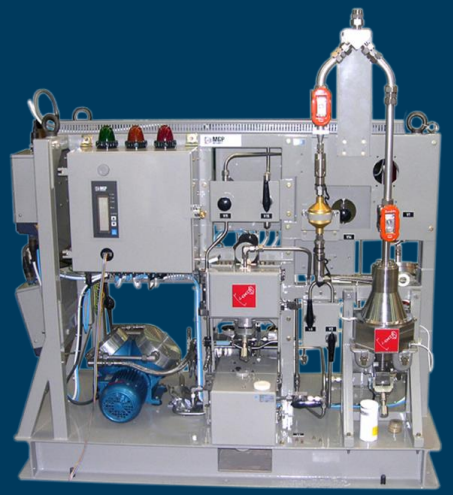
I&C “Safety, Protection & Control” Neutron Instrumentation and proTK™

Jörg von Loeben

MIRION TECHNOLOGIES



Reactor Instrumentation & Control

Our ultra-precise instruments help nuclear operators maintain reactor safety and peak operational performance.

- Radiation Monitoring Systems
- Tritium Measurement
- Neutron Flux Monitoring Systems
- In-Core & Ex-Core Detectors
- Nuclear Containment Seals
- Electrical Penetrations

I&C - Safety Protection & Control

We focus on providing the safest products for radiation and reactor monitoring.

Ex-/In-Core Neutron Detectors

Cabling and Connectors (harsh and mild conditions)

Digital Measurement Channels

Electrical Penetrations Assemblies

Nuclear Service Sensors

I&C - Safety Protection & Control

Full-service provider for NIS and Safety Systems

Horseheads (USA)

- Ex-Core Detectors incl. Fission Chambers
- In-Core (Miniature Fission Chamber)
- Cabling

Cambridge (Canada)

- In-Core Neutron Detectors and Reactor Feedthroughs
- Nuclear Service Sensors
- Analog Measurement Channels

Buffalo (USA) & Fussy (France)

- Electrical Penetrations

Munich (Germany)

- Ex-Core Detectors
- Digital Measurement Channels
- Project Management & Engineering
- RMS Detectors and Safety Systems

Recent Projects & Field-Proven Products

- Awarded: RMS & NFMS Systems for the TerraPower Natrium Reactor
- US Advanced Reactors projects and variety of upgrades & replacements for American research reactors (e.g. MIT, Purdue,…)
- Qualified key supplier of Ex-Core detectors for the Framatome EPRs and Westinghouse design NPPs
- 23,000+ EPAs installed in > 300 nuclear plants
- In-Cores for North American PWRs and CANDUs
- Key supplier for the Boronmeters for the French Nuclear Power Plants and US PWRs
- Several major Lifetime Extension projects for Belgium power plants from engineering till site acceptance test (NIS, safety-RMS and steam generator leakage monitoring)
- Neutron flux instrumentation for several research reactors worldwide
- New: **Partnering with Westinghouse for digital NIS upgrade in the US**

In the News

Westinghouse

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Westinghouse is Partnering with Mirion Technologies

June 25, 2025 by Westinghouse Electric Company

Categories: Blog

Westinghouse and Mirion Technologies Inc. are collaborating to supply advanced digital Excore Nuclear Instrumentation Systems (NIS), leveraging the state-of-the-art Mirion proTK™ product line to upgrade the aging NIS which exist today in operating nuclear power plants.

Mirion Technologies
265 Follower:innen
3 Wochen •

We are honored and excited to share that we've been awarded the contract to supply the Radiation Monitoring System (RMS) and the Nuclear Instrumentation System (XIS) for the Natrium Reactor ... mehr

Übersetzung anzeigen

TerraPower
59.229 Follower:innen
3 Wochen •

🎉 Procurement Milestone 🎉 TerraPower has awarded contracts to three additional suppliers for the Natrium® Reactor Demonstration Project, completing 100% of the long lead procurements necessary for ... mehr

Übersetzung anzeigen

TerraPower Awards Another Round of Vendor Contracts for Natrium® Reactor, Completes...
terrapower.com

November 16, 2023

MIRION

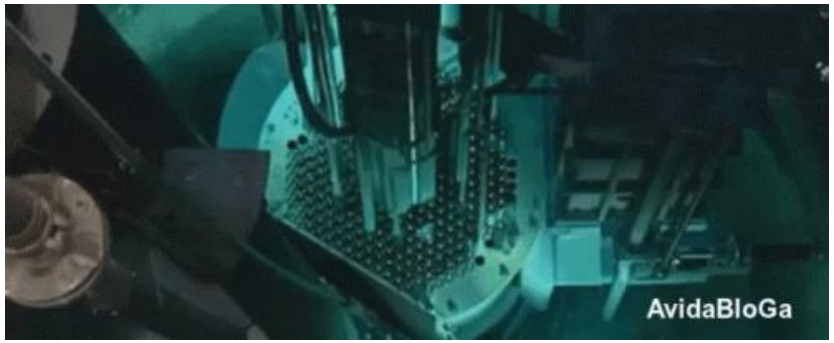
Mirion Technologies Signs Agreement with TerraPower for Molten Chloride Reactor Experiment

Contract to provide Nuclear Instrumentation System Design and Fabrication that will Advance the World's First Critical Fast-Spectrum Salt Reactor

Neutron Instrumentation System (NIS)

Introduction

Neutron Flux Density …



What is it?

- A direct and fast measurement of the reactor power
- Reactor “off” to 100 % full power: >10 orders of magnitude

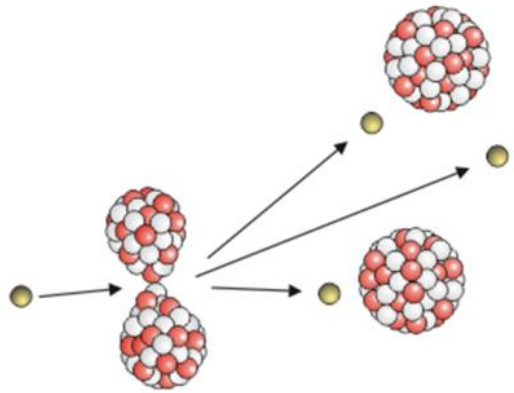
Why measure it?

- Too many neutrons = reactor might overheat; too few = not enough power
- Too fast increase = chain reaction might get out of control

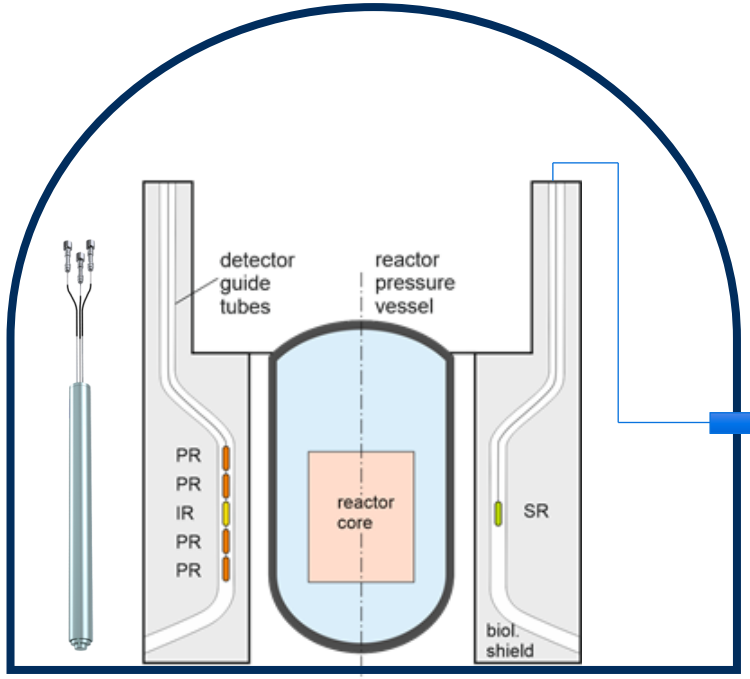
→ The Neutron Instrumentation System helps control the reactor power

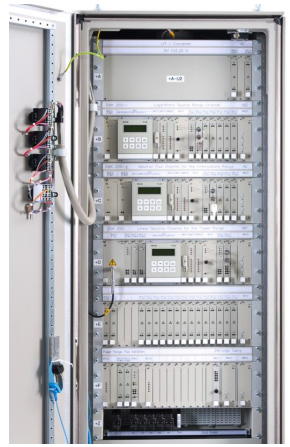
→ It shuts down the reactor if something goes wrong (→ Safety Relevant)

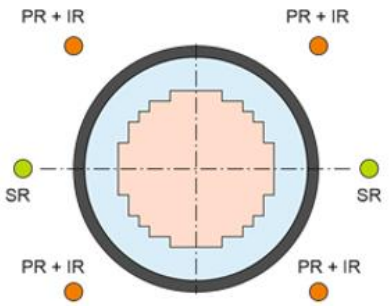
→ It helps balance the fuel and keep operation safe and efficient



