Dynamic corrosion appraisal

Monitoring time-varying corrosion with technology that inputs corrosion as a real-time process variable lets operators correlate corrosion excursions with operating and process parameters and helps manage chemical and other corrosion prevention treatments

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Corrosion severely affects refinery operations and hydrocarbon processing equipment, often leading to lost production, unscheduled downtime for maintenance or repair, even catastrophic failure that impacts on health, environment and safety. However, corrosion is commonly dealt with in a historical sense, after the damage has occurred and accumulated, and often with no knowledge of the conditions that produced it. Therefore, there is little opportunity to prevent a recurrence.

Over the past decade, the greatest advances in process control and automation have resulted from the increased availability of online, real-time data. Recent developments in corrosion monitoring technologies have increased the accuracy of data and made data available real-time, thus promoting its relevance and value to plant operators. These changes support the goal of operators to increase unit productivity. They provide a way to reduce corrosion damage, failures and unplanned outages, thus decreasing downtime and potentially increasing unit run time. Additionally, when interfaced with enterprise communications, it has also provided online connectivity for corrosion engineers, bringing them closer to and creating more value for the frontline staff responsible for process control and facility management. Under this new paradigm, corrosion becomes another real-time process variable. The corrosion measurement device now becomes the 'tachometer' for the facility showing, in real time, when processes go awry, which prompts remedial action before substantial damage occurs.

Current state of corrosion measurement

Corrosion measurement methods in use today include simple, offline techniques such as analysis of weight-loss coupons. However, this provides only a retrospective status check and average rates over long time periods rather than a means of active real-time process control. offline measurement methods also include such general corrosion measurement techniques as electrical resistance (ER) and linear polarisation resistance (LPR). These systems are usually operated in stand-alone mode providing 'spot' corrosion data via battery-powered, field-mounted instruments often with the data being logged for analysis later.

In some cases, offline LPR or ER measurements can be taken online. However, even with online systems, the data are still commonly viewed or analysed after the fact. This does not automatically include the ability to correlate the corrosion rate to specific process events. The corrosion engineer does this manually. Then, the corrosion engineer usually has to give the process engineer or manager the 'bad news' after the point when corrective action could have been easily implemented.

One example personally experienced was a case following a process change. After viewing long-term (three to six months) coupon data and inspection reports, the corrosion engineer realised that during the months since the process change, about 25% of the useful life of the unit corrosion allowance had been lost and the turnaround maintenance schedule had to be shortened resulting in repair, lost production and reduced profits.

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Real-time online monitoring

Modern field corrosion monitoring now includes a broad range of techniques (eg, LPR in combination with harmonic distortion analysis [HDA] and electrochemical noise [EN]). Techniques can be divided into two distinct groups, namely those providing indications of the cumulative damage sustained (retrospective) and those providing indications of the prevailing corrosion rate (usually online and continuous) and modality of corrosion – uniform or localised (pitting) attack.

Experience with the most commonly used online techniques such as LPR and ER indicates that they are particularly good for detecting trends in uniform corrosion rates. In this capacity, they are looked on as qualitative indicators of general corrosivity. That is to say, if the reading is going up, things are getting worse, and if the value is going down, things are getting better. These techniques are not sensitive to, nor can they differentiate between localised and uniform corrosion.

