Application Note AN-PAN-1032

Monitoring corrosion in power plants with online process analysis

Faster ultratrace measurements of iron (Fe) and copper (Cu)

Corrosion in the water-steam circuit of power plants results in shorter lifetimes of most metal components and can lead to potentially dangerous situations. Flow Accelerated Corrosion (FAC) leads to thinned pipes and elevated iron concentrations in the circuit. Additionally, metal transport issues such as with copper from «copper heat exchangers» can lead to deposition on the high-pressure turbine blades. Current methods can monitor these issues but cannot prevent them as analysis times are extremely long (up to three weeks).

This Process Application Note details the online ultratrace analysis of iron and copper in power plants. This method offers results in 20 minutes, meaning faster response times for out of specification readings. In combination with the power plant's Distributed Control System (DCS), online monitoring of these analytes using a process analyzer ensures that corrosion can be controlled before it affects the power plant efficiency, ultimately decreasing downtime and lowering maintenance costs.

INTRODUCTION

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 (Cu) heat exchangers, among other issues. At high temperatures, steam reacts with the iron (Fe) 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 Fe concentrations in the water-steam circuit (Figure 1).

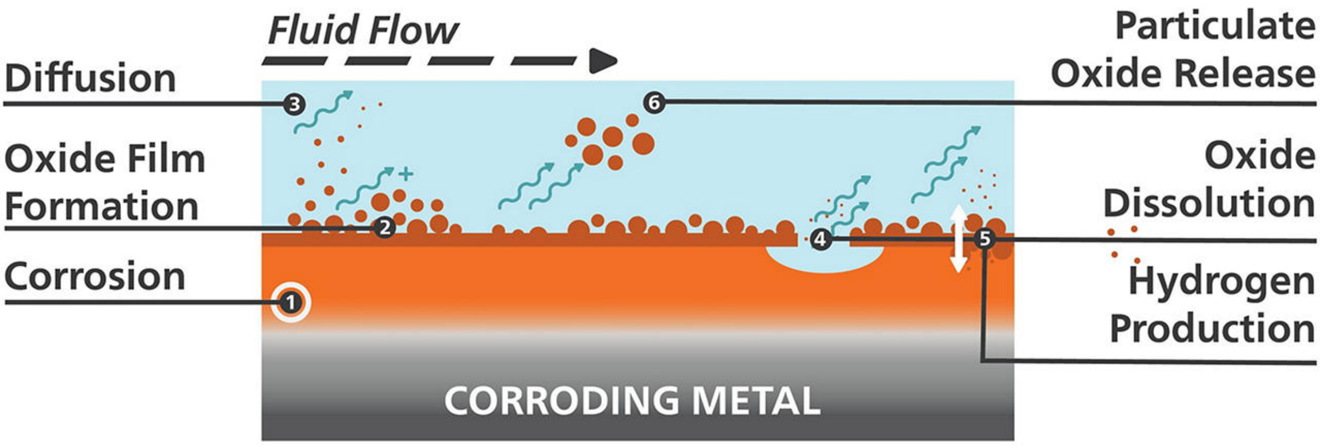

Figure 1. Diagram of processes occurring during flow-accelerated corrosion. Adapted from [1].

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 Cu 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 rate 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 obtain metal deposits almost immediately, losing efficiency and money until the next scheduled maintenance period. Corrosion Product Sampling (CPS) 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.

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

The continuous online ultratrace analysis of Fe and Cu in the water-steam circuit of power plants is possible using the 2060 Process Analyzer (Figure 2) from Metrohm Process Analytics. This automated process analysis system enables early detection of corrosion processes and peaks, and also monitors the formation and destruction of the protective oxide layer (Figure 3). 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.

Figure 2. 2060 Process Analyzer for photometric measurements of ultratrace iron and copper in the water-steam circuit of power plants.

