously recorded corrosion rates have shown potential risk and other plant particularities. It is also highly recommended to seek support from manufacturers of online monitoring tools to ensure the solution and device specifications are suitable for each specific application.

Conclusion

Online monitoring of corrosion risk and impact enables knowledge-based decisions to support operators to run a refinery at its full potential, increasing uptime and safety while potentially saving millions of dollars in lost revenue and reputation costs. Monitoring corrosion risk provides early warnings to process conditions that may harm the asset, allowing for better and faster mitigation responses. At the same time, it provides valuable data to optimize process parameters and support feedstock management. Monitoring corrosion impact supports better long-term maintenance planning as it delivers complete insight into the integrity of equipment and pipework, increasing plant availability while at the same time supporting the operator to determine root cause of failures based on high density historical data and actual asset conditions. Operators can benefit from reliable and continuous corrosion data from field to desk made possible by advanced wireless technology, and it is strongly recommended to apply both monitoring methods in tandem for the most comprehensive monitoring system that delivers valuable information pertaining to asset health and corrosion status.

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