Development of a long-life, moveable, wide-range, in-core fission chamber.

For safety-related source and intermediate range indication in BWRs, Advanced, and Small Modular Reactors.

As implemented in ABB-Atom BWRs

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Basis for Development

Reliable, economic core design calls for I&C with improved redundancy and increased efficiency. Use of neutron detectors capable of monitoring both source and intermediate range reduces the number of detectors, core space, and reactor penetrations. The availability of a moveable detector allows for detector storage in low flux areas during power operation - increasing detector lifetime and reducing detector replacement frequency.

Detector Design

Photonis coordinated with KWD Nuclear Instruments Sweden to develop a low noise fission chamber with sufficient neutron sensitivity on a mineral insulated cable that could be driven into and out of the core to provide detector life >10 years. The detector is installed in a dry tube and mated to a clever drive mechanism that minimizes space under vessel.

Nuclear Characteristics			
Sensitivity to Thermal Neutrons [1]	Pulse mode	10^{-3}	$c.s^{-1}/n.cm^{-2}.s^{-1}$
	Fluctuation mode	$4x10^{-29}$	$A^2.Hz^{-1}/n.cm^{-2}.s^{-1}$
	Current mode	10^{-16}	$A/n.cm^{-2}.s^{-1}$
Neutron Flux Ranges	Pulse mode [2]	$10^3 - 10^8$	$n.cm^{-2}.s^{-1}$
	Fluctuation mode	$10^7 - 3x10^{12}$	$n.cm^{-2}.s^{-1}$
	Current mode [3]	$10^9 - 10^{13}$	$n.cm^{-2}.s^{-1}$
Gamma Sensitivity		10^{-10}	$A/Gy.h^{-1}$
Exposure Limits	Thermal neutrons [4]	$max\ 2x10^{19}$	$n.cm^{-2}$
	Gamma exposure	$max\ 10^9$	Gy
	Gamma dose rate	$max\ 10^4$	$Gy.h^{-1}$

Electrical Characteristics			
Insulating Resistance at 400 VDC [5]	at 20°C	$min\ 10^{12}$	Ohm
	at 350°C	$min\ 5x10^8$	Ohm
Operating Voltage	Nominal up to 600°C	400	VDC
	Maximum at 20°C	600	VDC
	Limit with no radiation	800	VDC
Charge Collection Time [6]		150	ns
Cable Capacitance		170	pF/m
Cable Characteristic Impedance		50	Ohm

Mechanical and Physical Characteristics		
Detector	Case, electrodes	Stainless steel (Co<0.05%)
	Insulators	Al_2O_3
	Sensitive layer	U > 90% enriched in ^{235}U
Cable	Type	Coaxial, high immunity
	Insulator	MgO
	Curvature radius [7]	min 60 mm
Connector	Insulator	Al_2O_3

Figure 1: Technical Specifications

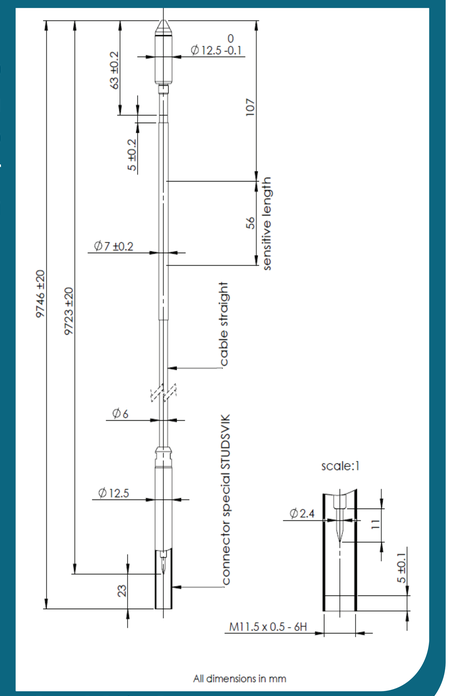

Figure 2: Outline Drawing

Test Results and Detector Performance

The detector was tested at the Swedish Bärseback BWR starting in 1975 and is now in use with all ABB-Atom BWRs in Sweden and Finland. The detector shows excellent noise immunity, and high sensitivity enabling sufficient overlap between ranges of power to allow seamless transition from one operating mode to the next.

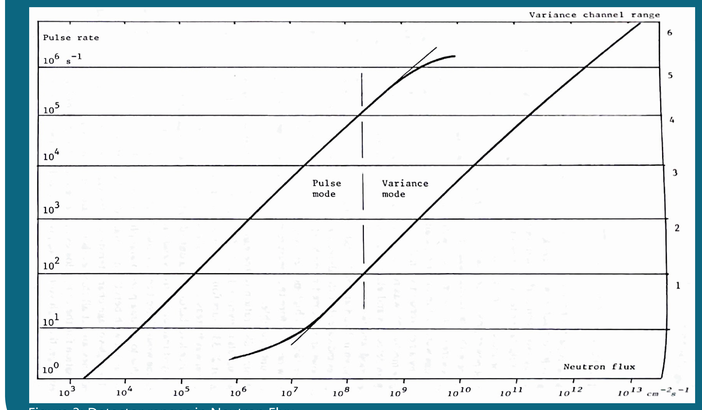

Figure 3: Detector ranges in Neutron Flux

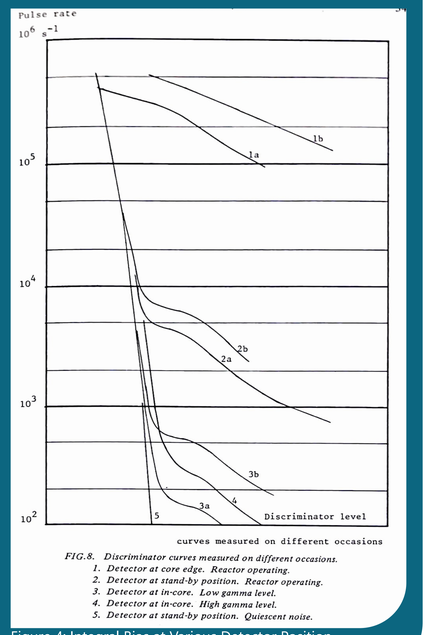

FIG.8. Discriminator curves measured on different occasions.
1. Detector at core edge. Reactor operating.
2. Detector at stand-by position. Reactor operating.
3. Detector at in-core. Low gamma level.
4. Detector at in-core. High gamma level.
5. Detector at stand-by position. Quiescent noise.

Figure 4: Integral Bias at Various Detector Position

Ref: Bjorkman, J. (1978). International Symposium on Nuclear Power Plant Control and Instrumentation, vol. 2.