

Application Note AN-PAN-1013

Online analysis of boric acid in the cooling water of pressurized water reactors

Boric acid is used to absorb neutrons in the primary circuit of pressurized water reactors (PWR) of nuclear reactors, thus controlling the reactor's reactivity. Therefore, near-continuous monitoring of boric acid concentrations is crucial. Boric acid is typically monitored by manual laboratory analysis methods, but these are time-consuming and prone to human error. However, fast, reliable, online analysis is possible with the 2060 TI Process Analyzer.

This Process Application Note discusses the online analysis of boron in nuclear PWRs. The 2060 TI Process Analyzer's adaptive software, IMPACT, automatically switches between various burets, each with a different titrant strength depending on the boric acid concentration to maintain optimal accuracy across the entire measurement range. When integrated with the chemical and volume control system (CVCS), real-time monitoring enables early detection and mitigation of potential boric acid concentration issues, optimizing reactor control for safe and efficient operation.

INTRODUCTION

Approximately 9% of global electricity comes from nuclear energy sources [1]. Pressurized water reactors (PWRs) are one of the most common types of nuclear reactors for electricity generation purposes [1]. The safe and efficient operation of PWRs is critical to ensure a reliable energy supply while also protecting the environment.

In these PWRs, boric acid (B-10 isotope, ^{10}B) is added to the primary coolant to regulate the nuclear reaction. Boron effectively absorbs neutrons, preventing them from sustaining the fission process. By adjusting the concentration of boric acid in the coolant, operators can precisely control the reactor's power output.

Boron is carefully controlled within the primary and secondary circuit (Figure 1). While these circuits are designed to be highly contained, potential risks such as accidents, leaks, or spills could lead to the release of contaminated water into the environment, ultimately impacting nearby water sources.

The boron concentration in the primary coolant varies from 0 to 2,000 mg/L or more, depending on the stage of the fuel cycle [2]. This is significantly higher than the maximum recommended level for drinking water, which is 2.4 mg/L according to the World Health Organization (WHO) [3], and 1 mg/L according to EU standards [4].

The CVCS is responsible for regulating boron concentrations in the reactor coolant. This system carefully adjusts the amount of boric acid added to the primary circuit to maintain optimal reactivity and ensure safe reactor operation.

