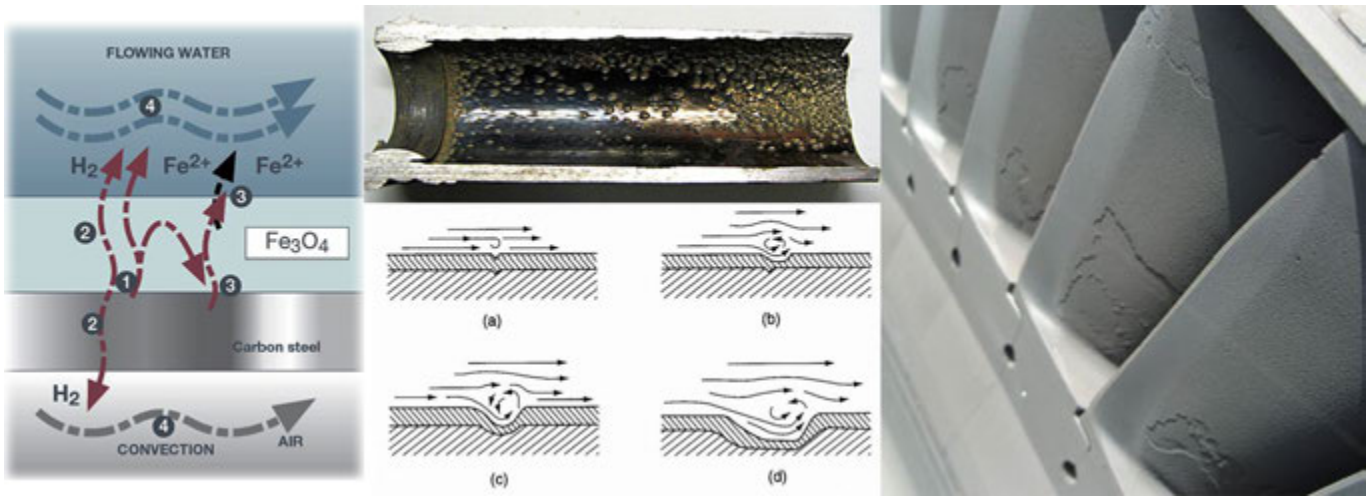
Process Application Note AN-PAN-1032

Monitoring Flow Accelerated Corrosion & Metal Transportation in Power Plants: Online Ultratrace Measurements of Fe and Cu

In power plants, corrosion is the primary factor leading to costly and critical downtimes. The water-steam circuits in fossil and nuclear power plants are inherently prone to corrosion, as metal components are constantly in contact with water. Corrosion leads to shorter lifetimes for the carbon steel pipework and copper heat exchangers, among other issues. At high temperatures, steam reacts with the iron in the carbon steel of steam boilers and forms a thin layer of magnetite (Fe_3O_4) or hematite (Fe_2O_3) (the form depends on the levels of oxygen present) which passivates and protects the surface against further corrosion (Schikorr reaction). Under turbulent flow conditions, Flow Accelerated Corrosion (FAC) can occur in which the inhibiting magnetite (or hematite) layer flakes off, leading to elevated iron concentrations in the water-steam circuit. The underlying metal corrodes to re-create the oxide, and thus Fe loss continues, potentially leading to catastrophic failure in the piping. In power plants which utilize copper alloy heat exchanger tubes in the condensate system, Cu corrosion and transportation is also an issue, leading to Cu deposition on high pressure turbine blades and loss of performance. Corrosion and metal transport increase with power output over a certain threshold, and therefore so does the deposition onto the turbines. Considering up to 10% loss of efficiency from the turbine blades, the power output will still be the same but 10% more energy has to be consumed, and as flow increases corrosion also increases.

Determining optimal power output with minimal FAC is important not only for saving costs but also for the safety of the workers. Current methods monitor wall thickness of the pipes, but can do nothing to prevent further thinning due to corrosion. If the power plant is shut down for cleaning and restarted without regard to the corrosive threshold determined by the power output, turbines can get metal deposits almost immediately, losing efficiency and money until the next scheduled maintenance period. Corrosion product sampling is a key metric in the cycle chemistry performance monitoring, as corrosion can occur at any time given the continuous contact between metal parts and water. Maintaining a good cycle chemistry program is much easier and less costly than taking corrective actions as a result of an inadequate program.



FAC reaction mechanism and metal deposition within the water-steam circuit at a power plant.

The metal transportation in power plants is currently monitored by Corrosion Product Sampling (CPS) racks, which collect particulate metals on filter pads over a period of one day to a week, are later digested, and the metals analyzed by ICP-OES or ICP-MS. Total analysis time can take from 1 to 3 weeks. Monitoring only the accumulated corrosion products causes a

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loss of transportation peaks, and detailed information on why the metal loss occurred is lost. A maximum of 2 µg/L Fe is recommended by the Electric Power Research Institute (EPRI) in order to avoid FAC-related issues in the water-steam circuit, and these levels are not accurately measured with the current CPS racks, as seen in long-term comparisons.

Continuous online ultratrace analysis of Fe and Cu in the water-steam circuit of power plants is now possible, thanks to the 2045VA Process Analyzer from Metrohm Applikon. This enables early detection of corrosion processes and peaks, and also monitors the formation and destruction of the protective oxide layer. Continuous analyses also signal a problem before dissolved metals can reach the condensate stream and thus the turbine blades where they would cause damage. In combination with the power plant's Distributed Control System (DCS), online monitoring of Fe and Cu ensures that corrosion can be controlled before it affects the power plant efficiency, ultimately decreasing downtime and lowering maintenance costs.

Application: This is a voltammetric method for the online analysis of iron and copper corrosion products using the 2045VA Process Analyzer from Metrohm Applikon. The sample can be processed with or without automatic thermal digestion allowing for separate analysis of soluble and particulate Fe and Cu. Typically, the Fe measurement takes 40 minutes and the combined Fe and Cu analysis is 58 minutes.

Typical Range: Dissolved Fe(II, III) and $Fe(OH)_2$: 0.2 – 80 µg/L Total Fe: 0.5 – 100 µg/L Cu: from 0.1 µg/L (range can be easily adjusted)

Remarks: This analyzer is built based on **The International Association for the Properties of Water and Steam, Technical Guidance Document: Corrosion Product Sampling and Analysis for Fossil and Combined Cycle Plants**. The ranges listed above are typically very low, and may not reflect the expected values due to the fact that CPS racks cannot measure with the same accuracy. It is expected that many power plants currently have much higher levels of dissolved Fe and Cu in the water-steam circuit causing problems. The ranges for the dissolved metals can be easily expanded for this reason. Other online applications are available for power plants such as: calcium and sulfate in flue gas scrubbing, boric acid in the Primary Water Circuit, amine concentration and CO_2 loading, silica in boiler feed water, and more.

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