Water Technologies & Solutions
case study

preventing improper boiler startups and associated costs using Sievers* TOC Analyzers

background

The Tennessee Valley Authority's (TVA) Allen Combined Cycle Plant near Memphis, TN is TVA's seventh combined cycle plant. Added in 2018, the plant contains two natural gas turbines (330 MW each), a combustion steam turbine (420 MW), and 3,000 solar panels supplying almost 1 MW. This totals more than 1 GW of electricity generation capable of serving over 500,000 homes.

The Allen plant replaced the 55-year-old Allen Fossil Plant, which contained three coal-fired units. The gas plant provides a significant reduction in emissions, making it TVA's most efficient gas fleet in 2018 (1). The plant requires 7-10 MGD (26,500-38,000 m^3/d) of water for condenser cooling during peak times (2). With pressure on production efficiency and asset optimization, any downtime is a large expense to the facility. A Total Organic Carbon (TOC) monitoring project was put in place to prevent costly damages from glycol leaks.

challenge

TVA Allen's boiler feed systems are of the same design as two other TVA facilities. Within the past year, these plants experienced a total of three glycol leaks from their closed loop cooling water systems that led to the shutdown of electricity production to maintain asset integrity. The Allen plant sought to create a proactive process to avoid a similar shutdown at its plant.

The Allen plant began examining the cooling water loops. Condensate and condensate spiked with cooling water (~35% glycol) were tested. Results revealed the contamination was caused by small glycol leaks entering the boiler feedwater pump in two possible ways, both involving faulty seals:

1. When the plant is not active, and the closed loop cooling water system is operating normally, there is a pressure difference of about 150 psi from the cooling water to the boiler feedwater pump. Glycol leaks could occur due to a defective pump seal.
2. When the plant is operating there is also the potential for glycol to leak if the feedwater pump seals are inadequate.

It is critical to identify the root cause of plant shutdown as quickly as possible to help mitigate the impact and return to normal operations.

Traditional monitoring techniques including pH and conductivity will not detect a glycol leak due to its nonionic state at room temperature and pressure. However, once the feedwater enters the system of low pressure (LP~70-80 psi), intermediate pressure (IP~300-350 psi), and high-pressure (HP~1600-1800 psi) drums, glycol oxidizes to harmful organic acids such as acetic acid. These acids cause the pH to drop quickly from around 10 to almost 5. As the water transitions from liquid to steam, this low pH condition can turn metal to molten state and thin down the walls of the piping. Furthermore, low pH conditions can force holes in the piping causing significant damage within 24 to 48 hours. In Allens's boiler investigation, it was initially thought that it would take several gallons of glycol to cause damage, but, in reality about 0.5 liters can shut down a plant (see **Figure 1**).

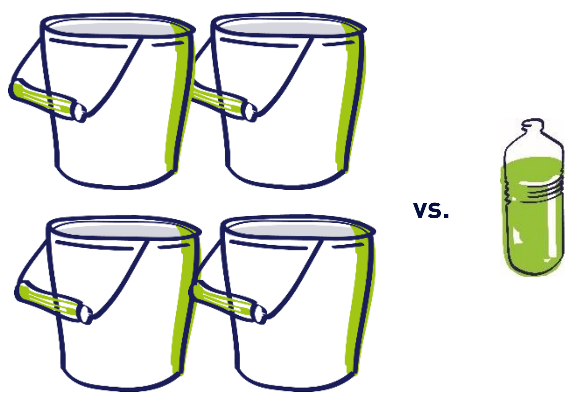
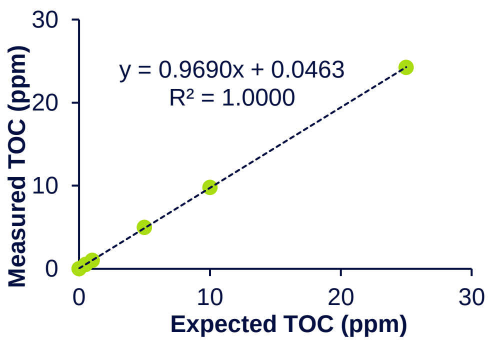


Figure 1. Perceived volume of glycol needed to cause equipment damage and pH shift (left) to the actual volume of glycol that could lead to plant shutdown and pipe aging (right).