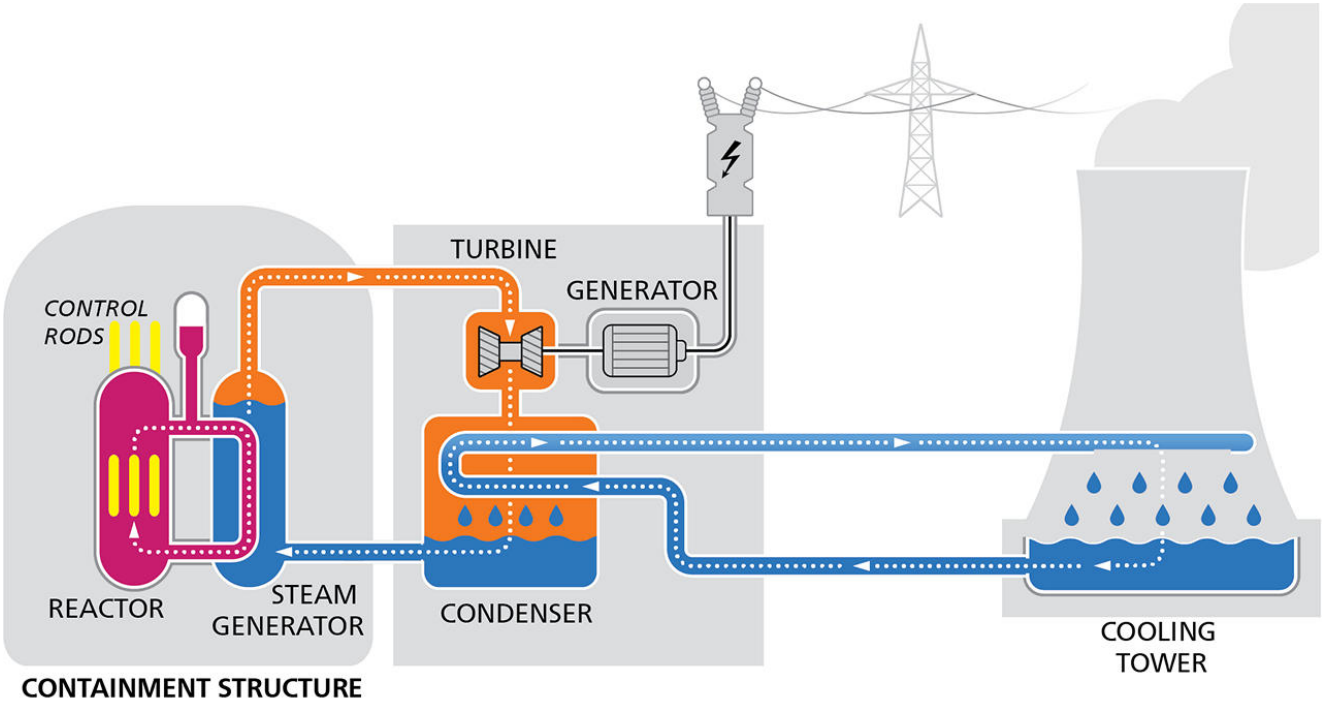


Figure 1. Illustration of the various water circuits in a nuclear reactor (left: primary circuit, center: secondary circuit, right: cooling circuit).

The 2060 TI Process Analyzer (Figure 2) offers a significant advantage over traditional laboratory testing methods in the nuclear sector. Its advanced titration technique enables continuous, real-time monitoring of boron concentrations in the PWR without the need for manual laboratory testing.

Furthermore, the analyzer's self-calibration feature ensures consistent accuracy without requiring frequent manual adjustments.
By seamlessly integrating with nuclear power plant control systems, the 2060 TI Process Analyzer enables automated reactivity adjustments based on measured boron concentrations. This automation enhances operational efficiency and helps maintain optimal reactor performance.

APPLICATION

Online monitoring of boric acid in cooling water is possible by means of potentiometric titration. The intelligent IMPACT software utilized by the 2060 TI Process Analyzer can automatically adapt to varying boric acid levels and switch titrant buret concentrations to ensure the highest accuracy is achieved throughout the full measuring range.

Table 1. Typical boric acid concentrations found in pressurized water reactors.

Parameters	[mg/L]
Boron	0–2000

REMARKS

Other process applications related to the water circuits of energy producers include silica, sodium, nickel, zinc, calcium, magnesium, and chloride. Reliable measurements of these critical parameters are possible with the 2060 TI Process Analyzer from Metrohm Process Analytics (Figure 2).



Figure 2. The 2060 TI Process Analyzer is suitable to monitor several critical parameters in nuclear pressurized water reactors.

CONCLUSION

The ability to monitor boric acid concentrations within the range of 0–2000 mg/L is particularly valuable in PWRs, where precise control of this parameter is essential for safe and efficient operation. The 2060 TI Process Analyzer's versatility and accuracy make it a valuable tool for nuclear power plant operators.

REFERENCES

1. *Nuclear Power in the World Today - World Nuclear Association*. https://world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today (accessed 2024-08-20).
2. Mesquita, A. Z.; Reis, I. C.; de Almeida, V. F.; et al. Boron-10 Effect on the Reactivity of the IPR-R1 Triga Research Reactor. *Annals of Nuclear Energy* **2019**, *132*, 64–69. DOI:10.1016/j.anucene.2019.04.023
3. *Boron, a key challenge for reverse osmosis systems, successfully treated with LG Chem TFN membranes GWI*. https://www.globalwaterintel.com/articles/boron-a-key-challenge-for-reverse-osmosis-systems-successfully-treated-with-lg-chem-tfn-membranes-lg-chem (accessed 2024-08-19).
4. *EU's drinking water standards*. https://www.lenntech.com/applications/drinking/standards/drinking-water-standards.htm (accessed 2024-08-19).

RELATED APPLICATION NOTES

AN-PAN-1016 Online analysis of silica in boiler feed water of power plants
AN-PAN-1032 Monitoring corrosion in power plants with online process analysis
AN-PAN-1038 Power generation: analysis of the m-number (alkalinity) in cooling water
AN-PAN-1040 Ammonia in cooling water of thermal power plants
AN-PAN-1042 Online trace analysis of anions in the primary circuit of nuclear power plants
AN-PAN-1043 Online trace analysis of cations in the primary circuit of nuclear power plants
AN-PAN-1044 Online trace analysis of amines in the alkaline water-steam circuit of power plants
AN-PAN-1045 Online monitoring of copper corrosion inhibitors in cooling water
AN-PAN-1056 Online monitoring of sodium in industrial power plants

BENEFITS FOR ONLINE PROCESS ANALYSIS

- **Safer working environment** for employees (nuclear reactor).
- **Fully automated diagnostics** – automatic alarms for when samples are out of specification parameters.
- **Guarantee compliance** with environmental standards.
- **High accuracy** for lower detection limits of boron.



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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.