Typical NIS (NFMS) of a PWR

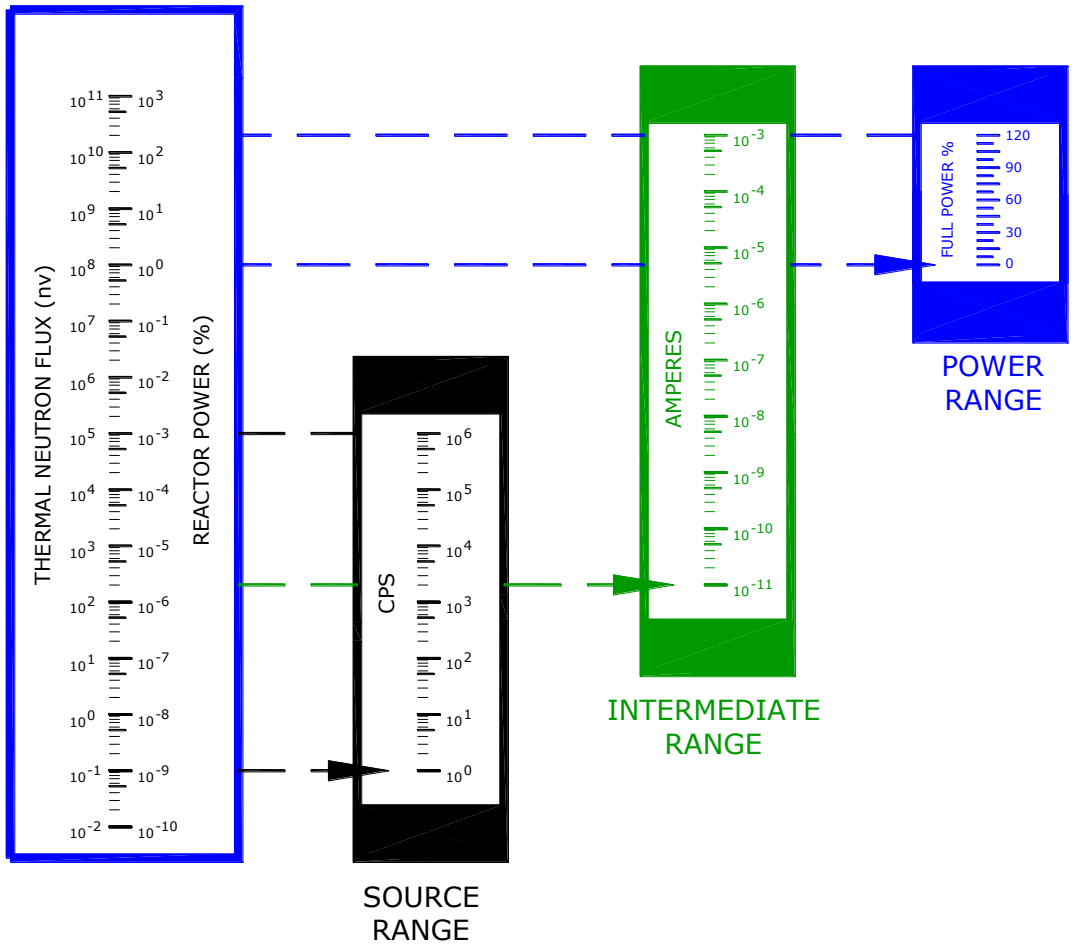






NFMS - The Challenge

- Reliable and accurate determination of the reactor power, expanding over 10-12 orders of magnitude
- Integration in existing I&C infrastructure; compatibility
- Provide reactor trip safety signal (SCRAM)
- Withstand harsh environments and high radiation (detectors + cables)
- Compliance to a variety of strict nuclear standards
- Qualification and life cycle for 40+ years of operation
- Fast response times comparable to Analog Systems (milliseconds)
- Convincing strategy to improve trust in digital safety systems



proTK™ - Digital NIS

Digital, modular, accurate, fast, testable and reliable

System Overview

- Scalable 19" rack-mounted multiprocessor platform for radiation and neutron flux monitoring
- Modular and third-party compatible, enabling seamless 1:1 form-fit-function replacement
- Real-time performance with fixed 2.5 ms / 5 ms cycle times
- Developed, qualified and certified to international nuclear safety standards (1E, CAT A)
  - IEC 61513 / IEEE 603;
  - IEC 60880 / IEEE 7-4.3.2; IEEE 1012
  - IEC/IEEE 60780-323; IEC/IEEE 60980-344
- The proTK™ Platform: Built on four distinct variants
  - Start-up (DAK 260-i), Intermediate (DAK 260-g), Power (DGK 260)
  - Wide (DWK 260)

✓ *Simple & Clear*

✓ *Deterministic & Fast*

✓ *Reliable*

✓ *Safe*

✓ *Simplified testing*

✓ *Independent V&V; Certification*

proTK™ delivers all the benefits of digital signal processing with proven reliability

Mirion Technologies - Munich

Mirion Technologies Munich
Full-service provider for Radiation, Process and Neutron Flux Monitoring

- Home of the proTK™ product line
- 70 years of experience, 80 experts and talented professionals
- Specialized in highly qualified, safety related radiation protection and neutron flux instrumentation
- Autonomous managing of complex, customer specific, nuclear projects
- Feasibility studies, simulations, technical reasonability, requirements management and realization (from first budgetary to site acceptance)
- Dedicated Teams for R&D / Engineering and nuclear qualification
- Production, Test and Service
- Certified to all relevant nuclear QA standards
(ISO 19443/9001, 10CFR50App.B, 10CFR21, NSQ-100, KTA 1401)

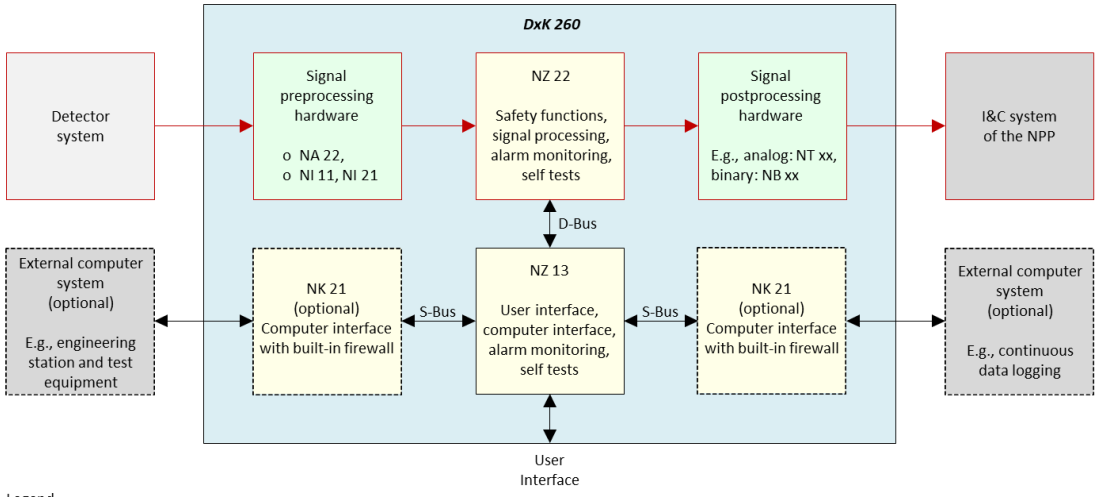
Headquartered in Atlanta, Mirion employs approx. 2,800 people and operates in 12 countries.
Mirion is a global leader in radiation safety, science and medicine, empowering innovations that deliver vital protection while harnessing the transformative potential of ionizing radiation across a diversity of end markets.

proTK™ - Digital NIS

Digital, modular, accurate, fast, testable and reliable

Software Architecture & Key Features

- SW is pre-developed, V&V'ed and certified
- **Common** base SW across the proTK™ platform
- Project-specific configuration with user-adjustable parameters
- Continuous self-diagnostic; redundant intrinsic design
- Structured test strategy for simplified maintenance



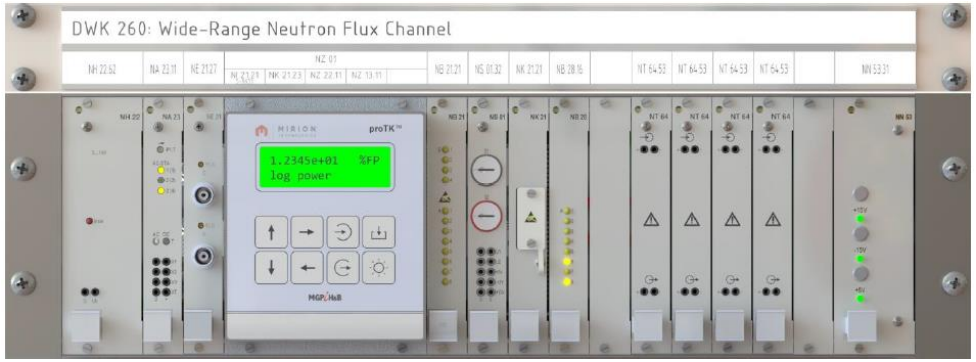
Field Proven Experience

- 35 years of digital safety systems in the field
- 3500+ operational years across 400+ safety critical systems
- 5x Westinghouse-designed European NPPs operating with proTK

proTK™ delivers all the benefits of digital signal processing with proven reliability

