framatome

BORONLINE

A new generation of boron meter

Principles

Boronline is our latest generation of boron meters that provides a permanent record of boron concentration in the primary circuit.

Measurement of boron concentration levels in the reactor coolant is essential to control the reactivity of the core and ensure safe operation.

To achieve this function, Framatome has designed Boronline, the latest generation of boron meter, which provides nuclear power plant operators with a permanent record of the boron concentration contained in a water cooling circuit by way of continuous sampling and real-time measurements.

Boronline is a product designed to allow the continuous measurement of boron concentration (Cb) in a fluid circulating through a derivation of the primary circuit of pressurized-water reactors.

The system performs real-time measurements, and data processing (values and alarms) necessary for reactor operation. The information is then available on local/remote displays and/or communicated to the unit computer.

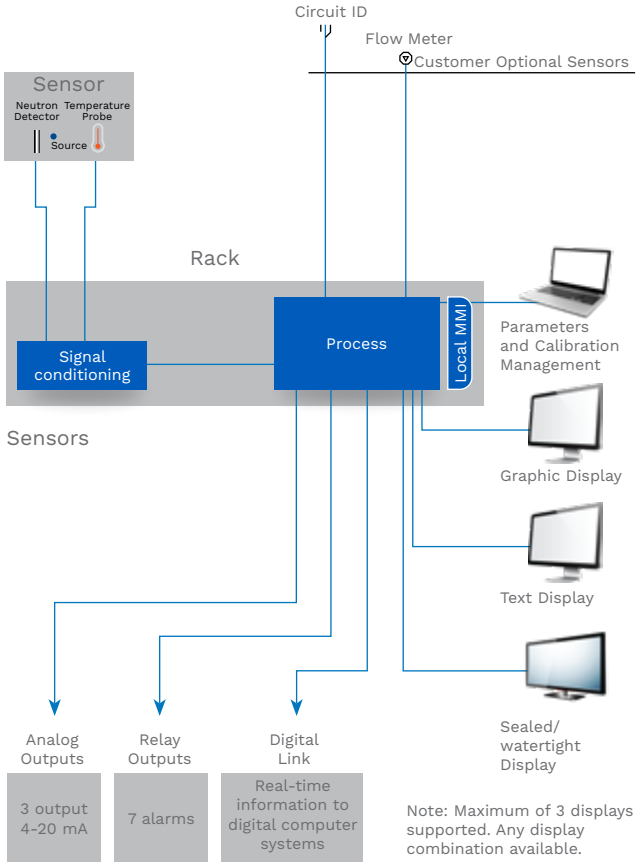
For the Cb concentration measure two options are available:

- A sensor, made up of a tank through which the fluid to be analyzed flows. The sensor support is anchored to the floor.
- A surface sensor, directly installed on the pipe.

In both cases, the fluid to be analyzed passes through the sensor containing a neutron-emitting source, and the resulting flux is measured by a neutron detector. The information acquired by the detector is then processed by our conditioning and processing electronics to determine the boron concentration in the fluid.

With the differential option, the first sensor, without source, allows the detection of any neutron background noise originating from the fluid to be analyzed (e.g., presence of fission products/ casing breach), which may interfere with the main sensor's measurements. The measurement electronics then compensate the measurement performed for this neutron background noise.

Example of Framatome boron meter architecture



Measurement accuracy, safety and reliability

Architecture

Boronline boron meter is a modular solution, composed of standards components.

