POWERFILM 10000 Reduces Corrosion in All-Steel Unit

NALCO Water
An Ecolab Company

CASE STUDY - POWER

CH-2081

BACKGROUND

The causes of Flow Accelerated Corrosion (FAC) are well-documented. In most systems, specific mechanical and operational factors cannot be changed and changes to the chemical factors can simply exchange one type of corrosion for another.

FAC REQUIRES FIVE CONDITIONS TO EXIST SIMULTANEOUSLY

- Steel construction
- Low pH
- Low oxygen concentration
- Rapid or turbulent flow
- Temperature between 212°F and 480°F (100°C – 250°C)

Complicating matters is the matter of cyclical operation. Around the world, many power plants are cycling more than they have in the past, as explained by Mike Caravaggio and Norris Hirota of the Electric Power Research Insititute (EPRI) in the June 2017 issue of *Power* magazine[1]. Cyclical operation stresses power plant systems and the corrosion and metal fatigue caused by it requires new operational and chemical approaches.

SITUATION

Increased competition from wind and gas-fired units has caused this once base-loaded coal-fired unit to begin cycling from full load (725 MW) during the during the day to as low as 400 MW at night. To address the problems created by cyclical operation, many power plants have evaluated film-forming corrosion inhibitors. This Missouri plant evaluated the efficacy of applying a filming inhibitor at a high dosage prior to an outage to reduce corrosion during the idle period and to reduce iron corrosion product generation upon startup.

Film-forming inhibitors reduce the potential for FAC by forming a non-wettable, oxygen-impermeable barrier between the base metal and the corrosive water. By preventing chemical interaction between the corrosive water and the mild steel of the boiler system, even during cyclical operation, FAC can be inhibited.

Chemical control at this plant, even during cyclical operation, is excellent. Although no reductant is applied, hotwell dissolved oxygen is at or close to zero ppb, which makes the feedwater chemistry look more like an AVT(R) program than AVT(O), exacerbating the FAC mechanism.

SOLUTION

The field trial protocol developed for the evaluation called for corrosion product data, collected with an integrated corrosion product sampler. These devices pass a metered volume of water through two filters of known

[1] Mike Caravaggio and Norris Hirota, "Changing Mission Profiles," *Power Engineering*, May 2017, p. 12.

Type of Unit	B&W drum boiler
Unit Output (MW)	725
Fuel	Coal
Drum pressure, psig	2,600
Superheat/reheat temperature, oF	1,050/1,000
Steam flow, lb/hr	4,900,000
Pre-boiler metallurgy	All-ferrous (SS feedwater heaters)
Feedwater/condensate treatment program	AVT(O) targeting 9.6 pH with Nalco 5711 (MEA/ NH3 blend)
Boiler water treatment program	Phosphate
Condensate polishing	Only during unit start-up

Table 1: Unit details

dimensions. One filter is a standard 45 mm, 0.47μ filter which captures insoluble material; the other is impregnated with cation resin and captures soluble materials.

By analyzing the filter pads, the concentrations of soluble and insoluble corrosion product can be calculated. A sampler was installed on the deaerator (DA) outlet.

Table 2 contains baseline iron corrosion product data collected over several months. Iron concentrations in the boiler feedwater are well above the EPRI recommended maximum of 2 ppb. Soluble iron (13% of the total in this case) indicates an active corrosion mechanism like single-phase FAC. Particulate iron (87% of the total iron) is iron oxide sloughed off pre-boiler surfaces. The percentage of soluble iron in this instance is relatively high, compared to concentrations normally measured in the final feedwater of most fossil units on AVT(O). This was strong evidence that FAC was the predominant corrosion mechanism.

	Particulate (ppb)	Soluble (ppb)	Total (ppb)
Mean	5.2	0.8	6.0
Median	4.3	0.8	5.1
Maximum	15.4	1.7	17.1
Minimum	2.3	<MDL[2]	2.3

Table 2: Baseline iron concentrations at deaerator outlet

POWERFILM 10000 is a filming corrosion inhibitor formulated with a surface active chemistry, meaning it has an affinity for metallic surfaces and forms a hydrophobic film. It contains no neutralizing or filming amine and contributes little or no cation conductivity at normal use concentrations. The major component of POWERFILM 10000 was derived from work done by Nalco Water in the 1940's. This compound, patented back then as a boiler defoamer, has physical and chemical properties that make it ideal to meet today's steam system treatment needs.

It is also the only non-amine filming corrosion inhibitor to meet all of today's stringent chemical safety requirements, including Toxic Substances Control Act (TSCA) clearance under the Frank R. Lautenberg Chemical Safety for the 21st Century Act[3].

In addition to mitigating the effects of cyclical operation, this plant has seen higher-than-acceptable deposit weights on their boiler tubes and wanted to reduce their iron "holds"— periods of time during start-up when the unit must wait for feedwater iron concentrations to drop before generating at full load. Reducing feedwater iron concentrations, particularly coming out of short-term outages would increase the plant's ramp rate, maximizing generation and revenue.

