



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.

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

The diagram illustrates the corrosion process at a metal surface, showing the interaction between the metal and the surrounding fluid. The metal is represented by a grey block at the bottom, labeled "CORRODING METAL". The fluid above is light blue. The corrosion process is depicted as a series of steps: 1. Corrosion: The metal surface is attacked by the fluid. 2. Oxide Film Formation: An oxide film forms on the metal surface. 3. Diffusion: Fluid flow (indicated by a black arrow) and diffusion (indicated by blue wavy arrows) occur. 4. Hydrogen Production: Hydrogen gas is produced at the metal surface. 5. Oxide Dissolution: The oxide film dissolves into the fluid. 6. Particulate Oxide Release: Particulate oxide is released from the surface. The diagram is divided into three horizontal sections: "Diffusion" (top), "Oxide Film Formation" (middle), and "Corrosion" (bottom). The "CORRODING METAL" label is at the bottom. The "Fluid Flow" label is at the top left, with a black arrow pointing right. The "Particulate Oxide Release" label is at the top right. The "Oxide Dissolution" label is in the middle right. The "Hydrogen Production" label is at the bottom right. The "Diffusion" label is at the top left. The "Oxide Film Formation" label is in the middle left. The "Corrosion" label is at the bottom left. The numbers 1 through 6 are placed at the locations of the processes: 1. Corrosion (bottom left), 2. Oxide Film Formation (middle left), 3. Diffusion (top left), 4. Hydrogen Production (bottom right), 5. Oxide Dissolution (middle right), and 6. Particulate Oxide Release (top right).

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

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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 ($\text{Fe}(\text{OH})_2$) 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 $\text{Fe}(\text{OH})_2$	0–10
Total Fe	0–10
Cu	0–11

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 CO₂ 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 corrosion 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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CONFIGURATION



2060 Process Analyzer

The 2060 Process Analyzer is an online wet chemistry analyzer that is suitable for countless applications. This process analyzer offers a new modularity concept consisting of a central platform, which is called a «basic cabinet».

The basic cabinet consists of two parts. The upper part contains a touch screen and an industrial PC. The lower part contains the flexible wet part where the hardware for the actual analysis is housed. If the basic wet part capacity is not sufficient enough to solve an analytical challenge, then the basic cabinet can be expanded to up to four additional wet part cabinets to ensure enough space to solve even the most challenging applications. The additional cabinets can be configured in such a way that each wet part cabinet can be combined with a reagent cabinet with integrated (non-contact) level detection to increase analyzer uptime.

The 2060 process analyzer offers different wet chem techniques: titration, Karl Fischer titration, photometry, direct measurement and standard additions methods.

To meet all project requirements (or to meet all your needs) sample preconditioning systems can be provided to guarantee a robust analytical solution. We can provide any sample preconditioning system, such as cooling or heating, pressure reduction and degassing, filtration, and many more.