Using Benzotriazole for Corrosion Inhibition of Low Conductivity Water at the Advanced Light Source

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Abstract

Copper corrosion is an ongoing issue for synchrotron and particle accelerator machines requiring low conductivity water (LCW) for cooling applications. Typical corrosion inhibition methods involve deoxygenating the water in order to drive the concentration of dissolved oxygen into a "low oxygen" operating regime of 2 to 10 ppb. The addition of deoxygenation plants, however, can often be problematic at facilities that are already built-out due to their high capital costs and space needed for additional equipment. Instead of deoxygenating LCW, the Advanced Light Source (ALS) has developed benzotriazole additive as a corrosion inhibitor. Studies performed on a small-scale plant are discussed and results from dosing ALS's main LCW system are presented. Preliminary results indicate a substantial reduction in copper corrosion rates.

Introduction

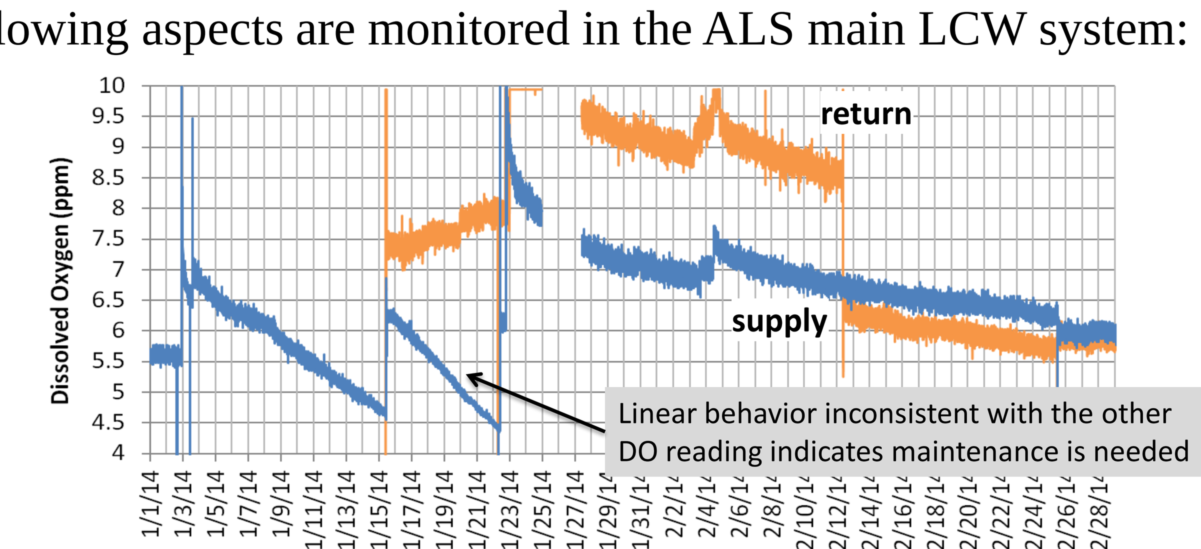
A significant portion of ALS's reliability performance is attributed to water-related issues: from 2008 to 2011, 18% of lost hours were due to water-related incidents. Evidence of black copper oxide was seen in the system and some magnet temperatures were abnormally high due to restrictions in hollow-core magnet copper conductors.

For synchrotrons and particle accelerators that need LCW for cooling, deoxygenation plants are typically used to scavenge oxygen from the water. Maintaining a dissolved oxygen concentration in the 2 to 10 parts per billion level is an effective way to prevent copper corrosion—there is essentially no oxygen in the system for corrosion to occur at an advanced rate. The ALS was not built with a deoxygenation plant, and doing so at this point is cost-prohibitive. As an alternative to oxygen scavenging, benzotriazole (BTA) additive is being evaluated as a method to reduce copper corrosion. BTA is an organic compound consisting of benzene and triazole rings. It is commonly used as a corrosion inhibitor in applications that do not require low conductivity, such as power plants and saline water systems, but has not been used in LCW applications for particle accelerators.