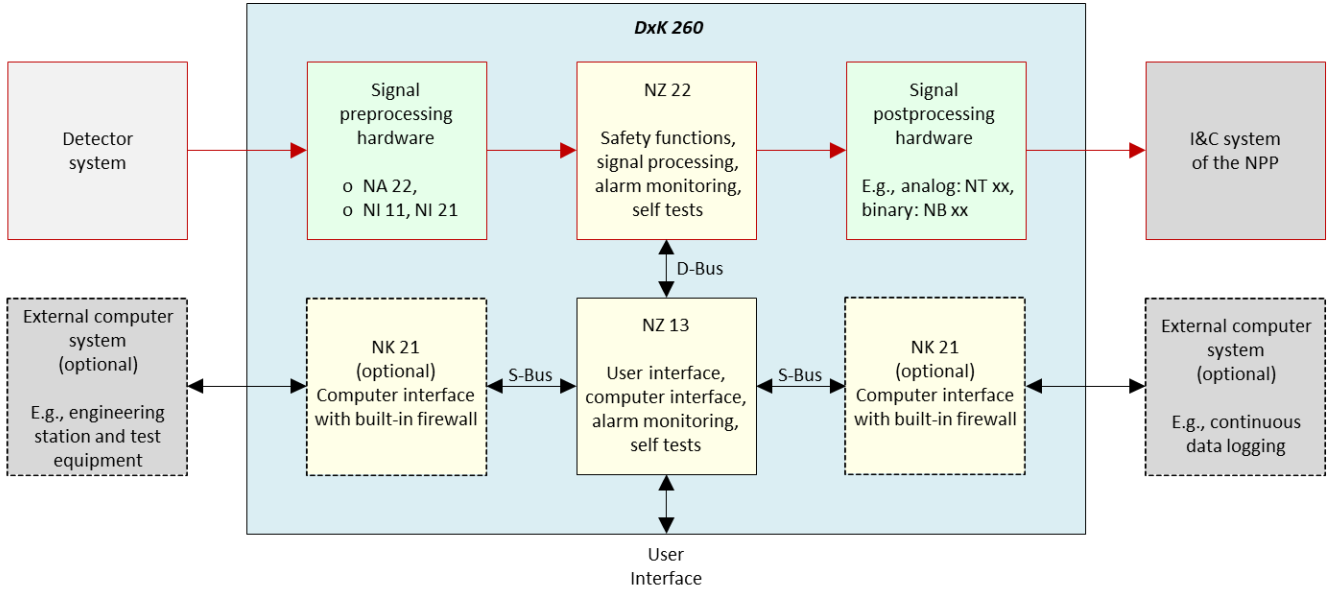
proTK™ - Basic Architecture

Neutron Flux

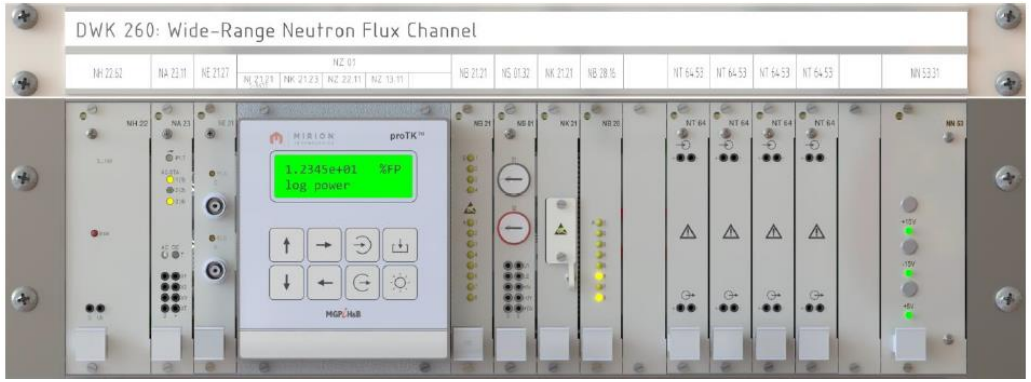


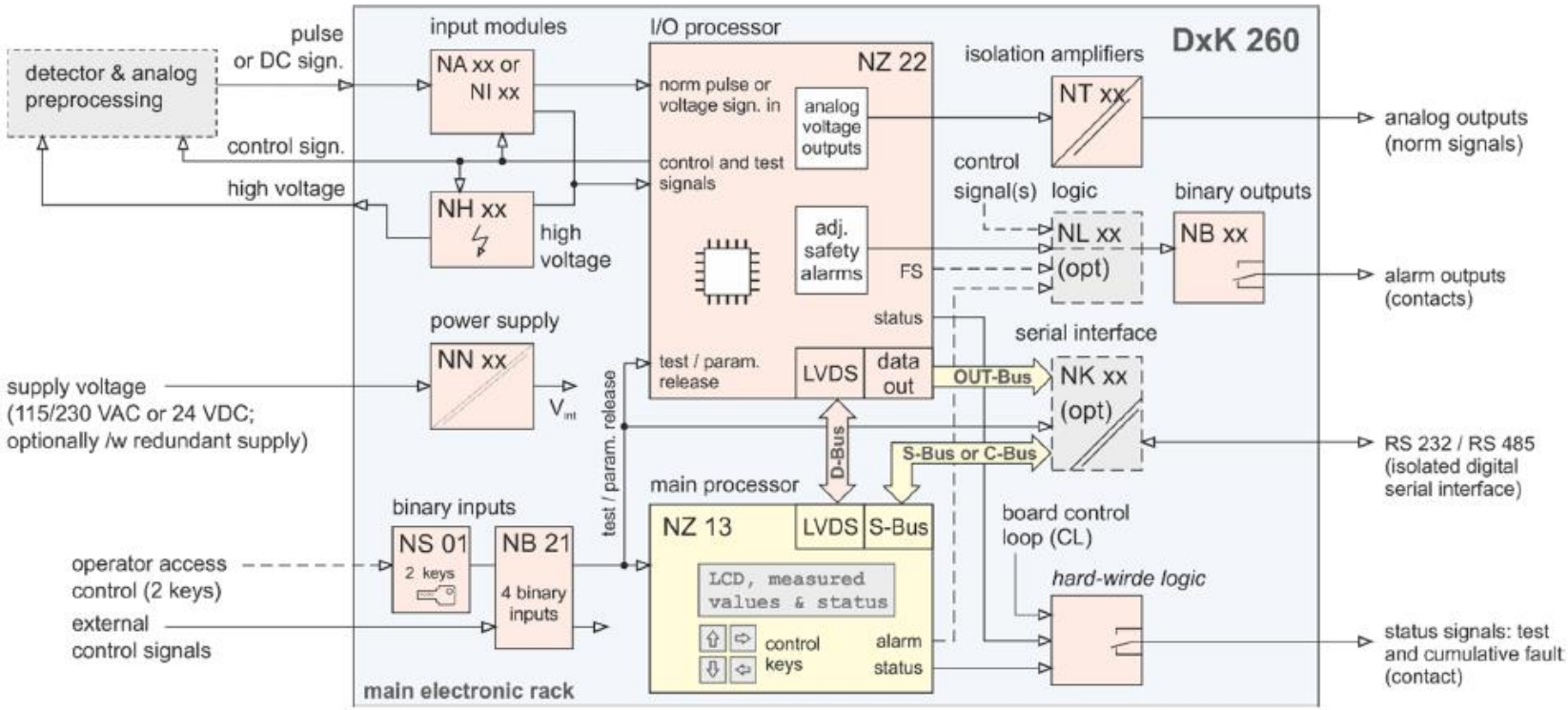
Reactor Power / Change Rate

Alarm / SCRAM

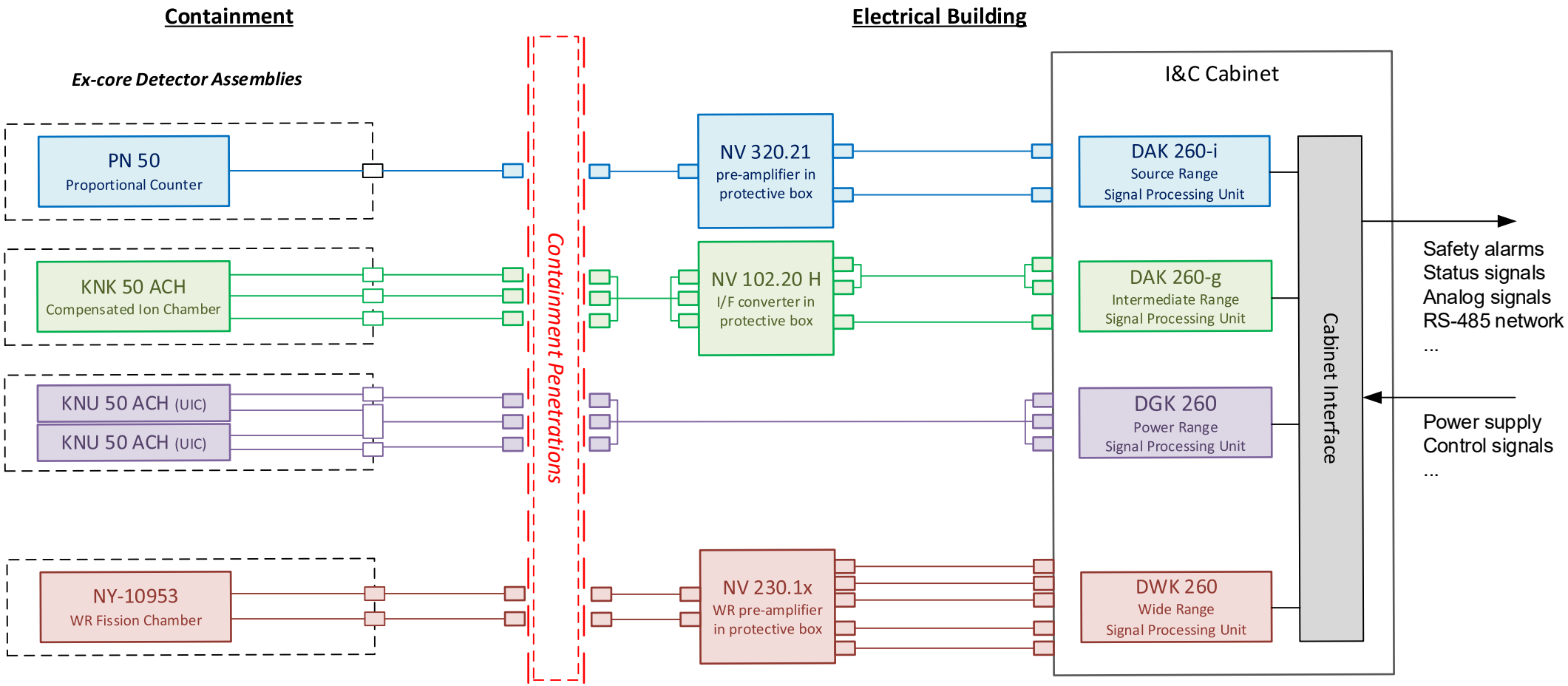


Basic Architecture of the proTK™ / 260 series





proTK™ - Typical NFMS Implementation



proTK™ - NFMS Detectors & Cables

A dedicated team of physicists and mechanical engineers develop detectors to fit project requirements and drive innovation

