Tom Mazzacavallo and Ed Kuenz, Nalco Water, an Ecolab Company, analyse how digital technology provides producers with real-time visibility, enabling them to stay ahead of fouling, scaling, and corrosion in their facilities.

Across the chemical processing industry, efficient heat transfer is critical for reliable, effective performance. Heat exchangers play a significant role in the process, controlling temperatures across reformers, cooling circuits, and refrigeration systems. When systems falter, it can cause cascading production challenges that compromise energy efficiency, damage plant equipment, and in extreme cases, shut down operations.

Traditional ammonia operations rely on periodic water tests for visibility, which measure a specific point in time and offer limited insights into asset health.

DRIVING PERFORMANCE WITH DIGITAL INSIGHTS

Indirect indicators, such as changes in pH, conductivity, or return water temperature, can suggest the development of problematic conditions but do not directly measure heat transfer efficiency to indicate how conditions may affect performance. Furthermore, periodic flow studies fail to detect performance degradation on a timely basis due to the interval between studies and variability in flow measurements.

Digital monitoring and sensing technologies offer ammonia producers continuous, real-time performance insights and visibility to manage the health and reliability of critical heat exchange assets. By applying monitoring and analytics, operators can address early signs of fouling, biofilm formation, and scaling, to address potential issues before performance suffers.

Performance risks and system stressors

Corrosion, mineral scaling, biofouling, and microbial growth are common challenges that can impact heat exchanger performance and reliability in cooling water systems. These conditions can reduce heat transfer efficiency, negatively impact equipment lifespan, and lead to unplanned downtime. For example, mineral scale precipitates at higher temperatures, creating an insulation layer that reduces heat transfer across the exchanger (see Figure 1 for an example of hard mineral scale deposits).

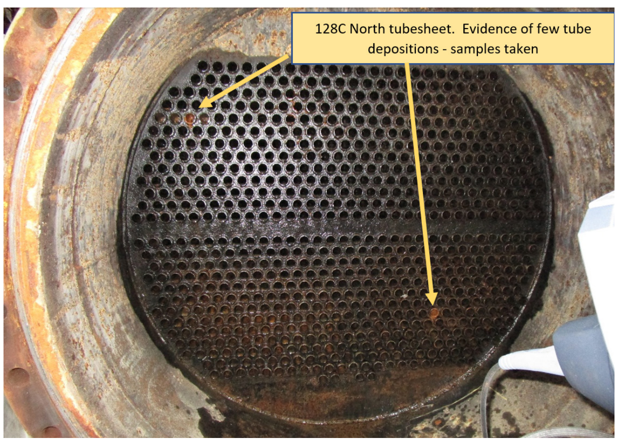

Figure 1. 128˚C tube sheet from an ammonia plant inspection showing a hard deposit restricting the flow and heat transfer within the unit.

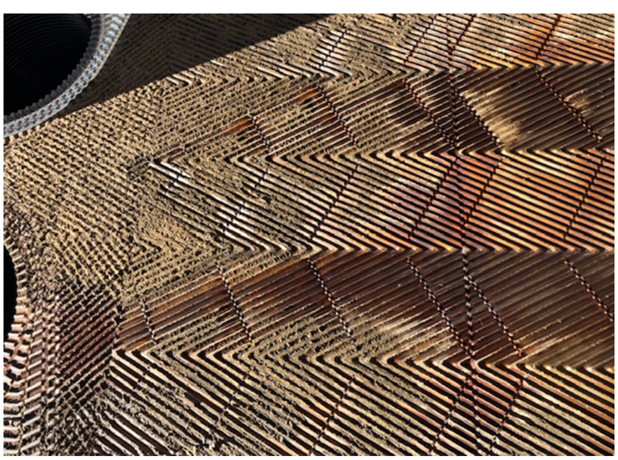

Figure 2. Plate from a heat exchanger taken apart during an ammonia production downturn. The grooves on the top of the plate are covered with a biofilm, adding a layer of thermal insulation.

As another example, biofouling can reduce heat transfer efficiency even more than a layer of mineral scale of the same thickness due to lower thermal conductance. Biofouling occurs when microbial growth in the bulk water attaches itself to the surfaces in the system and creates a film. Once attached, the biofilm starts to mature, attaching itself more firmly as it grows (see Figure 2). Biofilm creates an environment for under-deposit corrosion, which shortens the life of a heat exchanger.

To address these issues, cooling systems need proactive management that focuses specifically on heat exchanger health. Chemical treatment programmes, like corrosion inhibitors, dispersants, and biocides, help manage the underlying water risks, but operators need visibility into conditions as they shift and change. Traditional testing methods – such as weekly grab samples or intermittent flow studies – can only reflect a moment in time. Manual tests can demonstrate an imbalance, but they need additional analysis to link to a potential root cause. Without a more comprehensive view, operators may respond by over-treating a specific issue or fail to identify an issue altogether.