There are two different versions available, so that the system architecture can be adapted, depending on customer requirements and needs:

- Boronline HT
- Boronline HE

Two different sensors are available:

- Boronline HT: A tank sensor, made up of a tank through which the fluid to be analyzed flows, and a sensor support anchored to the floor
- Boronline HE: A surface sensor, directly installed on the nuclear plant pipe

Three different displays are available:

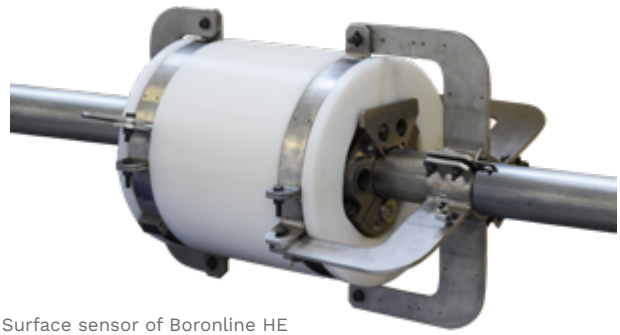
- A “text” 3.8” display, allowing the digital display of calculated data
- A “graphic” 10.4” display, allowing the digital display of the calculated data and the operational “lithium/boron” graph
- A “sealed” 5” display, that is resistant to dust and water splashes, for use in severe environments, allowing the digital display of calculated data

In every case, a Boronline system includes the following elements:

- A 19” rack, containing conditioning and processing electronics
- A sensor
- A neutron source
- A neutron detector
- A temperature probe
- One or more displays (3 max)

Framatome also proposes two additional tools for use during parameter modification and calibration phases:

- A calibration bench
- A calibration and settings station (PCP)



Surface sensor of Boronline HE

Sensor of Boronline HT, comprising a tank, a neutron source and a neutron detector

Functions

Common electronics allowing for implementation of many functions.

Acquisition of detector pulses

The pulses generated by the detector are conditioned before being processed.

Fluid temperature acquisition

Fluid temperature is acquired to allow temperature compensation of the calculated concentration.

Calculation of boron concentration

Boron concentration is a function of the detector's pulse count rate.

Filtering of boron concentration

The count rates obtained by the described process are the result of a statistical process and therefore fluctuate intrinsically. Digital filtering is applied to obtain both a high degree of measurement stability and a short response time.

Setpoint input

A command allows the operator to adjust the set point for dilution detection (DCb dilution alarm).

Displays

All values/alarms produced are distributed over a network of displays. This network comprises a maximum of three displays, whose type can be chosen by the customer: text, graphics, sealed.

Transmission to the unit computer

All values/alarms produced are distributed over a dedicated link to the plant computer. The computer may then process all data made available by the Boronline boron meter.

Transmission to recorders

The calculated Cb values are transmitted to any kind of customer recorders over 4-20mA links.

Response time

The intrinsic response time (instant Cb measurement for tank fluid) for the Boronline boron meter depends on the system's physical configuration (detector type) and the system settings applied. As an indication, it is a few seconds for a boron neutron proportional detector and several tens of seconds for a fission chamber detector.

Full scale

Full scale (maximum measured Cb) may be customized. Maximum full scale is set to 10000 ppm (natural boron).

Self-tests/diagnostics

The system comprises self-testing and diagnostics functions (Overall Test and DCb Test).

Calibration, adjustment and settings

Before the system is installed, settings that are dependent on the installation architecture are applied at the factory. When the system is first operated, customer settings are applied on site. This relates to all the operational parameters.

Adjustment and calibration is performed periodically on site (about every five years).

Units handled (mg/l; ppm; g/l)

The units used by Boronline can be chosen by the operator.

Low flow alarm

As an option, the system can handle data of the type "low flow" originating from a customer flowmeter, for display and communication to the unit computer.

Circuit number

As an option, the system can handle data of the type "circuit number" originating from customer indexed valves, used to select the desired sampling circuit for display and communication to the unit computer.

A large number of functions
that address customer needs.

Performance

Boronline is a modern digital technology to ensure safety and reliability.

Reduced response time

As a result of continuous measurement, the operator has real-time knowledge of the concentration in the measured circuit.