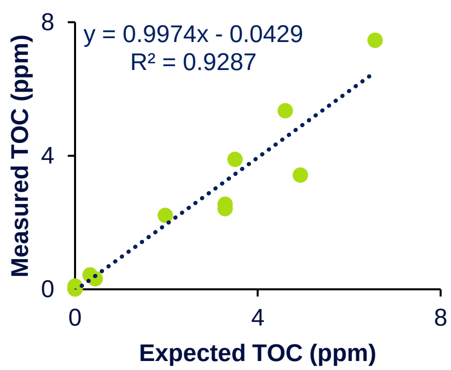
Any plant shutdown causes significant financial burden, with TVA estimating a loss of $1.7 million over a five-day shutdown. Allen's use of a backup combustion turbine helped reduce the cost due to the loss being limited to steam generation. Plants without these backup turbines could face loses of $5 million or higher depending on power generation demand at that time. Additionally, damage to equipment could lead to advanced aging of the plant, bringing costs a magnitude higher.

solution

The Allen plant deployed a sampling procedure that was rapid, accurate, and reliable for identifying glycol leaks. TOC analysis was used to measure the organic contamination. TOC directly and linearly correlates to the concentration of the glycol leak, thus can detect low levels of glycol in an ultrapure feedwater stream, as shown in **Figure 2a**. Prior to implementation, TVA conducted tests to understand the spiked glycol levels that would trigger a TOC response (**Figure 2b**).



(a)



(b)

Figure 2. (a) Previous studies completed in the SUEZ – WTS Analytical Instruments laboratory versus ethylene glycol showing recovery >97% across a wide concentration range. (b) Similar studies performed at TVA with propylene glycol.

From there, action limits were defined using a baseline of normal measurments compared to spiked results. The testing demonstrated that a leak of a few ounces of glycol would produce a TOC result of 400-700 ppb. Normal TOC levels from pure condensate were all below 100 ppb and often near 20 ppb.

A TOC analyzer oxidizes organic compounds to CO_2 and measures the evolved CO_2. There are several methods of oxidation and detection. The Allen facility used membrane conductometric detection and UV persulfate oxidation. This TOC method is used in drinking water, pharmaceutical, and semiconductor industries for monitoring source water to ultrapure water.

Testing procedures were developed to include TOC analysis and various sample checks to prevent harmful glycol leaks. This resulted in actions that operators could use for routine monitoring as well as providing flexibility to switch or shut down units. A schematic of the decision tree is shown in **Figure 3**.

