



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.

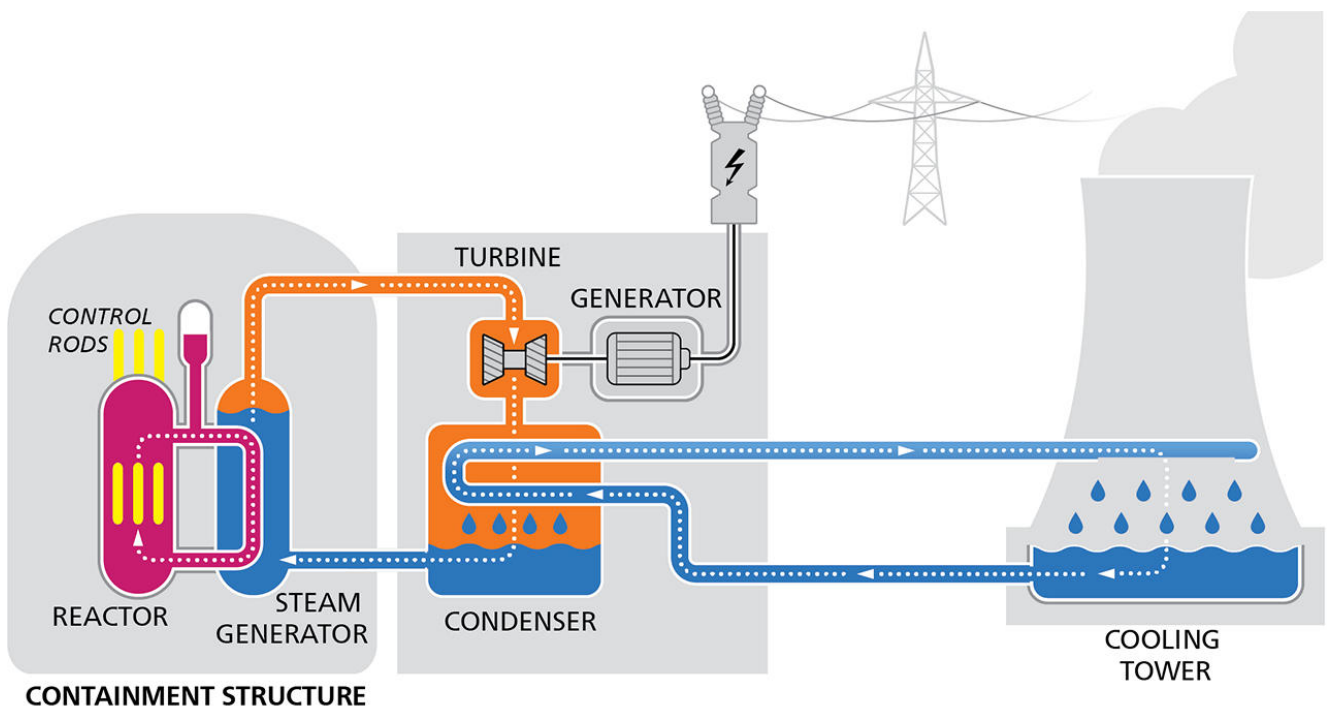


Figure 1. Illustration of the various water circuits in a nuclear reactor (left: primary circuit, center: secondary circuit, right: cooling circuit).

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

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

automated reactivity adjustments based on measured boron concentrations. This automation enhances operational efficiency and helps maintain optimal reactor performance.

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

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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.
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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

Le 2060 Process Analyzer est un appareil d'analyse par voie humide online adapté à un grand nombre d'applications. Cet appareil d'analyse de processus propose un nouveau concept de modularité reposant sur une plate-forme centrale, dénommée « armoire de base ».

Cette armoire de base se compose de deux parties. La partie supérieure contient un écran tactile et un PC industriel. La partie inférieure contient la partie humide flexible dans laquelle est logé le matériel nécessaire à l'analyse en elle-même. Si la capacité de base de la partie humide n'est pas suffisante pour résoudre un problème d'analyse, vous pouvez ajouter jusqu'à quatre armoires de partie humide supplémentaires à cette armoire de base afin de disposer de suffisamment d'espace pour résoudre les applications les plus difficiles. Les armoires supplémentaires sont configurables de manière à ce que chaque armoire pour partie humide puisse être combinée à une armoire à réactifs avec détection de niveau intégrée (sans contact) afin d'augmenter la disponibilité de l'appareil d'analyse.

Le 2060 Process Analyzer propose différentes techniques de chimie par voie humide : le titrage, le titrage Karl Fischer, la photométrie, la mesure directe et des méthodes d'addition standard.

Pour répondre à toutes les exigences de projet (ou à tous vos besoins), des systèmes de préconditionnement d'échantillons peuvent être fournis afin de garantir une solution analytique robuste. Nous pouvons pour ainsi dire fournir tout système de pré-conditionnement d'échantillon, tels que refroidissement ou chauffage, réduction de la pression, dégazage, filtration et bien plus encore.