Qualified to IEC/IEEE 60780-323, IEC 60515, IEEE-344, IEC-60980

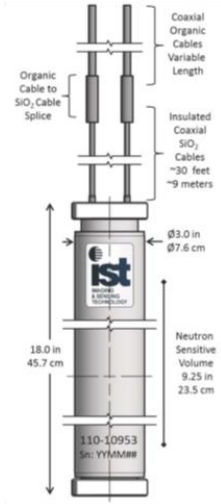
Can be customized to meet specific requirements

TKC – Mineral Insulated Coax Cables

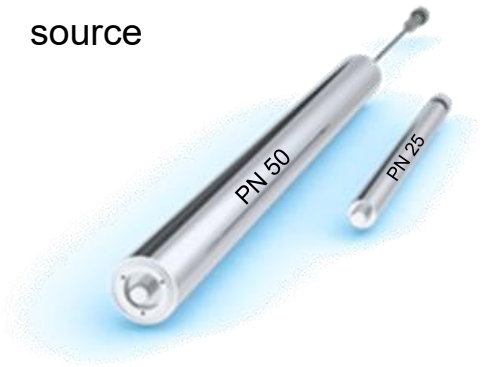
- B-10 and BF3 Proportional Counters for neutron detection in source range
- B-10 Neutron Ionization Chambers for neutron flux monitoring in intermediate and power range
- Fission Chambers for source and wide range
- In-cores (miniature fission chambers and SPNDs)
- Proven and customizable design of detector assemblies

- High-quality detector cables
- Special in-organic (MI-) cables for harsh environments (in containment)

wide



source



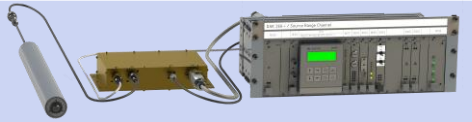
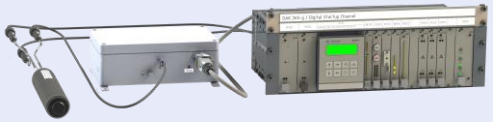
intermediate

power

proTK™ - Typical NFMS Application

Ex-Core Neutron Flux Monitors

- Reliable and redundant measurement of the reactor power and change rate in the source, intermediate and power range (typical 1E-9 % to 150 % full power)
- Providing reactor trip safety signals (SCRAM)

Neutron Flux Range				Monitor	Detector	proTK Channel	Quantities	
Full Range	Start-Up	Source	1E-09 … 1E-03 %FP 1E-01 … 1E+05 nv	SRM 50x	B-10 PC **PN 50**	Start-up Channel **DAK 260-i**	2 Channels 2 Detectors	
		Interm.	1E-06 … 150 %FP 1E+02 … 1E+10 nv	IRM 50x	B-10 CIC **KNK 50 ACH**	Start-up Channel **DAK 260-g**	4 Channels 4 Detectors	
	Power	Power	1 … 150 %FP 1E+08 … 1E+10 nv	PRM 50x	B-10 UIC **KNU 50 ACH**	Power Range Channel **DGK 260**	4 Channels 8 Detectors	
	Wide		1E-08 … 150 %FP 1 … 1E+05 nv	WRM 50x	U-235 FC **NY-10953**	Wide Range Channel **DWK 260**	4 Channels 4 Detectors	

%FP = % Full Power
nv = neutrons / cm² / s
SR, IR, PR = Source-, Intermediate-, Power Range
WR = Wide Range

PC = Proportional Counter
CIC = Compensated Ionization Chamber
UIC = Uncompensated Ionization Chamber
FC = Fission Chamber

NFMS Key Take-Away

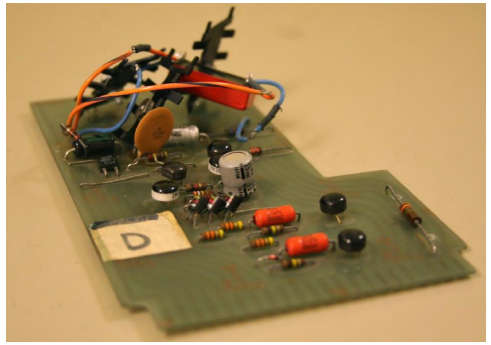
- The NFMS (or NIS) **monitors Reactor Power** and can shut down the reactor if needed.
- It consists of a **Detector, Pre-Amplifier, and Electronics**.
- Typically, three systems cover the wide measurement range, but a Wide Range Channel can cover it alone using a Fission Chamber. **All systems are available, and field proven with proTK™**
- Due to **strict Safety Requirements**, the electronics are often analog and software-free.
- Since 1988, proTK™ has safely operated digitally with embedded software and recently received upgrades and re-certification for use in Nuclear Power Plants and Research Reactors.
- NRC Safety Evaluation of the proTK™ platform is underway
- proTK's modular, digital, and customizable design allows easy integration and maintenance.
- Mirion supplies both **in-core and ex-core** neutron detectors.