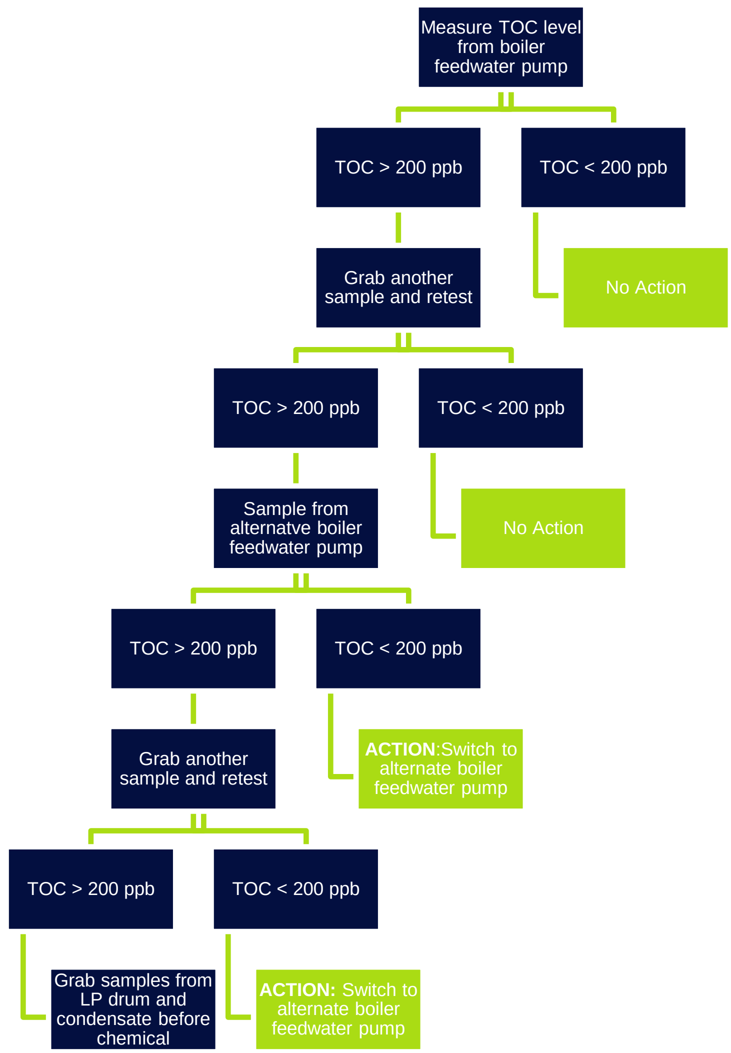


Figure 3. Decision tree of the TVA Allen plant's operational procedure for glycol detection using TOC analysis with action limits and actions to take.

Prior to startup, a sample is taken from the reservoir of the boiler feedwater pump and tested for TOC. There are two boiler feedwater pumps at the facility. If a result above trace levels is found in pump A, then pump B is tested, and will be used unless testing also yields results above trace levels. Samples are analyzed twice a day to detect any changes that might cause equipment or system damage.

Samples can also be taken from the low-pressure drum, as that would be the earlier detection point. This is used when replacing mechanical seals for the boiler feedwater pumps to ensure performance of the seal. If there is a leak found in the low-pressure, the system is rinsed and cleaned extensively to eliminate the acid and to restore high pH conditions. A full investigation of wall thinning is challenging without destructive testing. This robust procedure with measurable and repeatable TOC data helps the Allen plant monitor, detect, and prevent glycol leaks prior to plant shutdown and equipment degradation.

This testing process provides confidence in operations, with future potential for online testing to enable continuous monitoring at TVA.

conclusion

A pinhole leak of glycol can be detrimental to the integrity of plant and process equipment. At elevated temperatures and pressures, glycol can degrade to organic acids, which can acidify the stream and lead to accelerated system corrosion. While the extent of plant aging or wall thinning is difficult to quantify, plant shutdown can cost several million dollars a day in lost revenue. Unfortunately, pH and conductivity are insufficient to detect glycol leaks from feedwater pumps and do not alert operators of degradation to organic acids until it's too late. TOC proved to be the most valuable parameter for detecting glycol from low levels to high levels either in the lab or online. A change in TOC levels will indicate a glycol leak from the typical process levels.

The TVA Allen plant utilized TOC analysis for operational monitoring procedures to take actions to protect equipment and maintain plant uptime. TOC analyzers with membrane conductometric detection technology offer sensitivity for low-level leak detection as well as recovery of glycol and organic acids. This proved to be a useful tool for plant controls, with a return on investment realized upon first glycol leak detection. The action plan for glycol detection implemented at the TVA Allen Combined Cycle Plant utilizes TOC analysis to provide confidence in operation and simple insurance for equipment assets.

References

1. "Allen Combined Cycle Plant." TVA, www.tva.gov/Energy/Our-Power-System/Natural-Gas/Allen-Combined-Cycle-Plant.

2. "Allen Combined-Cycle Power Plant, Tennessee, United States of America." Power Technology | Energy News and Market Analysis, www.power-technology.com/projects/allen-combined-cycle-power-plant-tennessee/.