System accuracy

Final system accuracy is determined during installation, as it depends on several on-site settings. For information purposes, best accuracy values are:

- For HT sensor
  - Calculations/display of element boron:
    ± 12 ppm from 0 ppm to 1000 ppm
    ± 1.2 % of the measured value from 1000 ppm to Full Scale
  - Calculations/display of Boric Acid (natural enrichment):
    ± 60 ppm from 0 ppm to 6000 ppm
    ± 1 % of the measured value, from 6000 ppm to Full Scale

System accuracy is ensured through periodic calibrations. For optimum precision, we recommend the performance of a manual verification every month and full calibration every five years.

- For HE sensor
  - Calculations/display of element boron:
    <= 2 % of the measured value in range [1800 ; 2600] ppm

Accuracy is defined as standard deviation including all influencing parameters, as defined by “NF ISO/CEI Guide 98/Part3.”

Correction factor for calculated boron concentration

Due to its intrinsic physical principle, the boron meter is sensitive to the concentration of boron 10 only. Dilution does not change the boron 10/natural boron ratio. Nevertheless, depending on the reactor’s operating conditions, the B10/B11 ratio may change (so-called “boron depletion”). A correction factor allows the calculated boron concentration to be corrected.

Increased safety

Boronline allows the measurement and monitoring of boron concentration throughout all phases of the reactor operation without the need to handle hazardous substances.

Measurement precision, reliability and stability

The measurement performance has been improved thanks to the use of a proportional counter detector and to an upgraded digital signal processing.

The ‘Dilution’ alarm

It has been developed to detect unexpected homogeneous dilution, which may lead to a loss of anti-reactivity margin and if the situation worsens a reactor excursion incident, regardless of the operation phase of the reactor.

Temperature correction function

It allows permanent monitoring of the temperature of the fluid to be analyzed. An automatic correction algorithm allows temperature effects on boron’s neutron absorption coefficient to be cancelled out, allowing the specified precision to be maintained for the entire operating temperature range for the fluid.

Hydraulic connection between the sensor and the sampling lines

The piping ensures zero radiation from short half-life fission products, from the primary sampling point to the sensor.

Greater performance in terms of precision, response time and reliability.

