IAPWS Certified Research Need
ICRN #26

Behavior of Aluminum in the Steam Water Cycle of Power Plants

ICRN Issue Date: July 2011, renewed 2014

Closing Document

In consideration that research and power plant assessments have been conducted within the last 10 years but not openly published, and that there has not been further major fouling of steam turbines, the Working Group on Power Cycle Chemistry recommended at the 2025 annual meeting that a closing statement for this ICRN be developed. The important results have already been incorporated into the IAPWS TGD on Volatile Treatments (TGD3-10 (2015).

Background:

This ICRN was first issued in 2011 and renewed in 2014. Since then, a number of power plant assessments and customizations have been made on plants that contain low temperature applications in systems associated with the steam water cycle as well as in cooling loops. These plant customizations relate to units with a jet-spray condenser and a dry-cooled heat exchanger tower with aluminum tubes. In these part of the recirculating water is extracted and used as feedwater, and contains aluminum corrosion products which are present as dissolved cationic aluminum as well as particles of hydroxide or oxide. It is also known that high levels of aluminum in a cycle from any source can cause deposits in the boiler/evaporator tubes or on HP turbine blades in the same way that copper does, because of the significant volatility of aluminum compounds.

The results from these studies have been incorporated into the IAPWS TGD on Volatility (TGD3-10 (2015). Plants will need to take measures to change the operating parameters of AVT to control the quantities of aluminum released by the corrosion processes.

Some of the results of these studies can be summarized:

1. The limits adopted by a plant will depend on boiler pressure and chemistry, and condensate chemistry. It is, however, a reasonable approach to limit the feedwater of units with drum boilers/evaporators to < 5 µg/kg aluminum, boiler water to < 1 mg/kg and steam to < 5 µg/kg total aluminum. For boilers with < 10 MPa drum pressure, a larger aluminum limit in the boiler water can be considered. For plants with once-through supercritical boilers, a limit of < 3

µg/kg total aluminum at the economizer inlet will be required. The customization will be derived from monitoring of the aluminum content around the cycle.

2. To meet these aluminum levels, there are basically two options for the cycle chemistry: a) Low pH option with condensate pH = 7.7–8.0, corresponding to a feedwater pH = 8.0–8.3. Depending on the plant (drum or once-through/supercritical) and pressure rating, condensate polishing may not be required. b) High pH option with condensate pH = 8.4–8.7, corresponding to a feedwater pH = 8.7–9.0. 100% condensate polishing will be required.
3. Oxygenated treatment (OT) or AVT(O) should be used and operated according to the customized IAPWS TGD and normal limits. No reducing agent should be added.
4. Aluminum oxide (Bayerite $Al(OH)_3$) will form in the oxygenated low pH environments which becomes overlaid in service with a red/brown "coating" (hematite and magnetite)
5. Bayerite, β-$Al(OH)_3$, a polymorph of gibbsite, α-$Al(OH)_3$, often precipitates below ~ 80°C preferentially to either boehmite, γ-AlOOH, or gibbsite, despite being intrinsically less stable (more soluble). Bayerite will likely be the dominant aluminum corrosion product found on aluminum tubes taken from the cooling towers).
6. For chemical carryover on drum units only the soluble species is volatile. Solids such as boehmite can only enter steam via mechanical carryover. In once-through units carryover of boehmite particulates and ions must also be considered and these would presumably dehydrate to corundum rapidly if they are deposited on the HP turbine. The general decreasing solubility trend with pressure is consistent with the possible formation of corundum deposits on the first stage of HP turbine
7. For supercritical units, a feedwater pH range of 7.5 - 8.2 using only ammonia injection should be used.
8. The condensate polishing plant (CPP) will need to comprise a mechanical pre-filter (5 µm absolute) followed by either a 3 x 50% cation / mixed bed or 3 x 50% cation / anion deep bed polisher with Macroporous type resins.

In a new power plant, it may take up to one year until the aluminum levels in the steam/water cycle have stabilized. During this period, aluminum levels may be elevated if the aluminum tubes are not preconditioned.

Although from the scientific point of view, some of the questions stated in the ICRN are still open, due to lacking industry response the Power Cycle Chemistry Group suggests closure.

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