Advances in automated, multi-technique (LPR, HDA and EN) systems as

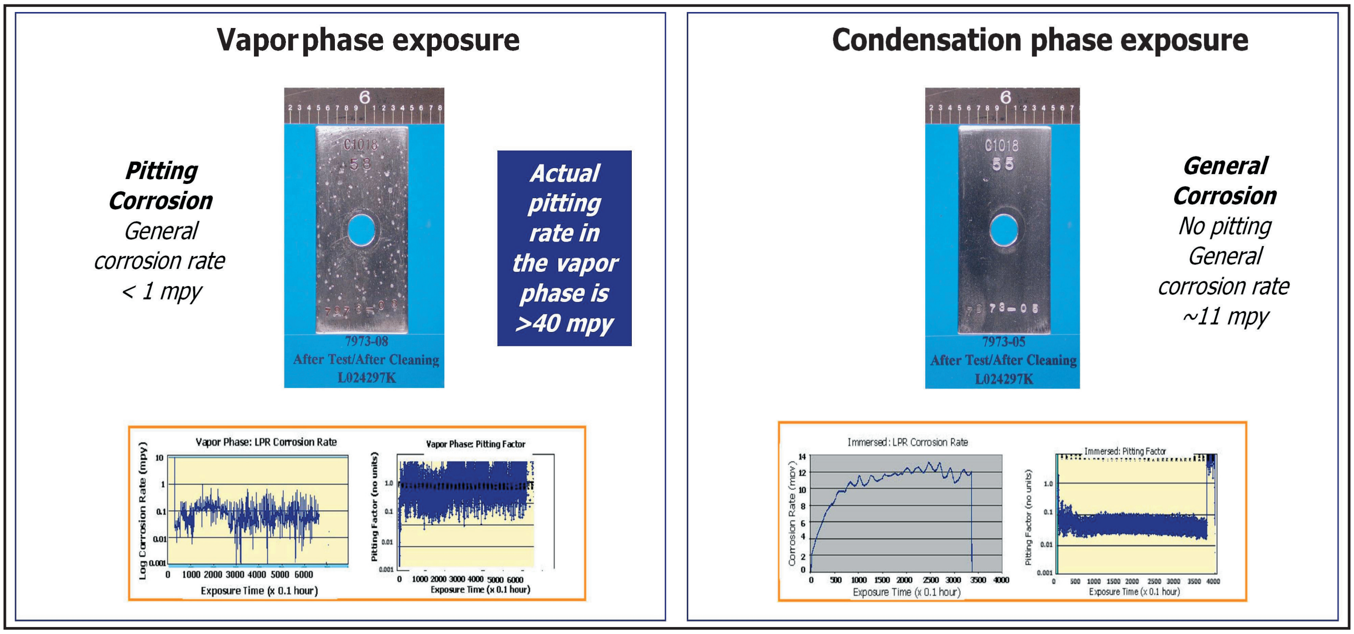

Figure 1 *Excellent agreement between coupon corrosion rates and pitting susceptibility and online corrosion monitoring data in liquid and vapour phases in gas pipeline environment*

found in the proprietary SmartCET technology have made it possible to incorporate and automate multiple corrosion measurements into a single instrument. Accuracy is therefore increased to the point of performing quantitative measurements and differentiating the onset of pitting from general corrosion, as process conditions change in a matter of minutes.

With these advances, the process and corrosion engineers can be 'plugged into' the same online, real-time data channel that is used for process control and optimisation and facilities asset management. Corrosion data can be automatically displayed with process data. The process engineer has access to the online corrosion data that the corrosion engineer sees, enabling uses of these data together as key performance indicators (KPIs). Both engineering functions can now work together in a new way[1]:

- **The process engineer:** The engineer uses the corrosion signal as another variable that needs to be optimised (eg, in order to minimise asset damage, increase production while controlling damage to acceptable levels, extend allowable run time, and manage the process to minimise inspection requirements)
- **The corrosion specialist:** With improved connectivity, the corrosion engineer can received notification of problems and provide valuable input regarding the causes and impact of process upsets immediately, rather than after the damage has occurred.

Corrosion in vapour or condensing streams

The use of online, real-time multi-technique monitoring methods has been able to provide quantitative corrosion rate trends and indications of modality in systems containing hydrocarbon gases in combination with condensed water/hydrocarbon films[2].

As shown in Figure 1, the combination of electrochemical techniques provides a complete representation of the corrosion taking place in both the liquid and vapour phases in a dehydrated gas environment containing methane, carbon dioxide and condensing water and glycol.

When compared to corresponding coupon data taken on the same exposure interval, it can be seen that the uniform corrosion rates are about a factor of ten higher in the liquid phase than in