Monitoring

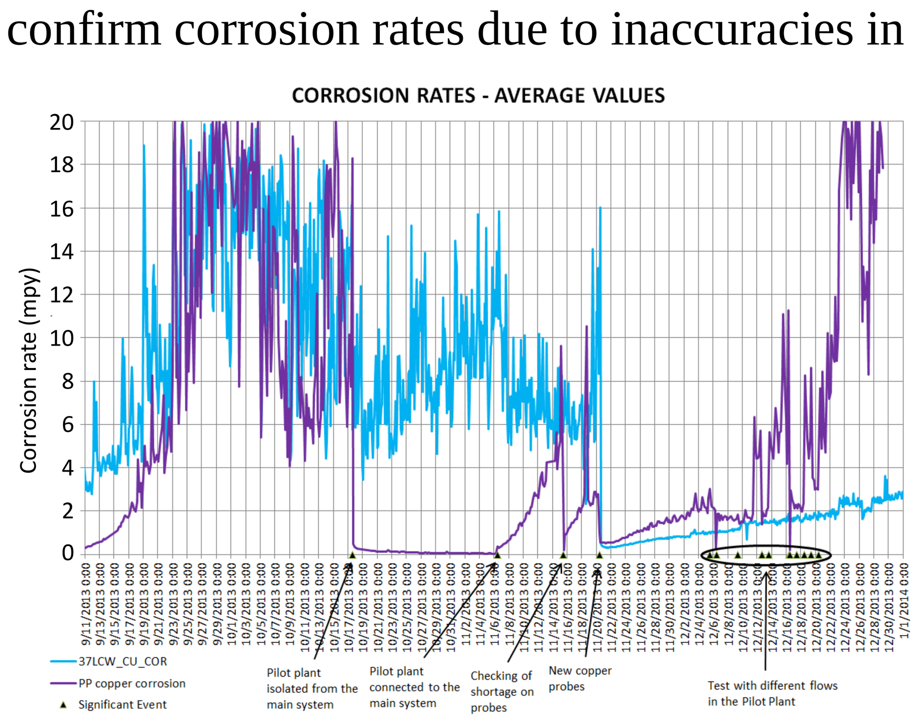
Monitoring is an essential part of maintaining a low-corrosion LCW system. In addition to controlling for conductivity, the following aspects are monitored in the ALS main LCW system:

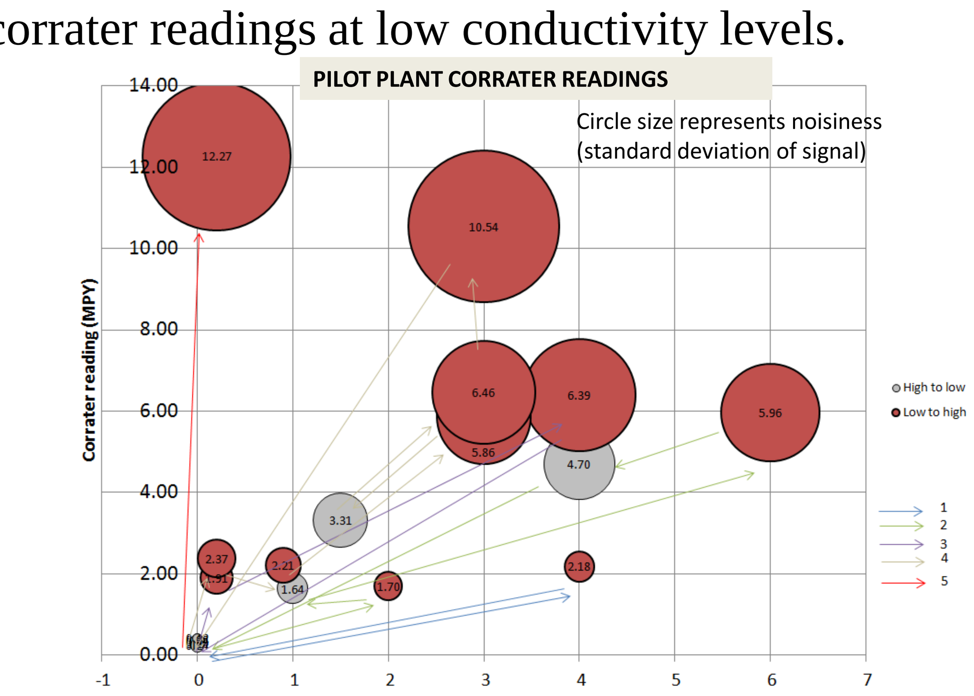
- pH (supply and return)
- Dissolved oxygen (DO)
- Temperature
- Copper corrosion rate
- Aluminum corrosion rate
- Make-up water valve