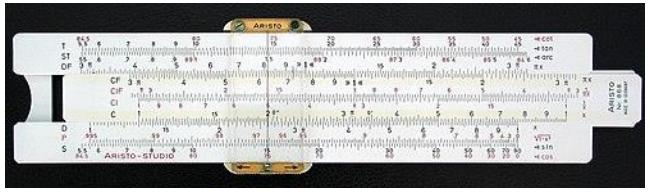
Digital NIS Upgrade

Examples

Analog to Digital

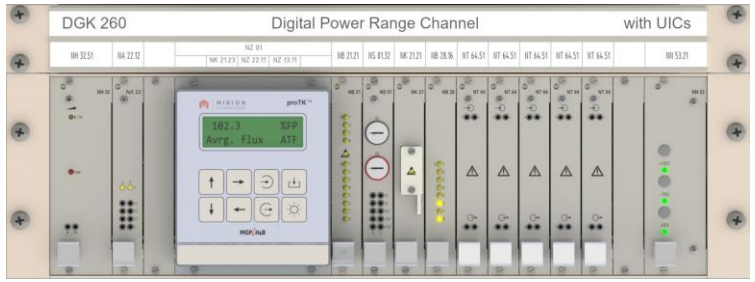
1950ies

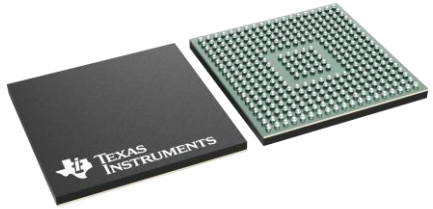




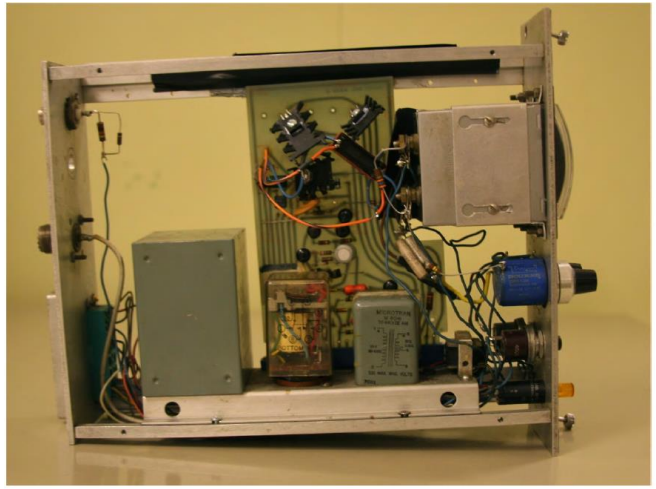
1980ies

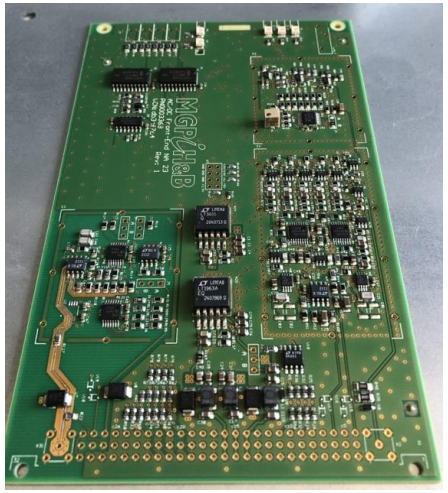
2020ies

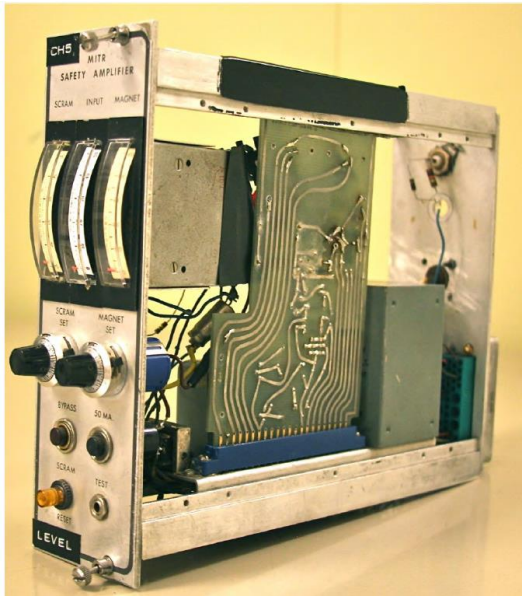


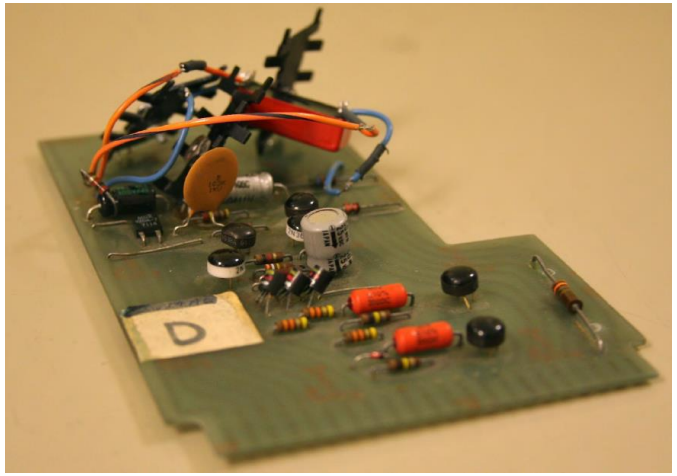


Analog to Digital



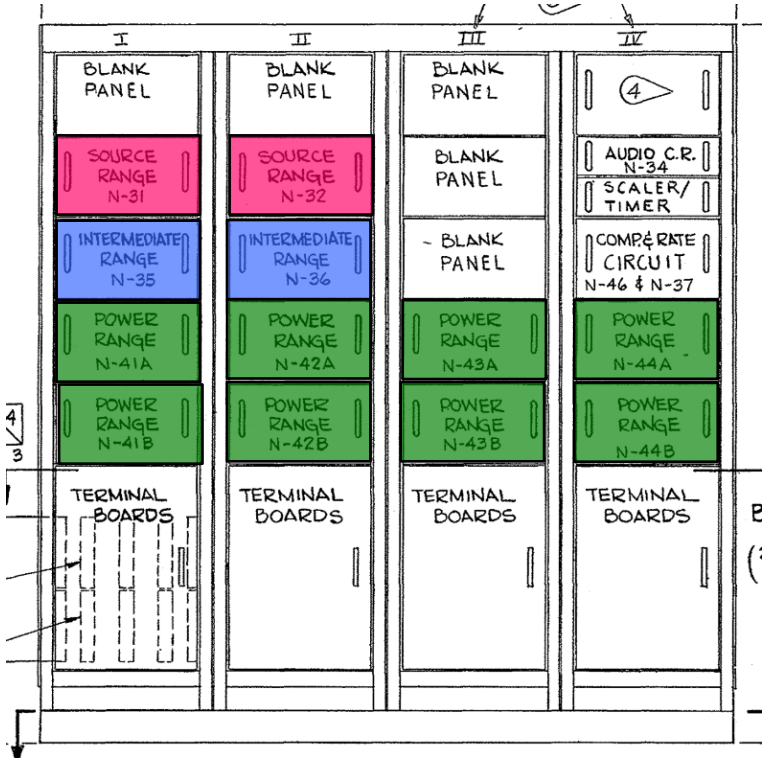






NIS Upgrade of Analog Drawers

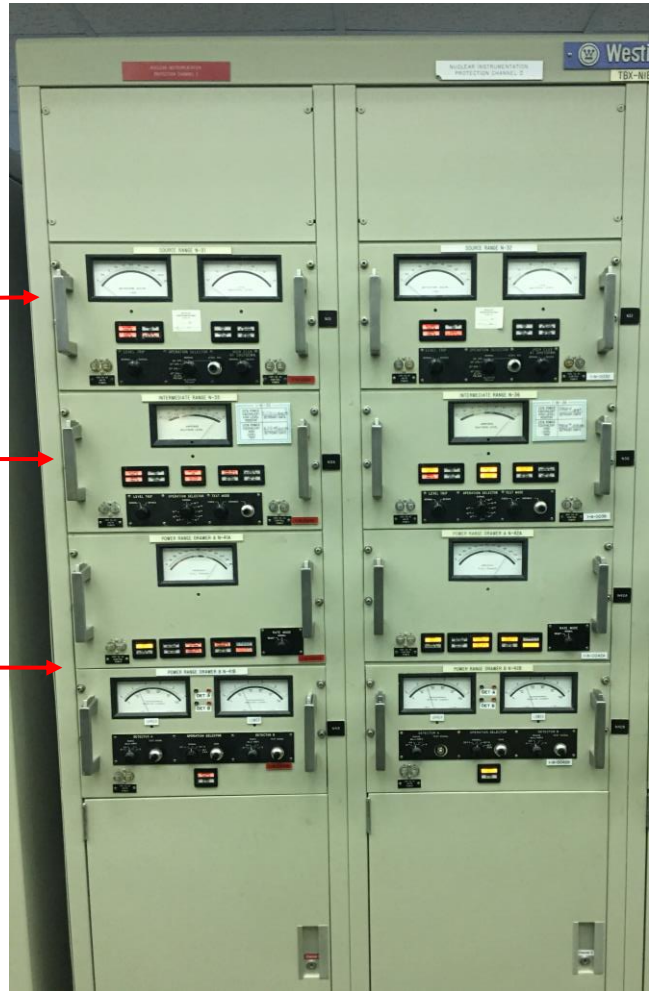
Westinghouse
Nuclear Instrumentation System Drawers



Westinghouse Source Range Drawer

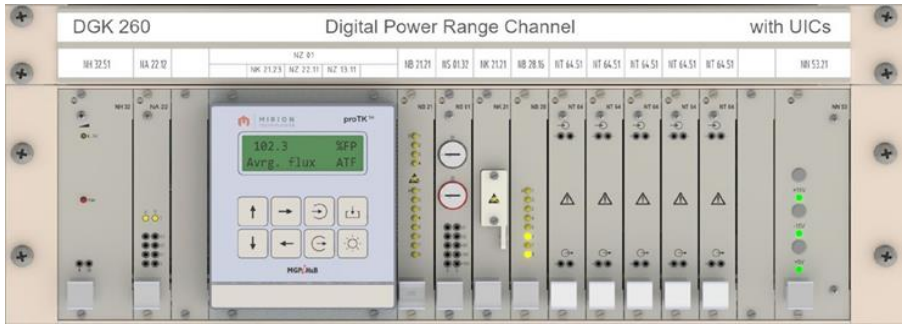
Westinghouse Intermediate Range Drawer

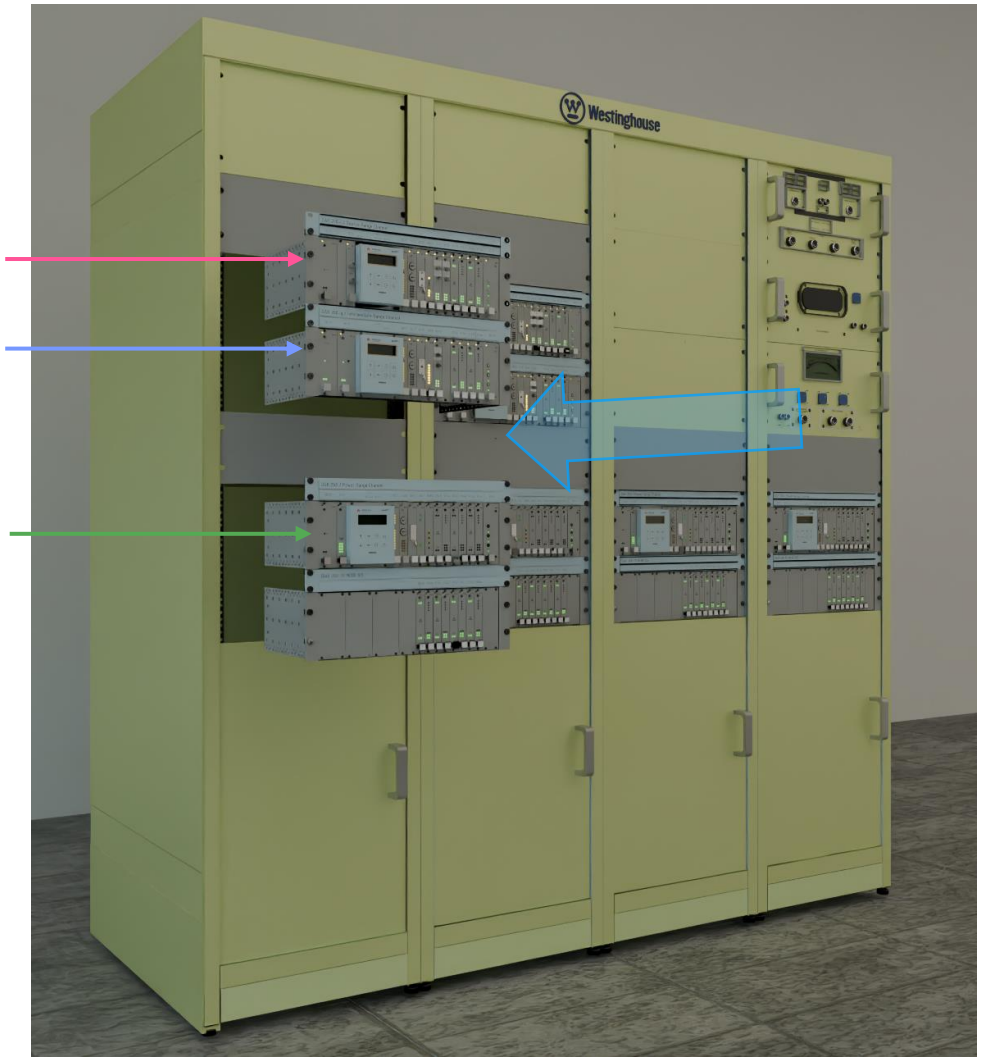
Westinghouse Power Range Drawers



Westinghouse Digital NIS

- Direct **Digital** Replacement for Analog Westinghouse NIS Drawers
  - Drop-in Installation
  - **Standard Licensing**
- Utilizes Mirion proTK™ 260 Series
  - **Proven** Neutron Flux Monitoring System
  - Digital Signal Processing
- Architecture **Agnostic**





