

## COMBO

### Continuous Measurement of Boron Concentration

Early detection of disturbances in the concentration of boric acid used to prevent criticality events and improve operations

#### Challenge

In pressurized water reactors (PWRs), including Russian-type reactors, slow changes in reactivity are controlled using boric acid dissolved in the coolant of the primary circuit.

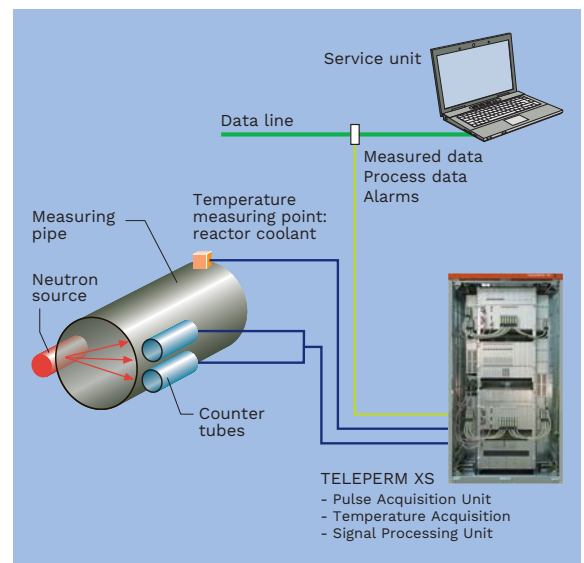
Dissolved boric acid is also one of the solutions used by the nuclear industry to prevent any criticality events in spent fuel pools.

Today it is still standard practice to measure boric acid concentration on a non-continuous basis via chemical analysis for those usages (titration).

#### Solution

Continuous Measurement of Boron Concentration (COMBO) allows the early detection of disturbances on an almost real-time basis. The measuring principle is based on the absorption of neutrons by the isotope B-10, which depends on the boron content of the coolant. Neutrons from an Am-Be source diffuse through the coolant and a portion of these neutrons is absorbed. The remaining neutron radiation is then detected by suitably positioned counter tubes.

For signal acquisition and processing TELEPERM XS – Framatome's instrumentation and control platform for safety-related applications – is used.



Principle of the COMBO system

#### Customer benefits

- Early detection of disturbances in the boric acid concentration within the primary circuit and the fuel pool cooling system up to medium temperatures of 200°C
- Rapid qualitative measurement within seconds
- A fully qualified system for safety-related applications
- Optimized installation of the equipment and systems in the plant with no welding intervention on pipes and easy integration in an expert system to support plant chemistry
- Easy service and maintenance by means of automatic diagnostics of all components

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is **our** everyday **commitment**

## Features

### Measurement range

- 0–1600 ppm Boron-10
- 0–8000 ppm Boron total (20% enriched)  
(can be adapted for specific projects requirements)

### Reference accuracy\*

- 20 ppm for boron concentration < 1000 ppm
- 2% for boron concentration ≥ 1000 ppm

### Response time < 1 min (depending on filter type)

### Radiation within working area

- < 100 µSv/h (on equipment surface)
- < 10 µSv/h (in 1 m distance)

### Sensor unit

- Installation mounted directly on pipe without any need for welding
- Neutron source: Am-Be –  $3.7 \times 10^{10}$  Bq
- Neutron detectors: Boron-lined counter tubes

### Medium temperature

- Measurement up to 200°C



COMBO sensor unit

## Technical information

The COMBO system is qualified for safety-related applications. Type tests and seismic load tests have been performed on the basis of IEC60780, IEEE 323 and KTA3505. Additionally, the TELEPERM XS hardware and software is qualified according to KTA3505 and IEC60880 with generic accelerations.

\* The stated reference value (total uncertainty) comprises statistical and systematic uncertainties, and is the average uncertainty at a statistical deviation of 1 sigma. The actual accuracy of the measured boron concentration depends on several factors, for example accuracy and frequency of calibration and parameterization of signal processing filters. The accuracy of the reference measurement used for calibration of COMBO is not included in this value.

Plant name	Country	Commissioning	Number of measurements	Monitored system
Grafenrheinfeld	Germany	1996 – only for test purpose	1	Chemical and volume control system
Mochovoe Unit 1 and 2	Slovakia	1998/1999	18	Chemical and volume control system, coolant makeup system and primary circuit
Neckarwestheim 1	Germany	2001	4	Chemical and volume control system and emergency borating pool
Isar 2	Germany	2002	1	Fuel pool cooling system
Callaway	USA	2004	1	Chemical and volume control system
Loviisa 1 and 2	Finland	2008/2009	4	Chemical and volume control system
Sizewell B	UK	2010	2	Fuel pool cooling pump
Taishan 1	China	2017	4 2	Chemical and volume control system, nuclear sampling system
Taishan 2	China	Ongoing	4 2	Chemical and volume control system, nuclear sampling system
Olkiluoto 3	Finland	Ongoing	4 2	Chemical and volume control system, nuclear sampling system
Flamanville 3	France	Ongoing	1	Chemical and volume control system

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