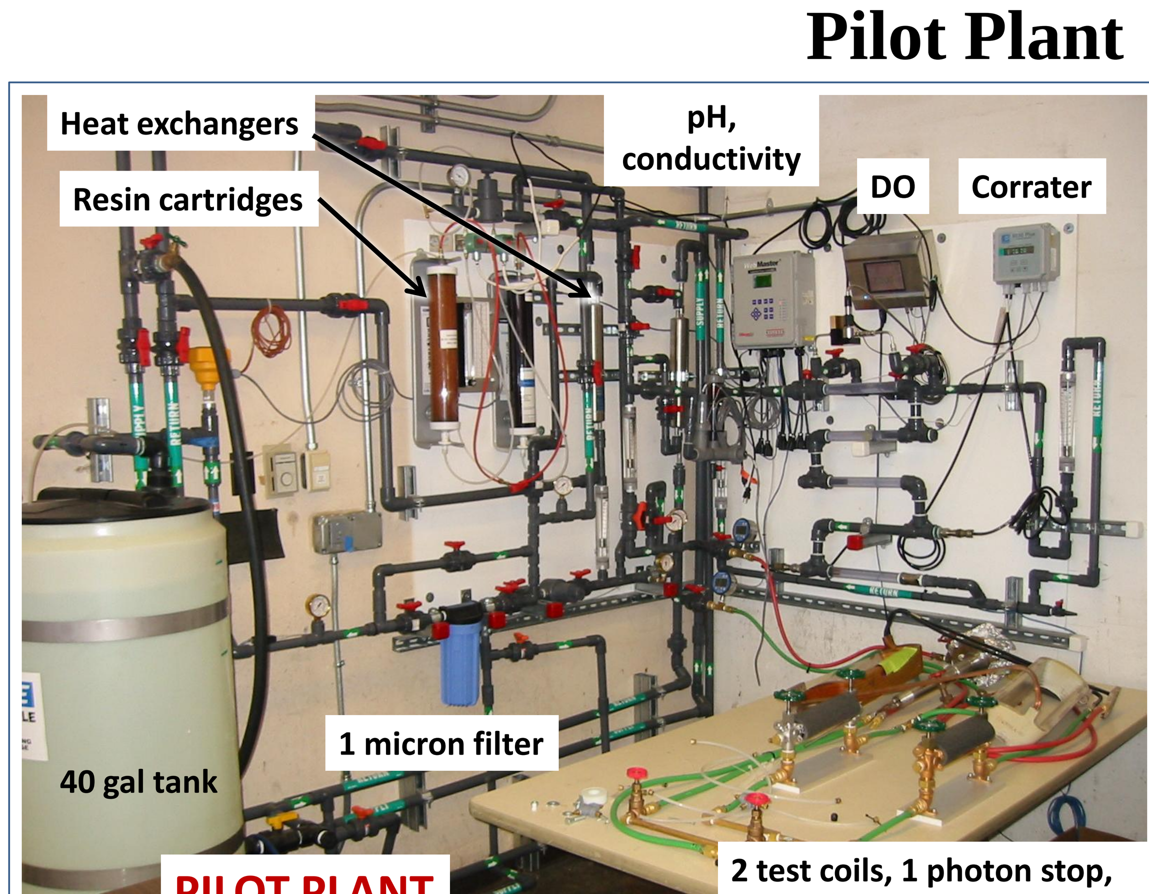
We noted that DO monitoring requires frequent maintenance. Recalibration is often needed and the electrolyte in probe heads require replacement every 2 to 3 months.