MIRION TECHNOLOGIES

Westinghouse

NRC Licensing Plan

Topical Report Content

- proTK Platform Description
- Equipment Qualification
- Regulatory Compliance
- Common Cause Failure Mitigation
- Description of Configurations
  - Source Range
  - Intermediate Range
  - Power Range
  - Wide Range

Topical Report Timeline

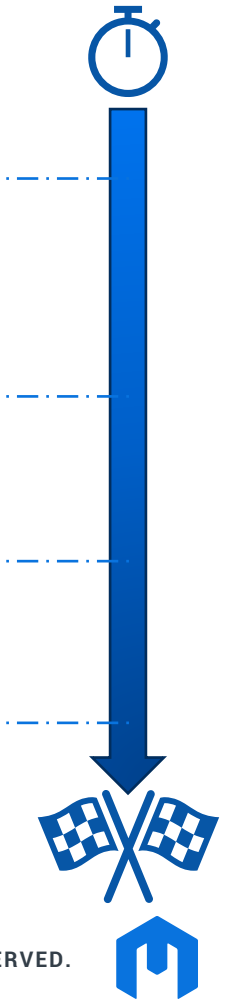
- Held First Pre-submittal Meeting

  May 20, 2025
- Scheduled Second Pre-submittal Meeting

  Sept. 3, 2025
- Submittal

  Q4 2025
- Safety Evaluation

  Q4 2026



Purdue Research / Training Reactor

- First US reactor with all digital I&C
- Replacement of 4 neutron flux monitors consisting of
  - Start-up channel: 1 x digital wide range signal processing unit of type DWK 250 and 1 x wide range FC
  - Log power / rate ch.: 1 x digital intermediate range signal processing unit of type DAK 250-g + 1 x CIC
  - Linear power (multi-range): 1 x digital interm. range signal processing unit of type DAK 250-g + 1 x UIC
  - Safety Channel: 1 x digital power range signal processing unit of type DGK 250 + 1 x UIC
- Web links:
  - First all-digital nuclear reactor system in the U.S. installed at Purdue University - Purdue University News
  - Nation's first digitally operated nuclear reactor dedicated at Purdue University - Purdue University News

Purdue Research Reactor

wnn world nuclear news

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US research reactor goes digital in licensing 'first'

10 July 2019

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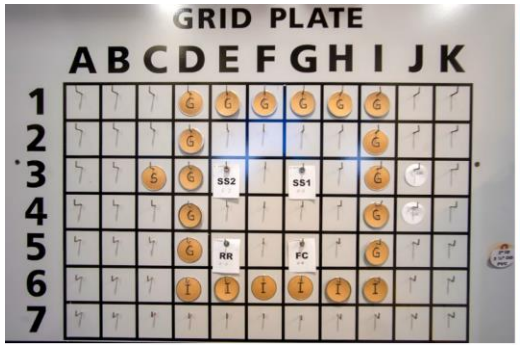
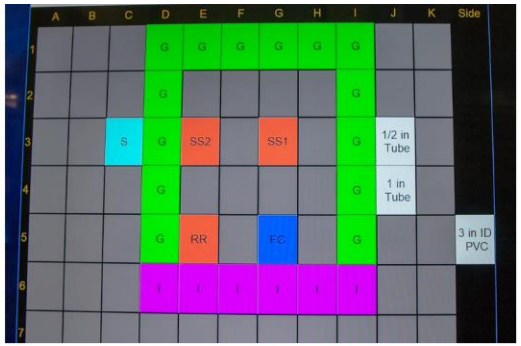
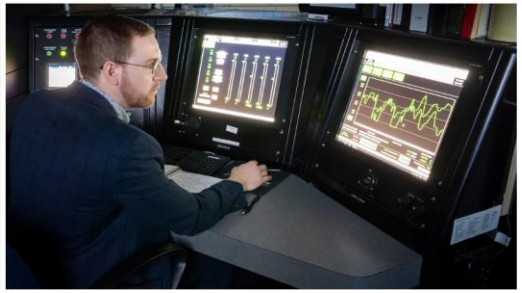
The US Nuclear Regulatory Commission (NRC) has licensed the first entirely digital nuclear reactor instrumentation and control (I&C) system in the USA, at a university-based research reactor originally built in 1962. The NRC licence also for the first time covers parts certified under standards laid down by a non-US regulatory body.

PUR-1 (Image: Vincent Walter)

Purdue University Reactor Number One (PUR-1) and its associated research facility have undergone a digital conversion which began in 2012, when the US Department of Energy awarded the university a grant under its Nuclear Energy University Program to replace reactor equipment with a state-of-the-art instrumentation and control system. The fully digital system was developed by the university in collaboration with Mirion Technologies and the Curtiss-Wright Corp.







NFMS for new Brazilian RR

- Supply of complete in-core and ex-core neutron flux instrumentation based on the **proTK™ / 260 series**

EX-CORE:

› 4 redundant I&C cabinets

each cabinet including the SR, IR and PR signal processing units

DAK 260-i /-g, **DGK 260**

› 4 redundant sets of neutron flux detector assemblies,

each set consisting of SR, IR and PR detector assemblies with:

- 1 x B-10 proportional counter **PN 50**
- 1 x gamma compensated B-10 ionization chamber **KNK 50 ACH**
- 2 x un-compensated B-10 ionization chambers **KNU 50 ACH**

› 1 non-safety cabinet with computer systems for

- Acquisition and storage of neutron flux information
- noise calculation, reactivity calculation, data analysis and visualization
- Additional terminals for configuration, visualization, analysis and maintenance

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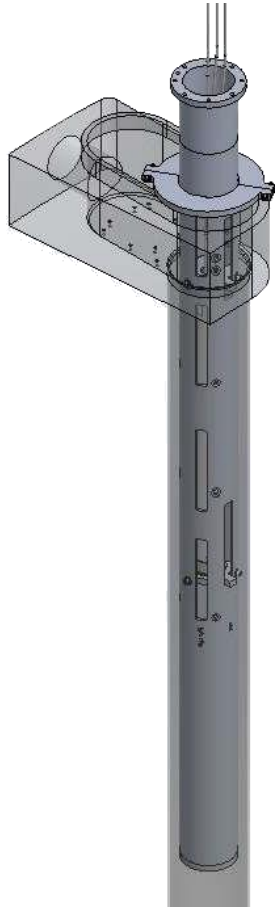
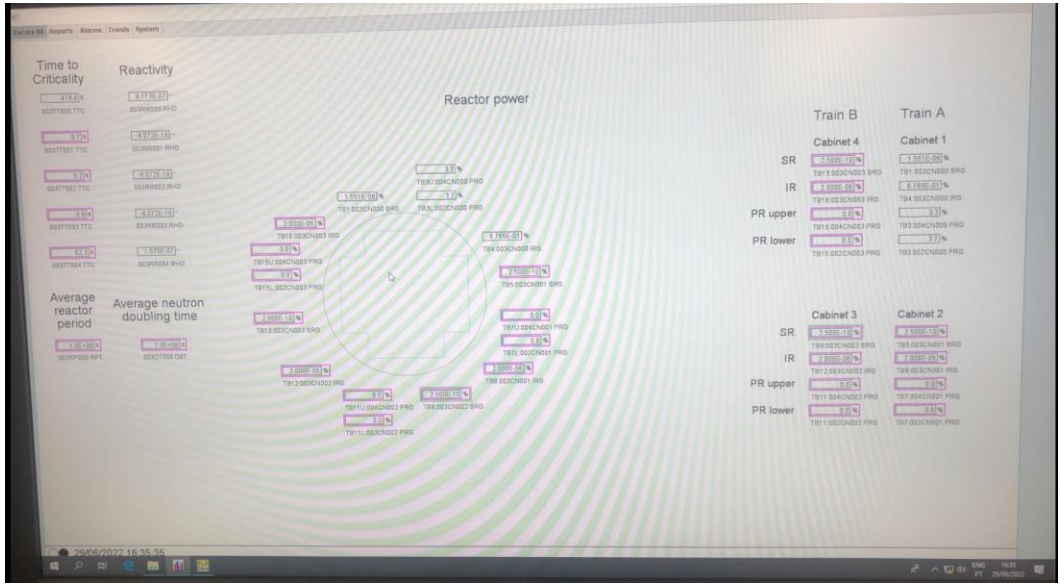
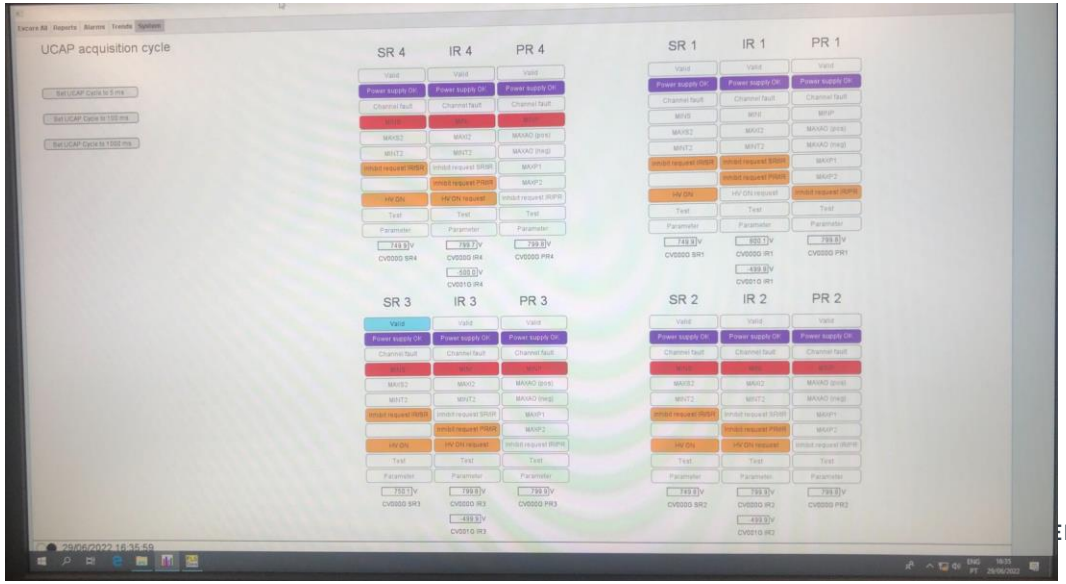
NFMS for new Brazilian RR