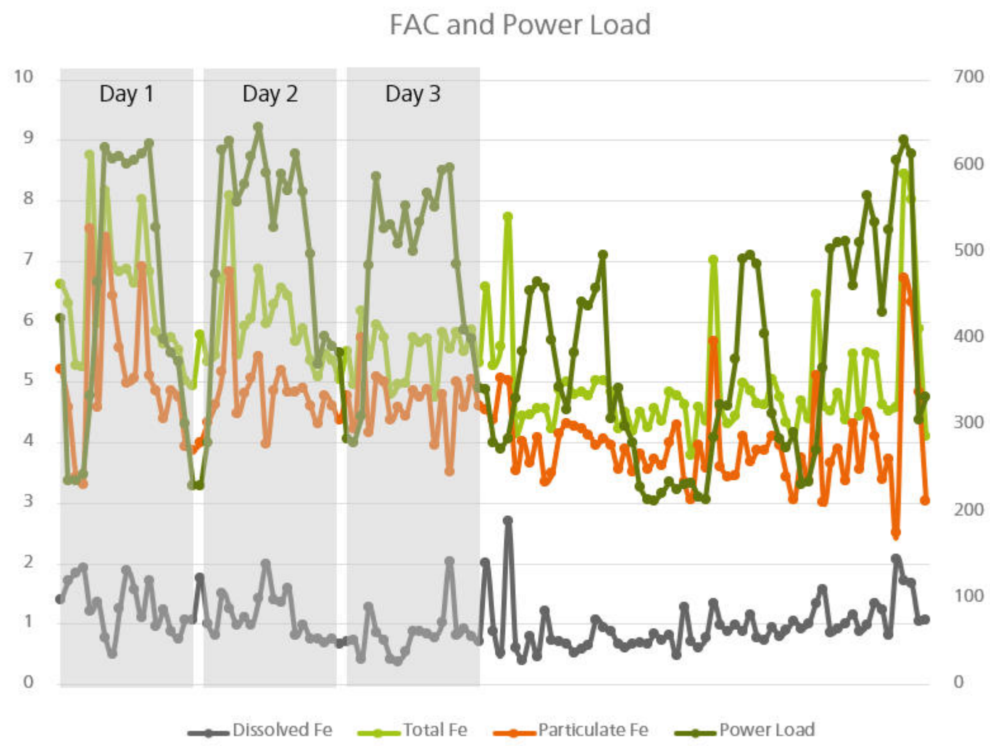

Figure 3. Data obtained from a Metrohm Process Analyzer in a power plant, used to monitor dissolved, total, and particulate iron (in µg/L), against power load (MW).

APPLICATION

Iron and copper content are determined by sample acid digestion followed by photometric determination using TPTZ and Bicinchoninate as color reagents respectively using the **2060 Process Analyzer** from Metrohm Process Analytics (**Figure 2**). Metal complexes such as magnetite, hematite, iron oxide (Fe_2O_3), and iron hydroxide ($Fe(OH)_2$) are dissociated into their dissolved forms by using nitric acid (HNO_3). The total analysis time is 20 minutes.

Table 1. Parameters to monitor in the water-steam circuit of power plants.

Analyte	Concentration (µg/L)
Fe(II, III) and $Fe(OH)_2$	0–10
Total Fe	0–10
Cu	0–11

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 [2]. The ranges listed above (Table 1) 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 measurement 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.

FURTHER READING

Related application documents

WP-076: Process analyzers as proactive solutions for online corrosion monitoring

AN-PAN-1045: Online monitoring of copper corrision inhibitors in cooling water

BENEFITS FOR PHOTOMETRY IN PROCESS

- Protection of company assets with built in alarms at specified warning limits to prevent corrosion
- Safer working environment for employees (corrosive environments)
- Guarantee compliance with environmental standards

REFERENCES

1. Dooley, B.; Lister, D. Flow-Accelerated Corrosion in Steam Generating Plants. 2018, 51.
2. IAPWS Technical Guidance Document: Corrosion Product Sampling and Analysis for Fossil and Combined Cycle Plants http://www.iapws.org/techguide/CorrosionSampling.html (accessed 2021 -12 -16)

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