Variability comes from a variety of conditions. Seasonal temperature changes, variations in makeup water quality, or stressors that upset normal processes can introduce risks that may eventually impact heat transfer efficiency. Further, the type and design of heat exchangers impact the type of risks. For example, shell and tube heat exchangers, commonly found in ammonia plants, may face an increased fouling risk on the shell side due to lower water velocity. Low velocities allow suspended solids to settle, which raises skin temperatures and triggers under-deposit corrosion. Plate and frame exchangers, which are built to be compact and efficient, can have higher biofilm and suspended solid accumulation due to tight flow paths. Stressors can accumulate and impact operations without immediate evidence. To understand the issues before they cause significant performance challenges, operators need to close the visibility gap.

The critical role of digital monitoring and insights

Monitoring and performance insights can transform how ammonia operators address operational risks, shifting from reactive responses to proactive management. By supplementing chemical treatment programmes with monitoring, sensing, and analytics solutions, operators gain a full picture of their operations to optimise heat exchanger performance for efficiency and reliability.

To keep a pulse on critical health and performance indicators, fast, accessible, and targeted insights are key. When fouling and scaling conditions occur, operators need to take immediate action – like adjusting cleaning schedules or adapting chemical feeds – to minimise the impact and potential downtime. To detect issues early, operators can use critical data points, such as U-value, to measure heat transfer efficiency. By pairing U-value data with water flow conditions and other indicators, operators can gain real time and proactive insights to diagnose and address challenging conditions rapidly. Furthermore, by understanding and managing data-driven performance benchmarks, operators can anticipate how to respond to seasonal conditions or process variability.

Deposit sensor technology goes a layer deeper by helping operators understand the nature of scale build-up and fouling. Biofouling, suspended solids fouling, and mineral scaling typically occur at different temperatures. To detect and differentiate deposits, sensors need to examine biofilm growth, mineral scaling and solids deposition based on thermal gradient. By assessing deposit risks, ammonia operators can take early remediation steps like proactively adjusting biocide dosing, changing blowdown schedules, or investigating water quality conditions. Together, continuous measurement of heat transfer efficiency and deposit conditions support reliable ammonia performance in real time while enabling plants to optimise future operations.

Putting proactive monitoring and insights into practice

Case study 1: intercepting biofouling

In one example, a US-based ammonia producer aimed to increase the time between maintenance outages by one year. Heat exchanger fouling was the primary challenge for extending turnaround time, caused primarily by high turbidity in the makeup water. To address the issue, the plant attempted to optimise the water treatment chemical dosage to maximise heat transfer efficiency, but challenges persisted. They decided to implement a monitoring programme on their most stressed exchanger, the amine coolers.

Subsequently, Nalco Water deployed Ecolab® Heat Exchanger IQ™, a digital solution that continuously trends U-value, a valuable indicator of heat transfer efficiency, through measurement of water flow and multiple water and process temperatures. Four weeks after a baseline was set, the U-value showed a slow, but consistent decrease (see Figure 3).

By collaborating with the plant's water treatment team to analyse chemistry indicators, Nalco Water determined that microbial activity was at the root of the issue. Summer water temperatures and higher suspended solids in the makeup water increased biocide demand. Operators adjusted the programme to account for the variability, and the U-value recovered completely within a few weeks. The plant avoided US$150 000 for every day of production loss that would have been experienced if premature offline cleaning would have been required.

Case study 2: preventing scale to mitigate efficiency impacts

At another US plant, operators implemented Nalco Water's 3D TRASAR™ technology for cooling water with deposit sensing capabilities. The deposit sensor relies on its ability to use a single cooling water sample stream to monitor the various fouling risks at a variety of temperatures. The plant, a nitrogen producer, was already using Heat Exchanger IQ for one of their critical exchangers to monitor performance. By applying the deposit sensor's insights, the plant could