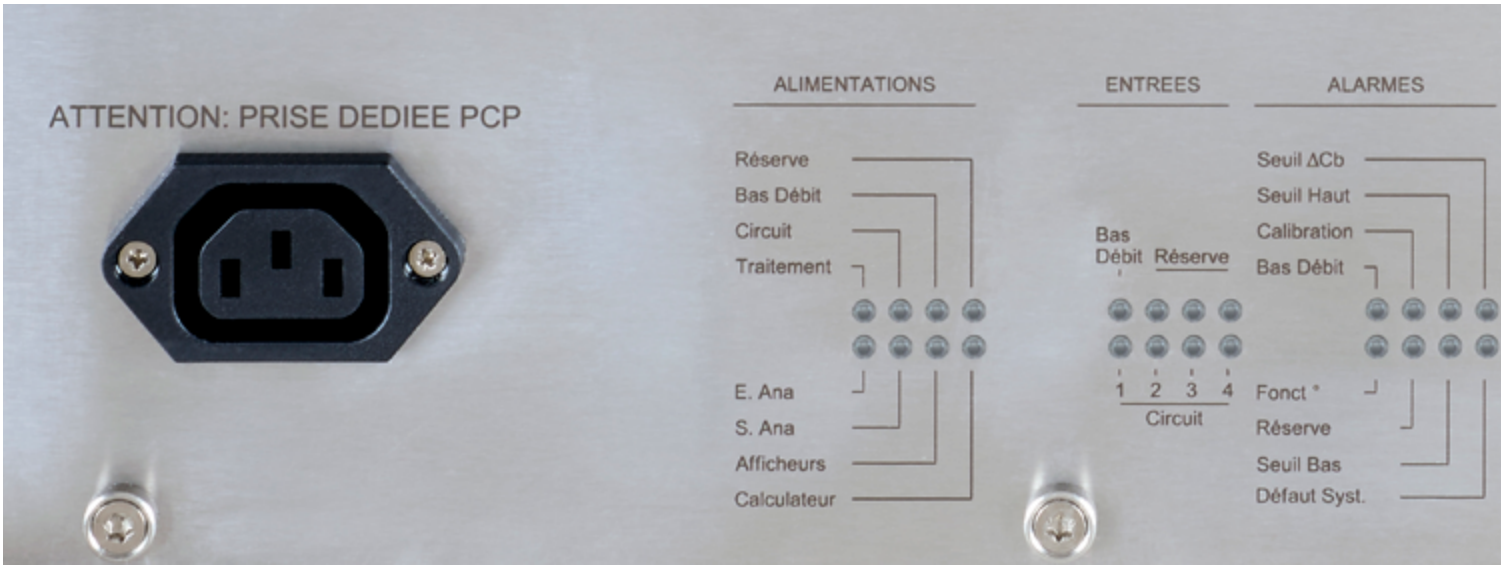
Technical specifications

Two options of sensors are available, enabling system architecture to be adapted to customer requirements.

Boronline HT

Tank sensor specifications

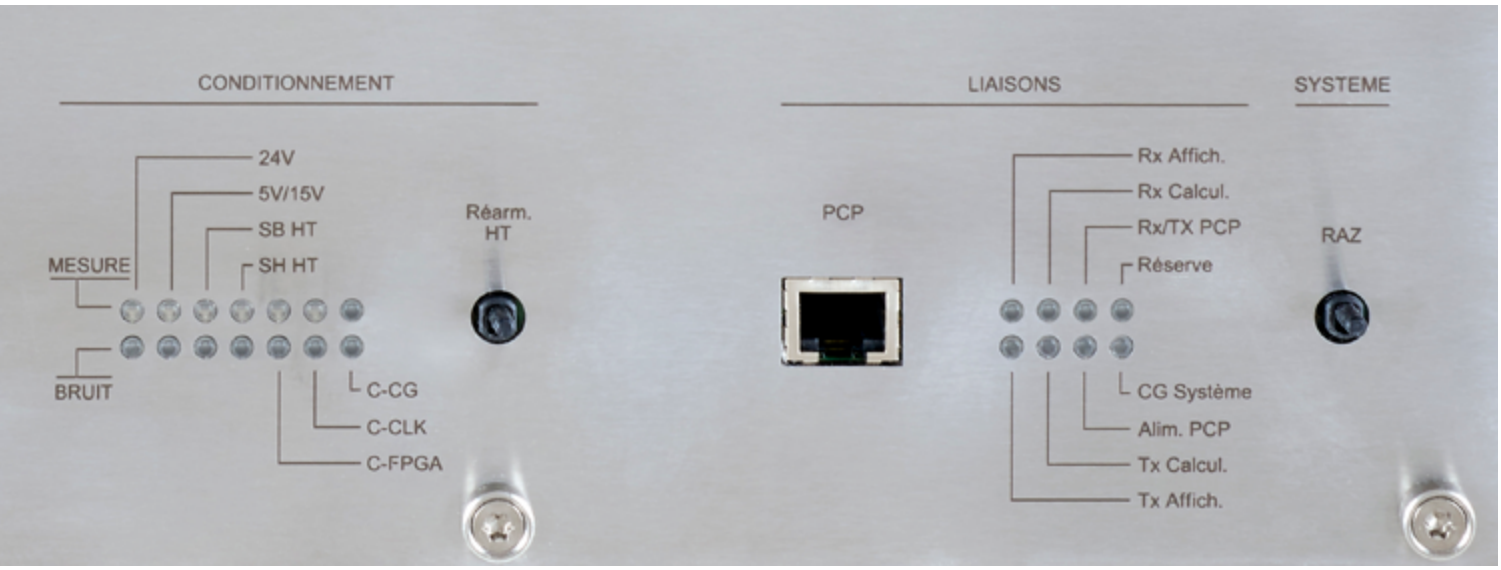
Tank sensor		
Dimensions	520 x 520 x 1320 mm (Length x Width x Height)	
Weight	Approx. 150 kg	
Hydraulic connection	By weld or swagelock rapid connection ((Φ_{ext} = 16mm, L=25.4mm). In both cases: stainless steel tube DN 3/8"(Φ_{ext} = 17.14mm, thickness 2.31mm).	
Sensor material	Stainless steel: ANSI 304L / AFNOR Z3 CN18-10.	
Sensor volume	Approx. 4.2 litres	
Nominal tank pressure	35 bar maximum	
Normal fluid temperature	80°C maximum	
Neutron source		
Type	AmBe, 111 GBq (3Ci)	
Dimensions	Φ = 32mm , L = 70mm	
Flux density	6.6 10^6 $n.s^{-1}.4\Pi$	
Neutron detectors		
	Proportional counter	**Fission chamber**
Neutron sensibility	4 $c.s^{-1}/n.cm^{-2}.s^{-1}$	10^{-1} $c.s^{-1}/n.cm^{-2}.s^{-1}$
Gamma dose rate	10 Gy/h max	10^4 Gy/h max
Operating voltage	800 V nominal	600 V nominal
Temperature	200°C max	250°C max
Use	Not usable in the presence of a highly radioactive fluid (gamma dose rate > 10Gy/h).	Usable in the presence of a highly radioactive fluid (gamma dose rate > 10Gy/h).
Temperature probe		
Probe type	Pt100	
Pt100 element diameter	6 mm	
Temperature measurement range	+10°C to +80°C	



