

Application Note AN-PAN-1043

Online trace analysis of cations in the primary circuit of nuclear power plants

In power plants, corrosion is the primary factor leading to costly and critical downtimes. Pressurized water reactors (PWR) are generally designed with a third water circuit in addition to the two found in other thermal power plants (e.g., boiling water reactors (BWRs) or coal-fired and geothermal power plants). In this so-called «primary circuit», the primary coolant water is pumped under high pressure to absorb heat generated by nuclear fission, further transferring this heat to the secondary circuit. The PWR ensures that radioactive materials remain contained and do not disperse to the secondary circuit and therefore potentially to the environment.

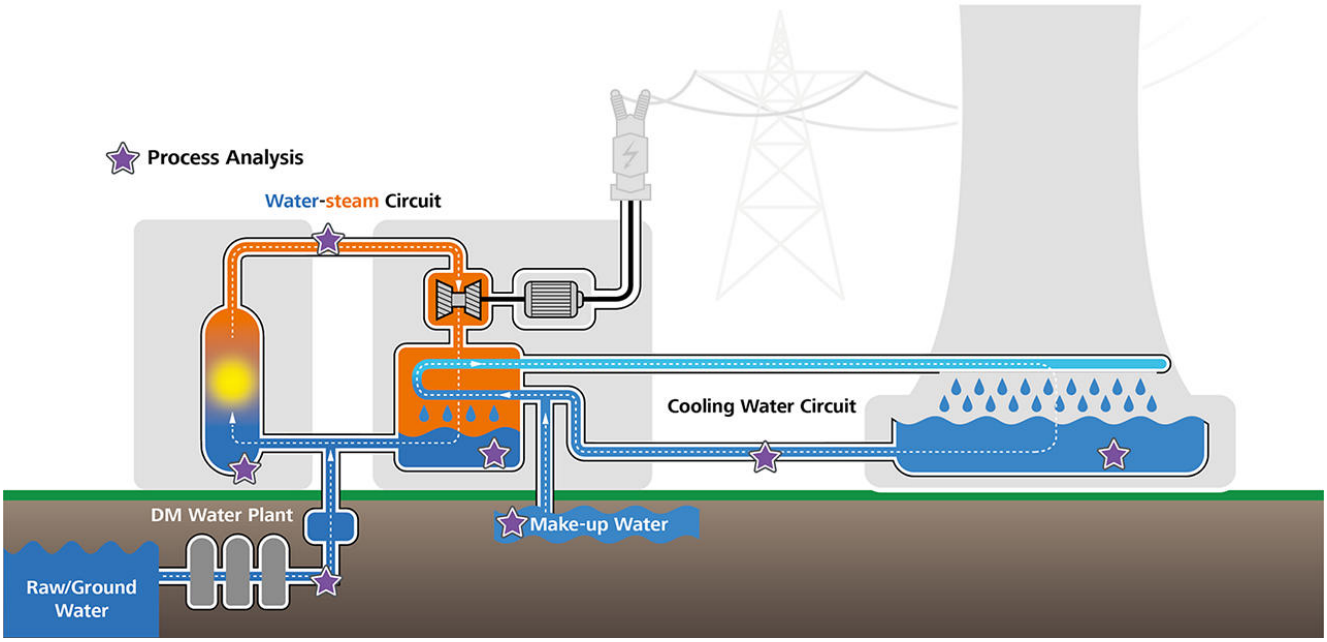

Figure 1. Diagram of a 3-water circuit nuclear power plant with stars noting areas where online process analysis can be integrated into the system.

This additional water circuit entails some specific requirements regarding chemical analysis and monitoring. In the PWR, light water is used as primary coolant. Boron (as boric acid, H_3BO_3) readily absorbs neutrons and is added to the coolant to control reactivity. Additions of monoisotopic lithium hydroxide (LiOH) to the primary circuit assures a pH value greater than 7 to prevent corrosion. Lithium is therefore a critical parameter to monitor in PWRs.

Nickel is an important alloying metal that increases the corrosion resistance of steel. However, in the dissolved form, nickel promotes corrosion, making regular checks of the Ni^{2+} concentration necessary.

In addition, metals released by corrosion undergo nuclear reactions and thus increase radiation in the power plant. To limit corrosion of the materials and to prevent the formation of radioactive products, the water is often treated with depleted zinc oxide. The zinc concentration must be monitored as well to ensure radioactivity does not spread.