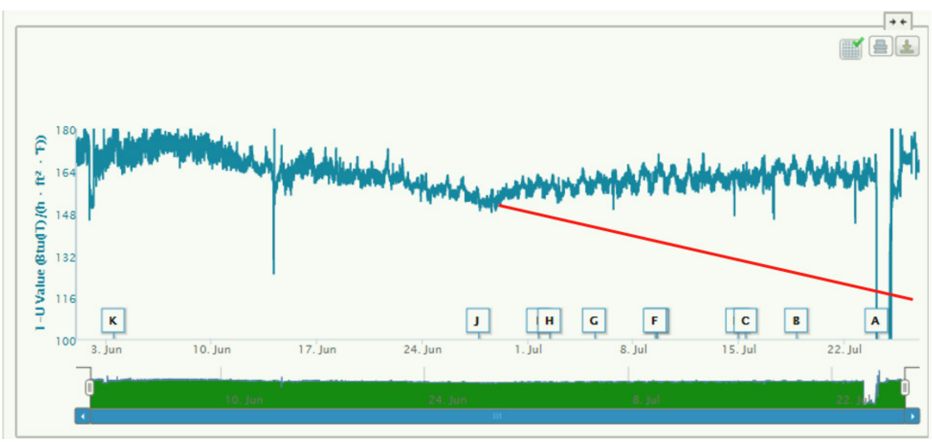

Figure 3. Graph of the U-value of the MEA cooler over time. After the trend was realised, chemical adjustments were made that helped recover efficiency.

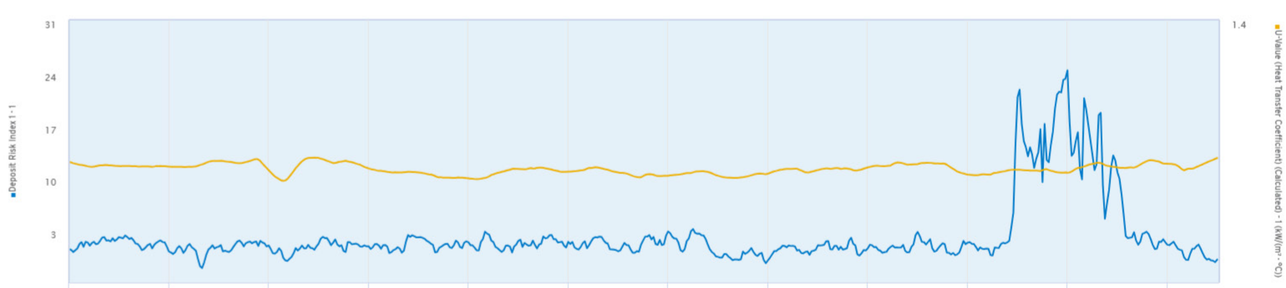

Figure 4. Graph of the deposit risk index increases indicating the scaling potential of the system. The graph also shows the Heat Exchanger IQ U-value trend that did not change during the occurrence.

recognise bulk water impacts and diagnose different types of deposits quickly.

A few weeks after deploying the deposit sensor, an alarm showed a deposit risk index increase, indicating that the system was entering an environment where mineral scale was likely to start forming on high-temperature heat exchangers (see Figure 4).

The plant immediately adjusted the scale inhibitor feed and blowdown process to enhance protection, while also investigating the root cause. Online data did not show any changes in pH or chemical control, but did indicate that the quality of makeup water may have caused an issue.

Operators determined that shortly before the alarm went off, the plant experienced a lime upset that led to high levels of calcium entering the system. They were able to take immediate action to fix the issue and return the cold lime softener back to standard performance. Once this happened, the deposit risk index slowly decreased, and the chemical feed rate also returned to normal.

An examination of the Heat Exchanger IQ data showed that no decrease in U-value occurred at the time. The plant was able to take proper action due to the early indication of scaling tendency from a bulk water sample through the deposit sensor, permitting a response timely enough that the heat transfer efficiency of their most stressed exchanger was not impacted.

Transforming the operations of ammonia producers

These case studies reflect a broader trend: ammonia producers cannot afford to wait for operational impact to diagnose issues. Producers need real time and proactive tools to:

- Extend time between cleanings and turnarounds.
- Reduce over-treatment and optimise chemical use.
- Prioritise maintenance with real-world performance data.
- Protect high-value exchangers from unseen stress.
- Improve energy efficiency and plant-wide heat recovery.

Both examples exhibit the same pattern: earlier insight leads to more effective intervention. By providing operators with direct visibility into exchanger conditions – and pairing with optimised chemical treatment programmes and expert support – monitoring technologies help enable plants to act fast, mitigate downtime, and extend asset life without guesswork.

Looking ahead

In an industry that runs hot and under pressure, downtime is more than an inconvenience. It puts revenue at risk. Digital monitoring solutions and performance insights close the visibility gap, providing operators with a reliable way to protect heat exchangers through informed, rapid action. By addressing risks like downtime and emergency maintenance, and by supporting improved reliability and optimised treatment, digital solutions enable ammonia plants to maximise performance and productivity. With the right chemistry, precision monitoring, and expert partners, ammonia plants are well-positioned to meet the future head-on. WF