Copper and aluminum corrosion rates are monitored using Corrater® linear polarization resistance probes for instantaneous corrosion rate readings. Copper coupons are still necessary to confirm corrosion rates due to inaccuracies in corrater readings at low conductivity levels.



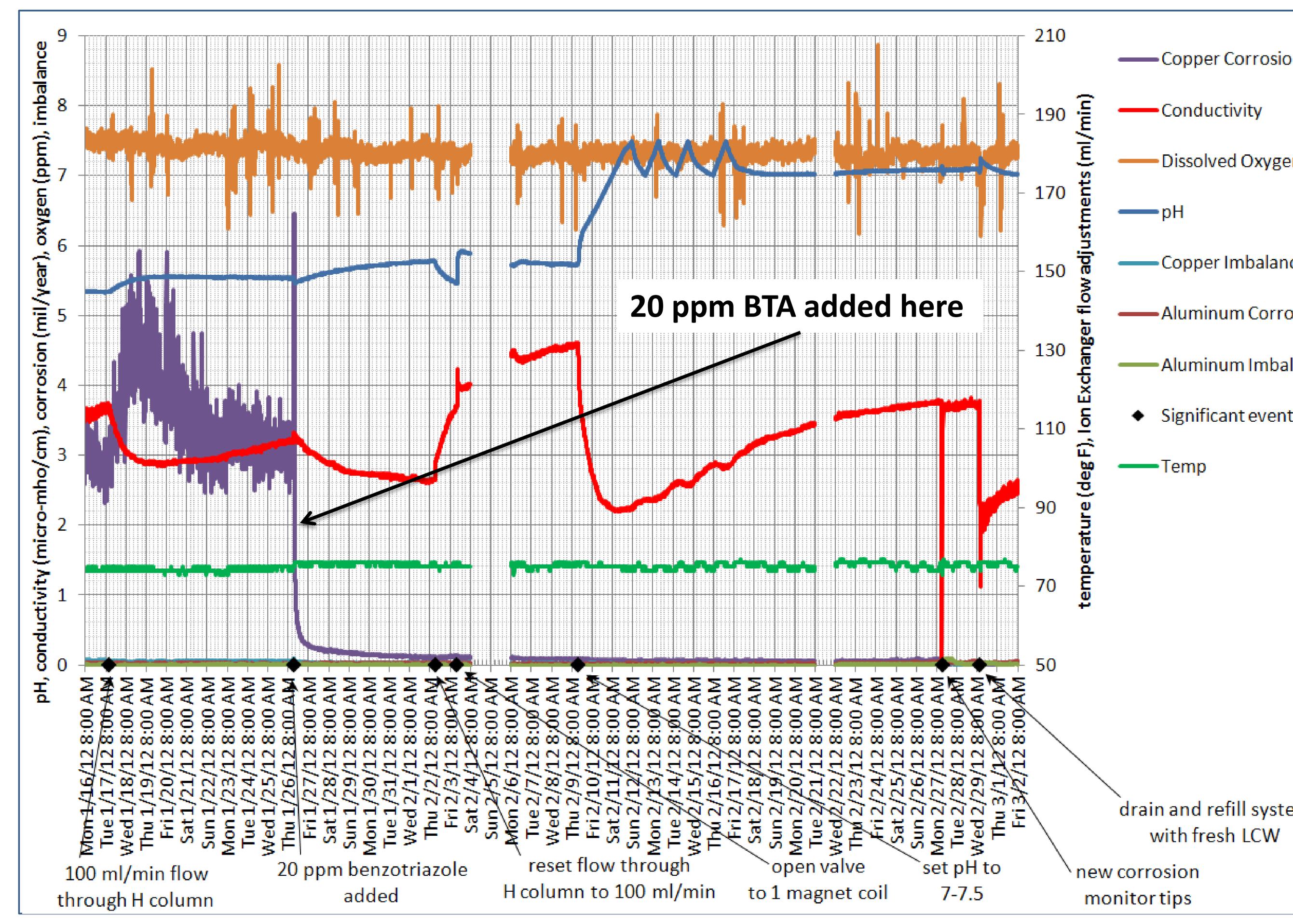


Pilot Plant



A self-contained pilot plant was assembled to provide a test bed that simulates the main LCW system. The pilot plant replicated the main LCW system's monitoring. Other components include a 1 micron filter, a 40 gallon tank, both sodium & hydrogen based resin cartridges for maintaining low conductivity with pH control, and