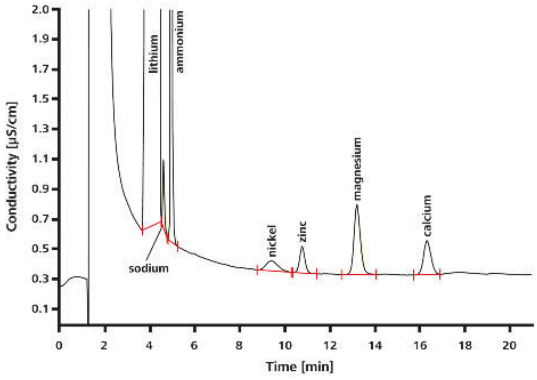

Figure 2. Simulated sample from the primary circuit of a pressurized water reactor containing 2 g/L H3BO3 and 3.3 mg/L LiOH spiked with 2 µg/L nickel, zinc, calcium, and magnesium; preconcentration volume: 1000 µL.

APPLICATION

These cations and more can be determined down to the sub-µg/L range in a single analysis using ion chromatography. However, precise, reliable trace analysis requires the method to be automated as much as possible. Metrohm Process Analytics offers a complete solution for this task: the 2060 Ion Chromatograph (IC) Process Analyzer featuring combined Inline Preconcentration and Inline Matrix Elimination. With one injection, the 2060 IC Process Analyzer is able to measure numerous ionic compounds in aqueous media from ng/L to % concentrations. The analysis system is fed directly and continuously with samples via a bypass in the process. Automatic calibration guarantees excellent detection limits, a high reproducibility, and excellent recovery rates.

The 2060 IC Process Analyzer provides alarms if preset warning or intervention concentration limits are reached, helping to save costs by preventing irreparable damage due to corrosion. The 2060 IC Process Analyzer can monitor both anions and cations with a single ion chromatograph and two detector blocks, giving a comprehensive overview of the water circuit chemistry. The possibility to connect one analyzer to up to 20 sample streams means multiple areas within water-steam circuits in a power plant can be monitored by a single instrument. With a built-in eluent production module and optional PURELAB® flex 5/6 from ELGA® for pressureless ultrapure water, the 2060 IC Process Analyzer can be configured to run trace anion analyses autonomously for up to several weeks.

The analysis is carried out fully automatically using a combination of Inline Matrix Elimination (for the H_3BO_3) and Inline Neutralization (for the LiOH). Analyte detection is by conductivity.



Figure 3. The 2060 IC Process Analyzer is available with either one or two measurement channels, along with integrated liquid handling modules and several automated sample preparation options.

BENEFITS FOR IC IN PROCESS

- Inline eluent preparation ensures consistently stable baselines
- Protect valuable company assets (e.g. pipes, PWR, and turbines, which are prone to corrosion)
- Safe working environment and automated sampling)
- High precision analyses for a wide spectrum of analytes with multiple types of detectors



FURTHER READING

Related application notes

Copper, nickel, zinc, and common cations in the water-steam cycle of a boiling water reactor (BWR)

Zinc, nickel, calcium, and magnesium in borated water of a pressurized water reactor (PWR)

Lithium in borated water of a pressurized water reactor (PWR)

Online analysis of trace cations in power plant water matrices

Other related documents

8.000.6072EN Trace-level determination of cations in the secondary circuit of a PWR-type nuclear power plant using ion chromatography after inline sample preparation

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CONFIGURATION



2060 IC Process Analyzer

The 2060 Ion Chromatograph (IC) Process Analyzer from Metrohm Process Analytics is based on the modular 2060 platform concept. This modular architecture enables the separation of the cabinets in different locations around a plant and the connection to up to 20 sample streams for time-saving sequential analysis at multiple areas inside of a plant.

This analyzer has no limits in terms of hardware, software, and applications customization. From continuous eluent production module, wet part modules for sample conditioning, and multiple IC detector blocks, the 2060 IC Process Analyzer has all the options for any industrial application.

The 2060 software is an «all-in-one» software solution that controls the analyzer to perform routine analysis, with different operation methods, time sheets, and trend charts. Furthermore, thanks to the variety of process communication protocols (e.g. Modbus or Discrete I/O), the 2060 software is programmable to send automatic feedback and alarms to the process and take action if necessary (e.g., re-measure a sample, or start a cleaning cycle). All of these features ensure fully automatic diagnostics of the industrial process – around the clock, seven days a week.