NFMS for new Brazilian RR





NFMS for new Brazilian RR

Supply of complete **IN-CORE** neutron flux instrumentation based on the **proTK™ / 260 series** including:

- In-core detector bundles, each consisting of various **SPNDs + Thermocouples**
- I&C cabinets with **proTK™ Analog Front End** (AFE) modules for processing the signals from the SPNDs, and data acquisition and processing units for reactor power distribution calculations and for monitoring functions

Technical Information

Current Input NA 27.11

Features

- 2 independent current inputs
- 6 measurement ranges 5·µA, 0.5 µA, 50 nA, 5 nA, 0.5 nA, 50·pA
- Front plug for external test signals
- Remote activation of test inputs
- Digital interface for remote gain selection

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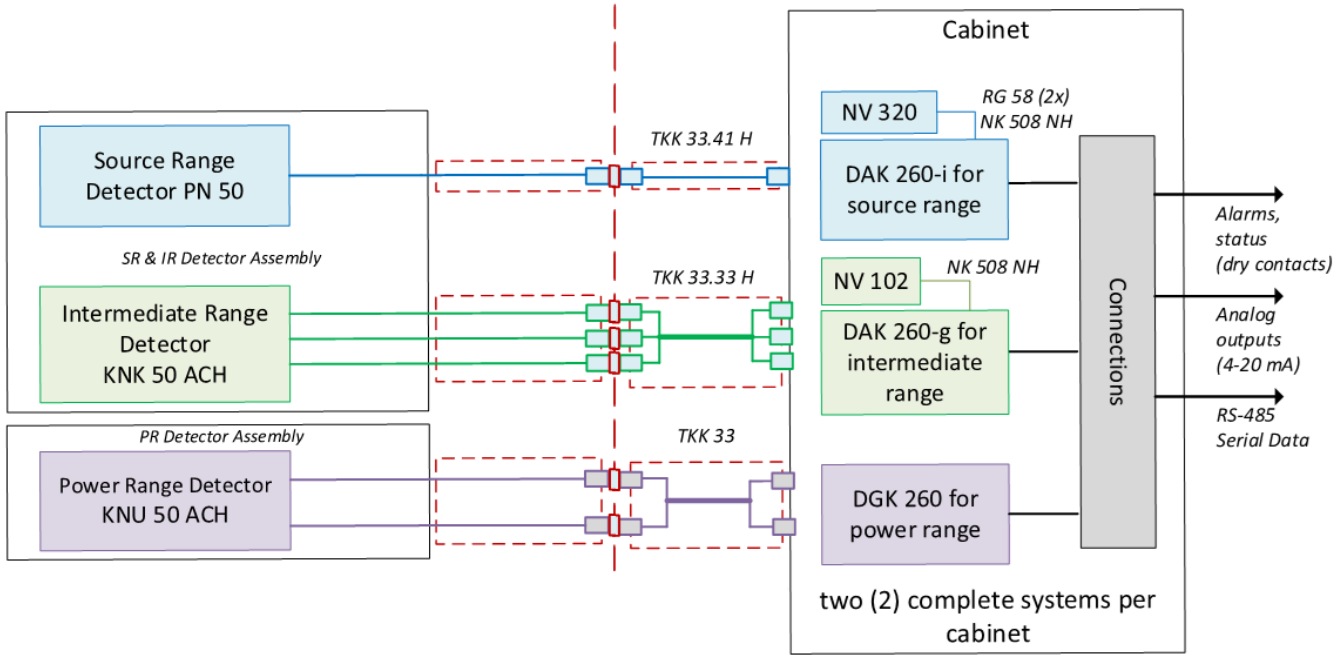
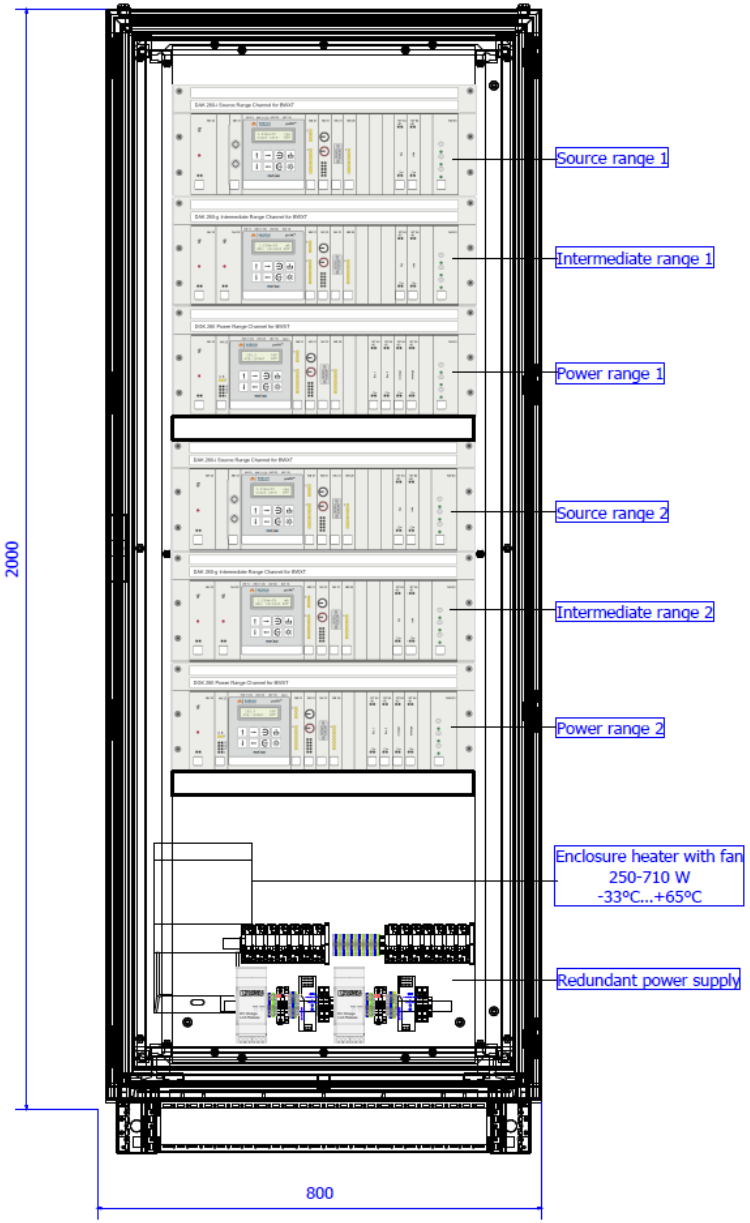
Complete NFMS for new Brazilian RR

- A full Nuclear Qualification, including Seismic Testing, was conducted on the system.

Advanced Nuclear

- Multiple SMR projects have been awarded in the US
- Customers show strong interest in digital NFMS
- Mirion has received highly favorable feedback as a comprehensive NFMS service provider
- The latest project features the DWK 260 wide range channel along with a high temperature fission chamber





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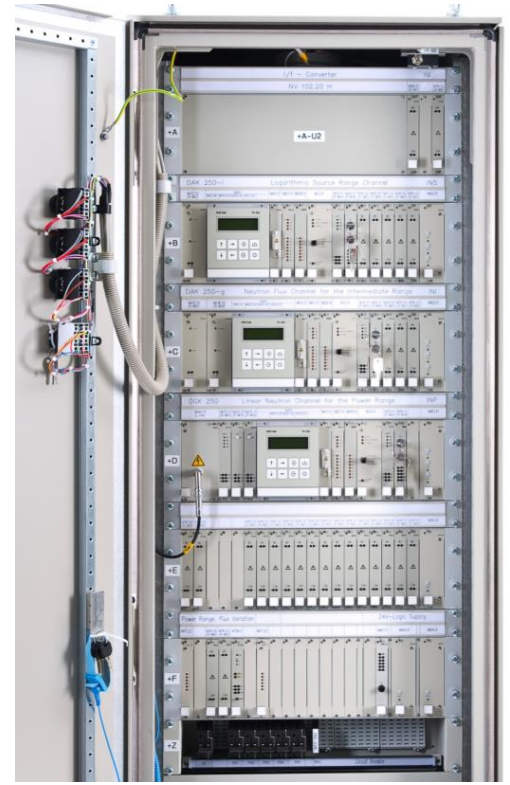
proTK™ Productline