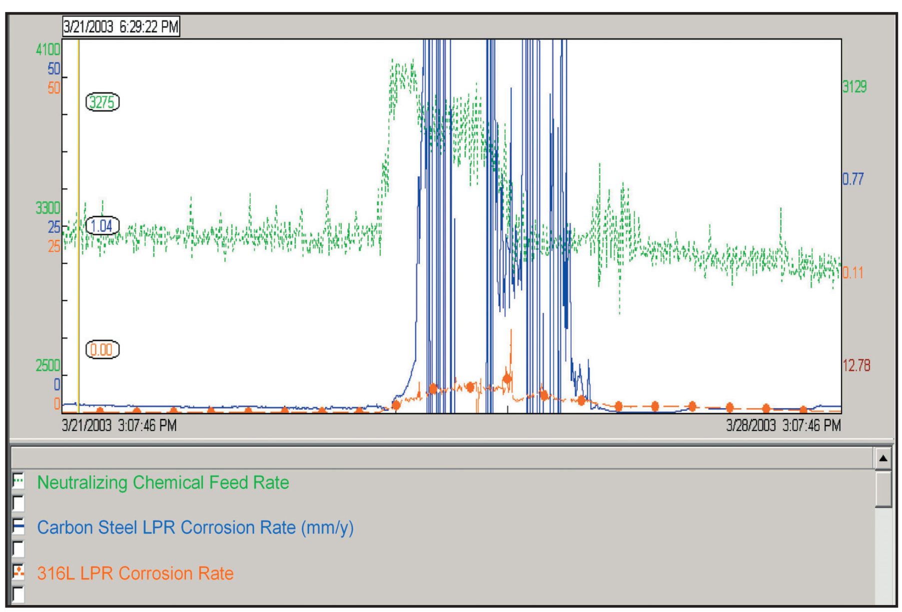

Figure 2 *Online, real-time relationship between corrosion rate and feed rate of neutralising chemicals in 98–99% organic process*

the vapour. The rates obtained by monitoring were very similar to those independently determined by mass loss measurements on the coupons, but in a matter of hours versus weeks or months for coupon data.

More importantly, the monitoring data quickly and correctly identified the mode of corrosion in the condensing vapour phase to be pitting corrosion, a critical condition that warrants immediate action. Therefore, the online data is a basis for remedial actions in real-time before substantial damage has occurred, thus minimising costly damage, repair and lost production.

Hot organic stream with 1–2% corrosive water

This example involves monitoring performed at a BASF plant where much of the plant is constructed of carbon steel, 304L and 316L. Decades of de-bottlenecking and other process modifications had produced corrosion problems. After a year of unsuccessful efforts to untangle their process problems offline, an online, real-time electrochemical corrosion monitoring system was installed. For the first time, materials engineers, process engineers, and plant operators were able to see immediate changes in corrosion behaviour caused by specific variations in process and work together to identify process modifications and remedial actions to substantially reduce damage to equipment[2].

Based on the results of the initial process evaluation that required only a few weeks, five predominant factors were confidently identified that related to the chemical aggressivity of the plant environment, which varied substantially with process and operational variables, including an upstream vessel on an automatic pump-down schedule so that it pumped its contents into a reactor approximately once per hour. Every time the vessel pumped down, the corrosiveness of the stream increased.

Operators had varied the concentration of a neutralising chemical in the process. However, contrary to what was expected, it was found that increasing feed rate of neutraliser increased corrosion rates rather than reducing them (Figure 2). This new information helped reduce corrosion rates and also provided chemical engineers with new insight into the chemistry of the process.

Having viewed the corrosion data for the first time, a plant technician pointed out that an increase in corrosion rate of the 304L occurred right after they mixed a new batch of catalyst and it varied with feed rate, which was controlled to minimise corrosive attack.

The corrosion rate also varied quite significantly with process and operational events. These included noting that the corrosion rate of carbon steel correlated with the quantity of a key gaseous chemical used in the process.

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Short-term spikes to very high corrosion rates were observed week-after-week. The corrosion rate spikes coincided with the pumping of a laboratory waste stream into the process. Operators changed their procedure and now dispose of lab samples another way, thus stopping the corrosion spikes.

The future

Clearly, corrosion behaviour in process environments has a number of influencing factors that can vary with time and result in dynamic corrosion events. Inspections and offline measurements do not afford the operator the opportunity to correlate corrosion excursions with operating and process parameters, making control a difficult proposition. This illustrates the importance of implementing an appropriate and correspondingly dynamic means of corrosion appraisal to help manage chemical and other corrosion prevention treatments, and to maximise the availability of the plant assets.

References

1 Kane, RD, Eden, DA and Eden, DC, 'Online, Real-Time Corrosion Monitoring for Improving Pipeline Integrity – Technology and Experience,' *Corrosion 2003*, Paper No.03175, NACE International, March 2003.

2 Eden, DC and Kintz, JD, 'Real-time Corrosion Monitoring for Improved Process Control: A Real and Timely Alternative to Upgrading of Materials of Construction,' Paper No.04238, NACE Corrosion 2004, March 2004.

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