Boronline HE

Surface sensor specifications

Surface sensor	
Dimensions	600 mm (length) x 400 mm (cylinder external diameter)
Weight	Approx. 100 kg
Mechanical characteristics	On-pipe sensor, usable on 3” and 4” pipes
Sensor material	Biological shield: High-density polyethylene (HDPE) Mechanical on-pipe support: stainless steel 316L
Normal fluid temperature	80°C (nominal value); up to 110°C (maximum value in incident condition)
Neutron source	
Type	AmBe, 111 GBq (3Ci)
Dimensions	Φ = 32mm , L = 70mm
Flux density	6.6 10^{6} $n.s^{-1}.4\Pi$
Neutron detector: Proportional counter	
Neutron sensibility	4 $c.s^{-1}/n.cm^{-2}.s^{-1}$
Gamma dose rate	10 Gy/h max
Operating voltage	800 V
Temperature	200°C max
Use	Not usable in the presence of a highly radioactive fluid (gamma dose rate > 10Gy/h).
Temperature probe	
Probe type	Pt100
Pt100 element diameter	6 mm
Temperature measurement range	+5°C to +110°C



Technical specifications

Standard components and calibration tools

Rack specification

Mechanical characteristics				
Width	19” rack			
Height	3U (i.e., 132.5 mm)			
Depth	471 mm			
Power consumption (approx.)	50W / 230V AC (rack assembly alone)			
Ambient temperature	40°C max. (ambient to cabinet) 55°C max. (ambient to rack)			
Inputs				
	Connection		**Cable type**	
Detector	HN connector		Coaxial cable	
Temperature probe	9 pin Sub-D connector		Pt100 4-wire (2-wire possible option)	
Flow alarm (optional)	Screw terminal		Dry contact (potential-free), Closed on alarm	
Circuit number (optional)	Screw terminal		Dry contact (potential-free), Closed on circuit number	
Outputs				
	Number	Connection	Type	Values
Analog	3	15 pin Sub-D	4-20mA	- Filtered boron10 concentration - Filtered natural Boron Concentration - Boron concentration setpoint
Binary	7	Screw terminal	1 NO+NC contact for each output	Alarms: - Low threshold overshoot - High threshold overshoot - Dilution - Low flow rate - Operational alarm - System fault - Calibration in progress
Displays	3	9 pin Sub-D 9	RS485-Modbus	(available on demand)
PCP	1	RJ45	RS485	
Digital plant computer	1	9 pin Sub-D	RS485-Modbus-RTU	