Like many plants, this station gets very little warning before an outage, so the engineering staff decided to apply a high concentration of POWERFILM 10000 just prior to an outage to establish the protective film quickly to protect the system during the outage. A normal maintenance dosage of POWERFILM 10000 is 1.0 ppm, as product, by weight, applied to the condensate pump discharge. In this case, 9 ppm was applied, continuously, for the three days prior to an outage on two occasions.

RESULTS

After two high-dose POWERFILM 10000 applications, the particulate iron concentration in the feedwater was 1.86 ppb and the soluble iron concentration was less than the minimum detection level. Iron concentrations were reduced 64% compared to baseline conditions. The filter pads from the integrated sampler were noticeably lighter in color after only two applications of POWERFILM 10000, as shown in *Figure 1*[4]. Users of other filming inhibitors report measuring high concentrations of corrosion products when first applying the inhibitor. No evidence of such "cycle clearance" was seen in this system.

[2] <MDL: less than minimum detection limit

[3] The EPA Accession Number for POWERFILM 10000 is 215817. The Pre-Manufacturing Notification Number is P-16-0398. This information can be found on the EPA website: https://ofmpub.epa.gov/sor_internet/registry/substreg/searchandretrieve/cbi/search.do

[4] The corrosion product sampler totalizes the volume of sample passed through the filters over a known time period. For the baseline period filters, 336.77 liters of feedwater passed through the filters. For the POWERFILM 10000-treated period, 306.5 liters of feedwater passed through the filters.

Figure 1: Baseline filters (left) and powerfilm 10000 filters (right)

A complete internal inspection of the steam-water circuit was performed after the POWERFILM 10000 treatments. Very significant hydrophobicity — water beading — was observed in the condenser hotwell, deaerator, boiler drum and the LP exhaust hood/condenser inlet. *Figure 2* shows the hydrophobic film formed on the dearator trays and is typical of surfaces observed elsewhere in the steam-water circuit. EPRI has cautioned against using hydrophobicity as the sole indicator of corrosion inhibitor performance because there is no way to assess the extent or uniformity of the phenomenon. The presence of this film does show that POWERFILM 10000 is readily transported around the entire circuit when injected into the condensate and that such a film does form when the product is applied.

PRODUCT CONCENTRATIONS

There is no field method for measuring the concentration of the product, but the Nalco Water Analytical Laboratory can analyze samples for POWERFILM 10000. The results of that testing are reported in *Table 3*. They verify product distribution throughout the steam/water cycle.

Sample Location	Product Concentration (ppm)
Condensate Pump Discharge	7.6
Deaerator Outlet	8.6
Boiler Drum	18.0

Table 3: product concentration

CATION CONDUCTIVITY

At normal use concentrations, POWERFILM 10000 contributes little or no cation conductivity to the feedwater. In this plant, the product was applied at nine times the normal use concentration. Condensate pump discharge cation conductivity increased from the normal range of 0.2-0.4 µS/cm to a maximum of 1.5 µS/cm during the high dosage applications of POWERFILM 10000.

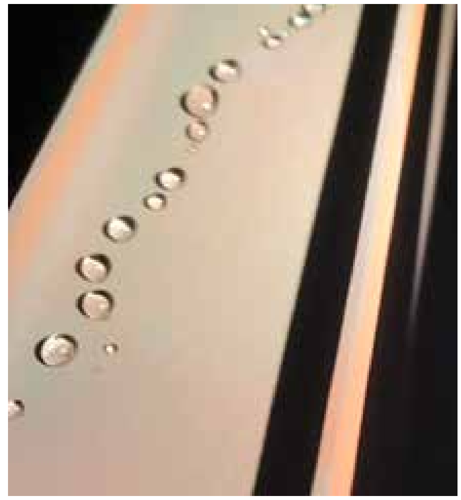

Figure 2: hydrophobic film on the dearator trays

IMPACT ON SENSORS

Despite application of high concentrations of POWERFILM 10000 for relatively short periods of time, no impact was detected on the response or sensitivity of on-line instrumentation, including pH, dissolved oxygen, cation conductivity, and sodium analyzers.

FUTURE ACTIONS

With the efficacy of the treatment established, POWERFILM 10000 will be injected at the condensate pump discharge, continuously, at a dosage of 1.0 ppm, as product, by weight, based on feedwater flow. The corrosion product sampling systems will remain in operation to document the performance of the product under other operating conditions. POWERFILM 10000 concentrations will be measured at various times and sample locations and correlated to cycle chemistry and unit operating conditions.

CONCLUSION

Changing operational schedules and the financial pressures faced by coal-fired power stations prompted operators to look for new solutions. POWERFILM 10000 represents a step-change in performance by reducing corrosion product concentrations, even in cyclical operations. This field evaluation documented the efficacy of high dosages of POWERFILM 10000 for short periods of time to deliver system protection during short-term outages.

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