MIRION
TECHNOLOGIES

proTK™ Product Line

Focused on safety

- Modular, digital system for Radiation and Process Monitoring and Neutron Flux Measurement
- Highly customizable and extendable to meet functional, normative and customer requirements
- Qualified up to highest safety standards for „Safety related equipment class 1E“ and „Cat A“ Software.
- Compatible to 3rd party components and suitable for „1:1 form fit function replacement“ at existing facilities
- proTK™ HW and SW is developed, customized, manufactured, qualified and tested in house
- **Full-service provider for Radiation, Process and Neutron Flux Monitoring**



proTK™ - NFMS Measurement Channels

CAT A measurement equipment acc. to IEC 61226

HW and SW is developed, designed, produced, tested and qualified in-house

Digital, modular, accurate, fast, testable and reliable

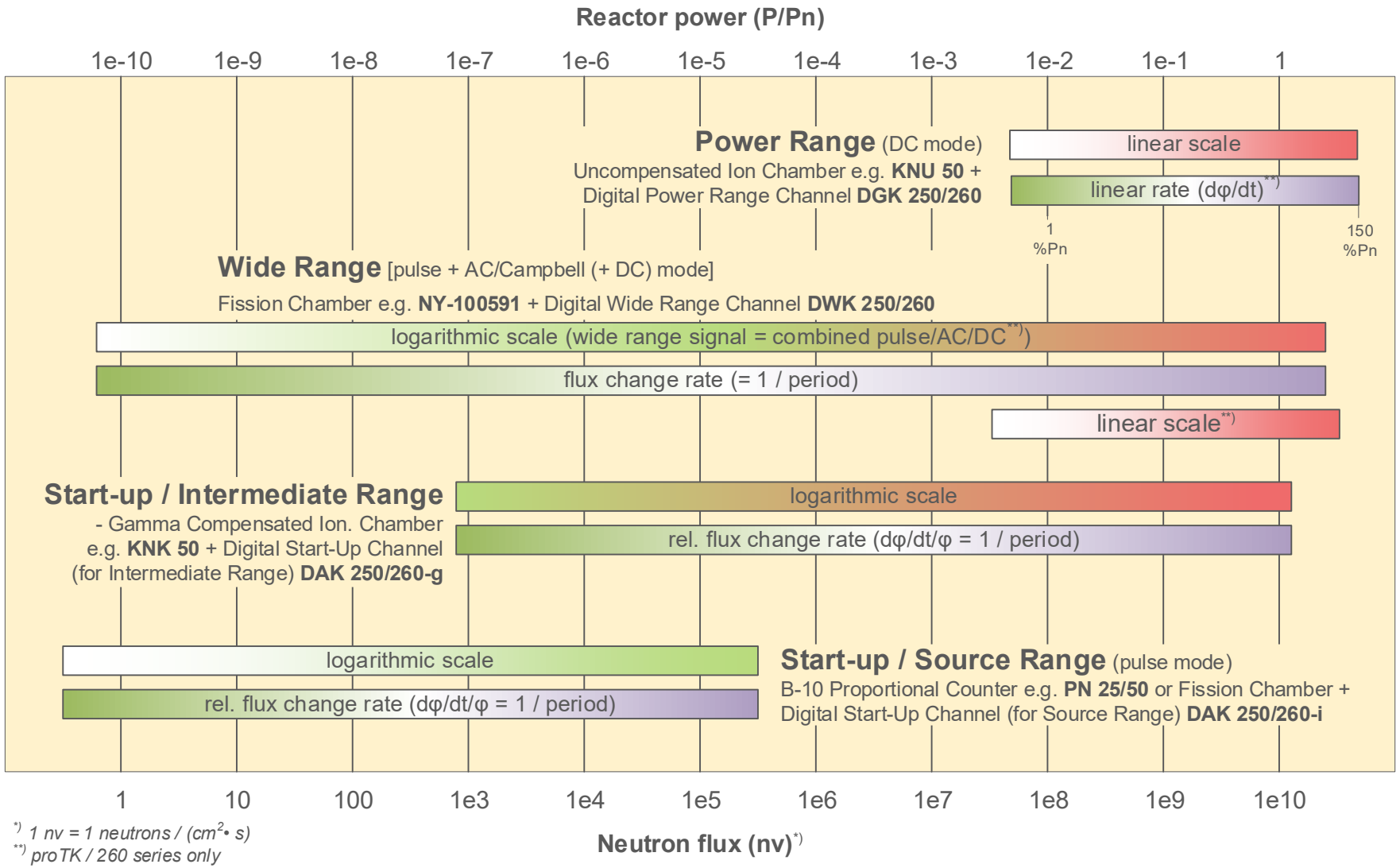
Qualified to highest safety standards such as IEC 61513/IEEE 603, IEC 60880/IEEE 7.4.3.2, IEC/IEEE 60780-323, IEEE/IEC 60980-344

DAK 260-i	**Pulse/Startup Channel** (source range, for counter tubes and pulse FCs)
DAK 260-g	**Intermediate Range Channel** (DC current measurement, CICs and UICs)
DGK 260	**Power-Range Channel** (linear channel, UICs)
DWK 260	**Wide-Range Channel** (guarded or non-guarded fission chambers)

A typical setup of NFMS signal channels

DWK 260 available in 2024
proTK™ / 250 series available since 1988 and still being maintained

Wide Range Channel



*) *1 nv = 1 neutrons / (cm² • s)*
**) *proTK / 260 series only*

proTK™ Installations of NFMS Channels

	DAK – Startup and IR	DGK - Power	DWK - Wide
NPPs & Research Reactors	Germany, Netherlands, Belgium, Jordan, Switzerland, USA, Finland, China, Brazil	Germany, Netherlands, Belgium, USA, Jordan, Bangladesh, Brazil	Germany, Netherlands, Switzerland, USA, Jordan, Bangladesh
Total installations	261	63	57
Available since	1994	1996	1988
Installed units	196	40	57
Channels x Years	2006	603	750 (500 in NPPs)
Qualification basis (SW)	KTA 3503 / 3505 IEC 60880	KTA 3503 / 3505 IEC 60880	KTA 3503 / 3505 (IEC 60880)
Certifying authority	TÜV Nord	TÜV Nord	TÜV Nord TÜV Rheinland

plus >500 non-safety istallation for RMS applications

proTK™ - RMS Solutions

Particulate, Iodine and Noble Gas Monitors

- Consisting of DPK 251 or DEK 251 measurement channels and
- Gas, particulate and iodine filter systems equipped with
- NaI or plastic scintillators
- Designed and qualified acc. to German KTA standards
- Customized solutions **available** on request (e.g. 1E cat A systems; accident monitoring)

Iodine Monitor
(filter unit)
JD 24

Remote Alarm/Signaling Unit

Gamma Dose and Process Monitoring

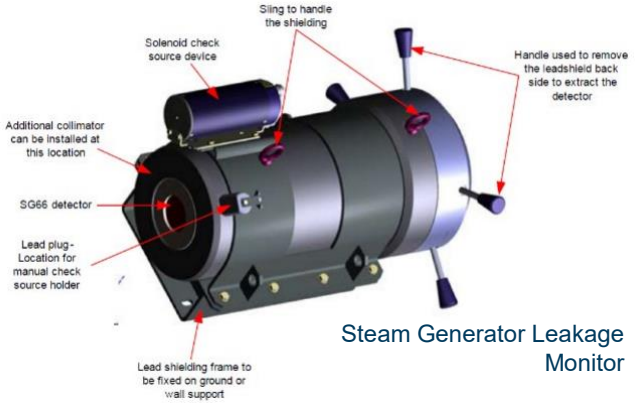
- DPK 251, DAK 250 or DAK 260 measurement channels
- Suitable detectors (gamma or neutron) and pre-amplifiers for measurement task
- Examples:
  - Ambient dose rate meters
  - Accident gamma dose rate monitor
  - Reactor gamma flux measurement
  - Measurement of delayed neutrons or N-16

Complete Gamma Dose Rate Monitor

proTK™ - More Safety Systems

Steam Generator Leakage Monitoring (Cat. A)
SGLM / SGTR

- Consisting of DAK 250-i and rugged NaI gamma scintillation detector SG 66 R; optional lead shielding
- Version with DAK 260-g and robust gamma ionization chamber



Steam Generator Leakage Monitor

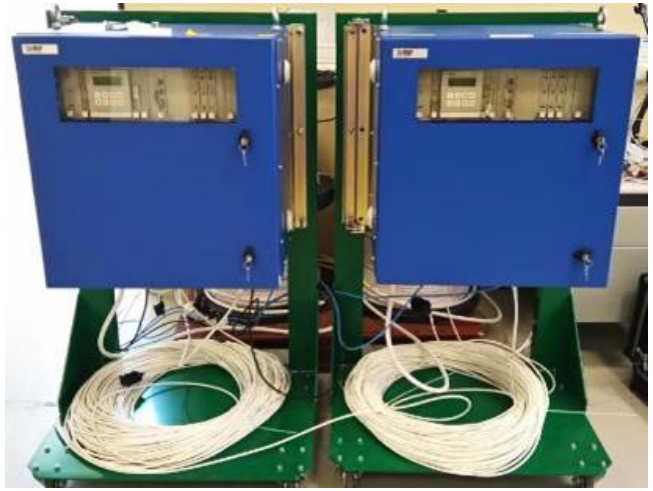

Rugged NaI in shielding


DAK 250, wall mounted

Boron Concentration Monitor (Cat. A & Cat. B)
BM 501 / BM 502

- Designed to continuously measure the B-10 concentration in water circulating in process pipes in a light water reactor (LWR).
- Components: two proTK digital signal processing channels DBK 250 and two pre-amplifiers NV 320 , one detection assembly consisting of two B-10 lined proportional counters (PN 25), a neutron source, moderating / shielding materials.

Boronmeter Channels DBK 250




Boronmeter detector system (AmBe source, moderator, PN25 detector in support for online mounting

Dr. Jörg von Loeben

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Thank you!

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