Display specifications

	Text screen	Graphics screen	Sealed display
Data displayed	Displays all the data calculated by the central unit (calculated Cb, dilution set point, alarms, etc.)	Displays all the data calculated by the central unit (calculated Cb, dilution set point, alarms, etc.). Also displays the operational Lithium/Boron diagram.	Displays all the data calculated by the central unit (calculated Cb, dilution set point, alarms, etc.). The display is watertight (IP65).
Dimensions	Front panel 169 x 169 mm	Front panel 300 x 300 mm	Case 280 x 180 mm
Depth	248 mm	133 mm	118 mm
Type of mounting	Plate mounted	Plate mounted	Wall-mounted (anchor plate included)
Panel cut-out	142 x 142 mm	278 x 277 mm	n/a
Anchor screw separation	152 x 152 mm	287 x 287 mm	300 x 210 mm
Power consumption	Approx.20W/230V AC; 20W/120V AC	Approx. 25W/230V AC; 20W/120V AC	Approx. 25W/230V AC; 20W/120V AC
Ambient temperature	40°C	40°C	40°C

Maintenance tools

	Function	Characteristics
PCP	**Settings are programmed using a PC. This PC is supplied with "PCP" Framatome software, allowing settings management and periodic calibration of the equipment.**	**- Standard commercially-available portable PC** **- The portable PC is powered using an AC outlet on the Boronline rack front panel** **- Power consumption is approximately 150W / 230VAC**
Calibration bench	Mobile unit "Calibration bench" is required for Boronline T calibration phases. During this phase, the sensor must be disconnected from the circuit to be analyzed and hydraulically connected to the Calibration Bench.	Overall dimensions (Length x Width x Height): 1100mm x 580mm x 900mm Power consumption: Approx. 1200W / 230VAC

Standards

Developed according to international & local nuclear standards and regulations

Boronline HT - Tank sensor

- ESPN Decree of 12 December 2005 (ESPN = Nuclear Pressure Equipment): Category 0, level N3.
- European Directive PED 97/23/EC (PED = Pressure Equipment Directive): Category article 3.3.
- ASME:
  - Design (including pressure calculation note): ASME VIII version 2001.
  - Procurement: ASME II version 2007.
  - Manufacture: ASME VIII version 2007.
  - Qualifications (welders and processes): ASME IX version 2007
  - Verifications (methodology): ASME V version 2007.
  - Verifications (acceptance criteria): ASME VIII version 2007.

Boronline HE - Surface sensor

- RCC-E 2005: Chapter B3000 and chapter B4000 (K3 seismic level).
- Functional and seismic tests have been performed on the basis of standards RCC-E 2005 and IEC 60780.
- RCC-M: volume H, S2 level.

Electronics

Electronic components meet the requirements of the following standards:

- RCC-E 2005: seismic level (chapter B4000)
- CRT 80.C.012.00, v2005

Software

Software processing system complies with the development requirements of standards RCC-E 2005 category C2, IEC 62138 category B.

Experience

Boronline is the culmination of over 30 years of experience.

Boronline is the fourth generation of boron meters developed by Framatome.