corrosion coupons. A heat exchanger is used to maintain temperature. The pilot plant is also plumbed to enable direct connection to the main LCW system.

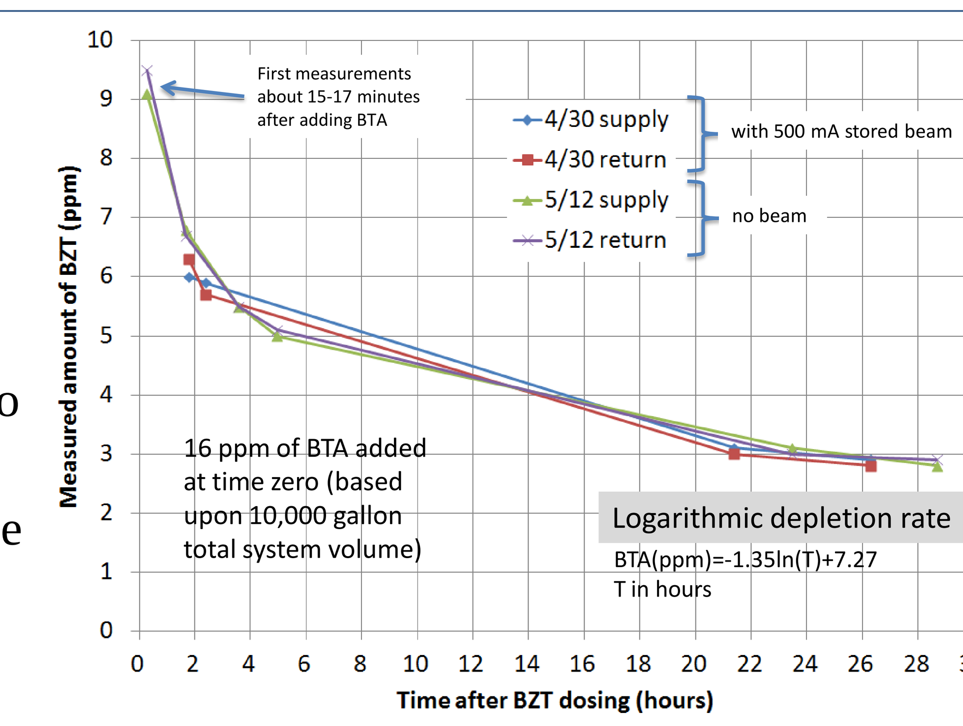
Pilot Plant Test Results



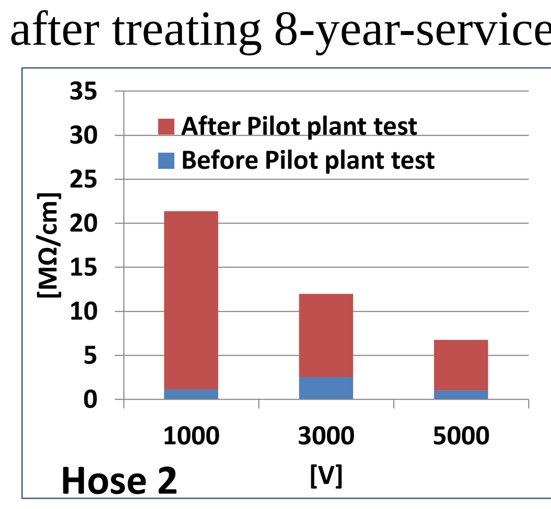
One of the purposes of the pilot plant was evaluation of the effectiveness of BTA. BTA addition had a dramatic effect on corrosion rates, dropping it from 3 to 4 mpy to less than 0.1 mpy. Conductivity and pH were both temporarily depressed but regained their previous values. The effect of increasing pH to between 7 and 8 was also evaluated; no discernible improvement was seen for pH>7.

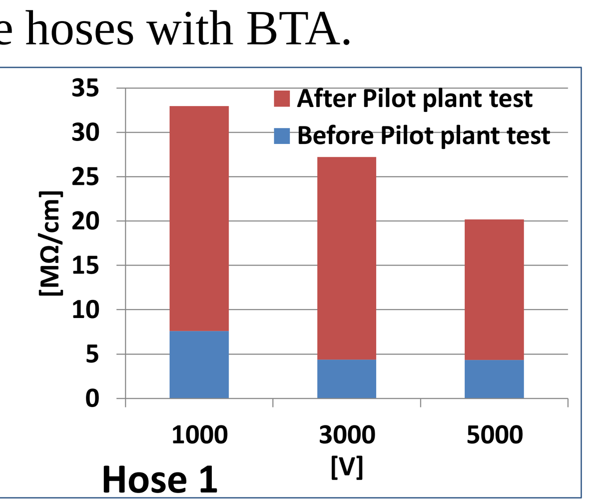
Evaluating Potential Detrimental Effects from BTA

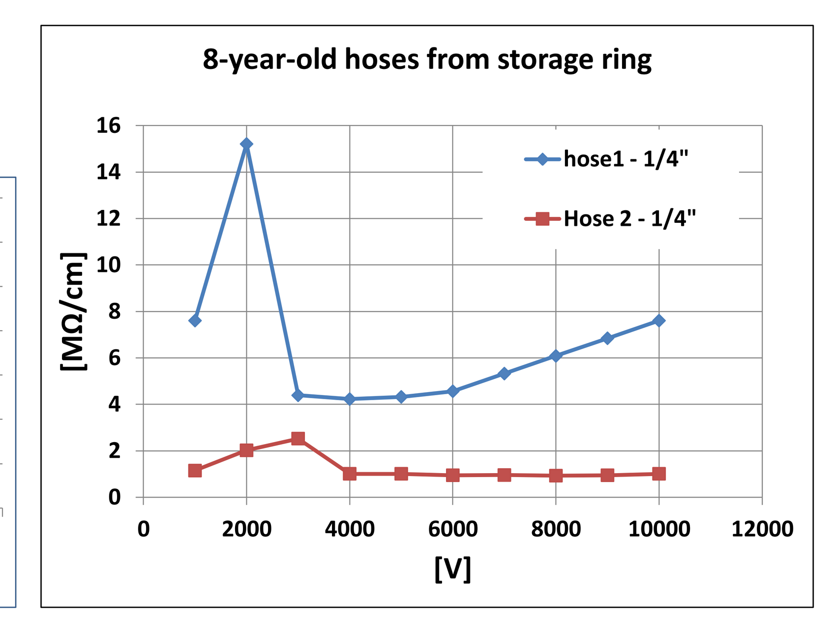
Although pilot plant results were promising, there was concern over irreversible and wide-scale detrimental effects to adding BTA to the main LCW system. One of the concerns was a breakdown of BTA due to radiation in the storage ring. We evaluated BTA decay rates with and without beam in the ring and found no discernible difference in decay rates.



A second concern was the effect on cooling line hoses; specifically issues of potential embrittlement and loss of resistivity. Eight-week soak tests in 57 ppm of BTA did not indicate any effect. Conductivity tests not only showed no detrimental effect, but improvement after treating 8-year-service hoses with BTA.