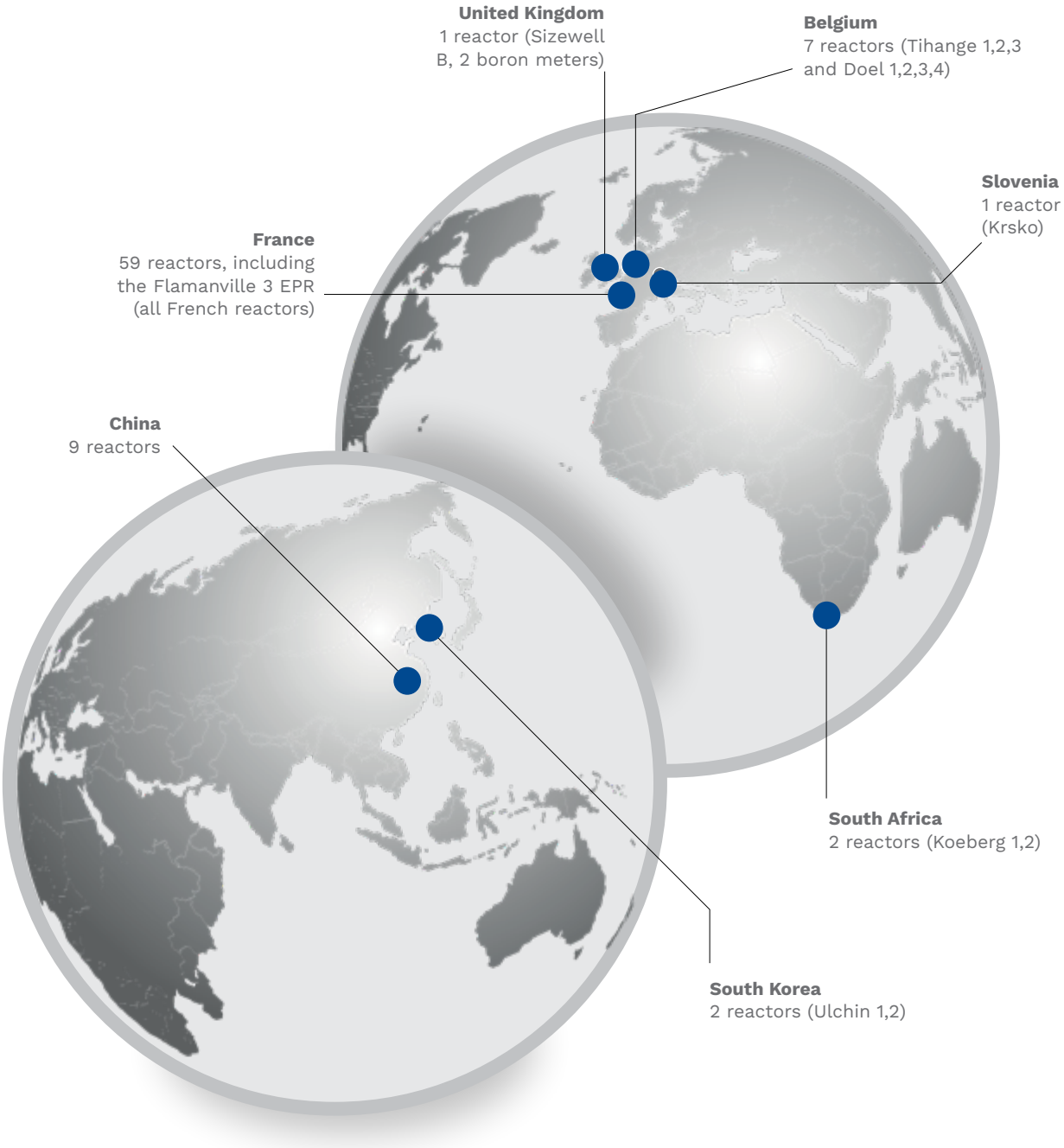
Its development is the culmination of over 30 years of experience, during which we have supplied boron meters to more than 80 nuclear reactors around the world.

The Boronline boron meter is designed to adapt to all types of nuclear reactor, both in the frame of a refurbishment and for installation on a newly built nuclear reactor.

Boronline will be installed on the French EPR at Flamanville 3.

In 2015, Boronline was selected by EDF to supply boron measurement systems for the entire fleet of 900MW nuclear reactors in France.

References



Framatome is an international leader in nuclear energy recognized for its innovative solutions and value-added technologies for the global nuclear fleet. With worldwide expertise and a proven track record for reliability and performance, the company designs, services and installs components, fuel, and instrumentation and control systems for nuclear power plants. Its more than 15,000 employees work every day to help Framatome's customers supply ever cleaner, safer and more economical low-carbon energy.

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