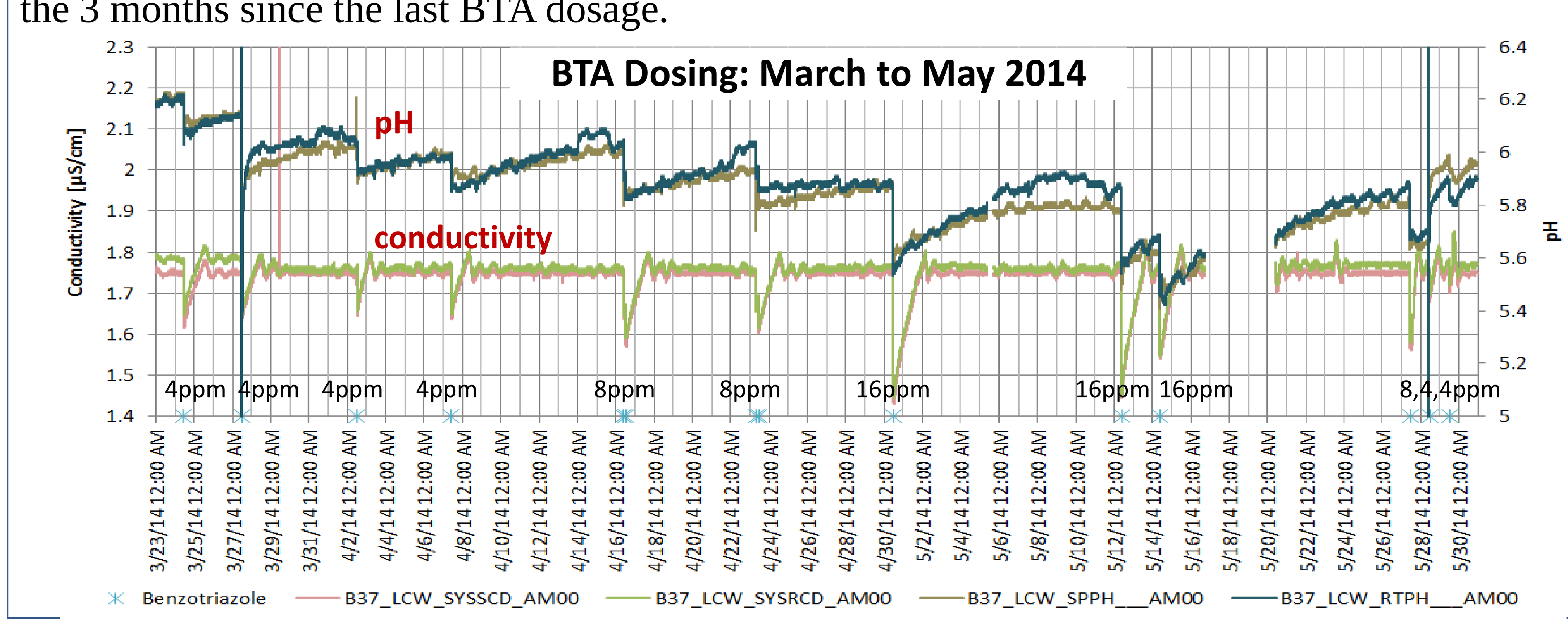






Results from Dosing Main LCW

The main LCW system at ALS was dosed with BTA over a span of 5 months from January to June 2014, with weekly dosages ranging from 2 to 16 ppm. Corrosion rates fell from 0.3 mpy prior to BTA dosing to less than 0.01 mpy as measured from corrosion coupons, and continue to remain low. Corrosion rates continue to be ~0.01 mpy even during the 3 months after the last BTA dosage. Each BTA addition results in a temporary drop in conductivity and pH. The 5 months of weekly BTA dosing drove pH down to ~6.0 but the system has recovered to ~6.8 in the 3 months since the last BTA dosage.



Conclusion and Next Steps

Recent application of benzotriazole to the ALS LCW system has shown effectiveness at reducing copper corrosion rates. Continuous dosing at rates typically used in other applications has the disadvantage of lowering system pH, but corrosion rates are seen to remain low even up to 3 to 4 months after benzotriazole application.

We continue to monitor the system and are working on a minimal BTA application schedule that yields low long-term corrosion rates while minimizing impacts on system conductivity and pH. We expect monthly or bimonthly benzotriazole dosages during regular shutdowns will suffice.