Sustaining Excellence in Reactor Safety

Strategic collaboration for gamma metrics neutron flux monitoring systems

Paragon

Reuter-Stokes

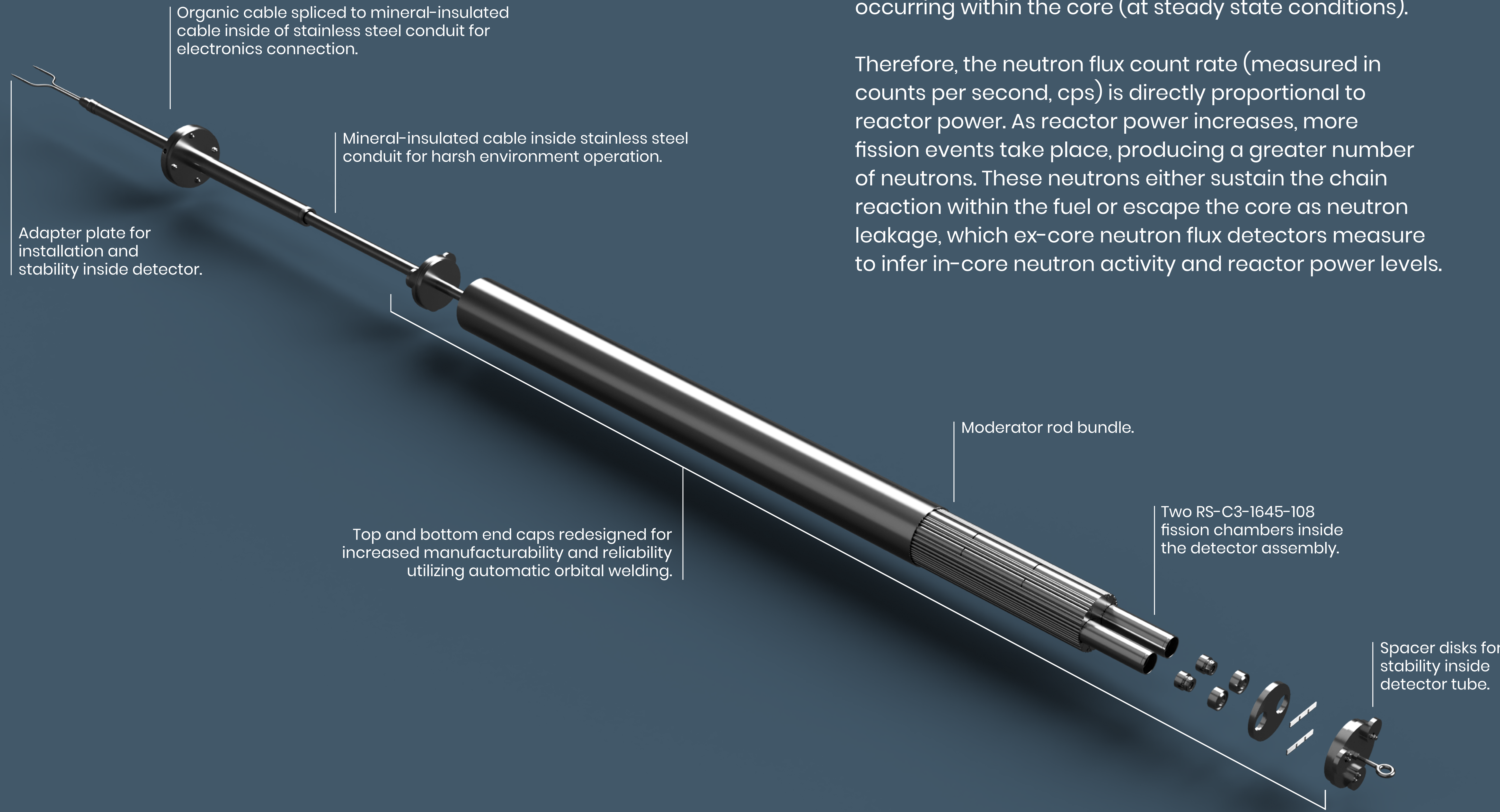
Nuclear power is one of the most reliable and sustainable energy sources. Ensuring the safety and efficiency of commercial nuclear reactors requires advanced Neutron Flux Monitoring System (NFMS) technologies that deliver accurate, real-time data for reactor power determination, core power distribution, reactor control, and fuel management.

Contents

Introduction

In a nuclear reactor, the neutron production rate is proportional to the number of fission reactions occurring within the core (at steady state conditions).

Therefore, the neutron flux count rate (measured in counts per second, cps) is directly proportional to reactor power. As reactor power increases, more fission events take place, producing a greater number of neutrons. These neutrons either sustain the chain reaction within the fuel or escape the core as neutron leakage, which ex-core neutron flux detectors measure to infer in-core neutron activity and reactor power levels.



Operation & Applications

Nuclear instrumentation systems process the neutron flux count rate using logarithmic amplifiers, which compress a wide dynamic range into a manageable signal output. They use neutron signal conditioning circuits to stabilize the raw signal for readability and operational use.

Reactor operators adjust control rod positions using neutron flux data to precisely regulate power levels.

Another essential application involves optimizing fuel efficiency. **By monitoring neutron flux patterns, operators can identify stability irregularities in power distribution and modify reactor settings accordingly.**

Uneven neutron flux causes uneven fuel burn-up, which diminishes the longevity of nuclear fuel and increases operational costs.

Through meticulous neutron flux monitoring, operators can ensure fuel is utilized efficiently, minimizing waste and extending the reactor's operational lifespan.

The International Atomic Energy Agency (IAEA) and the U.S. Nuclear Regulatory Commission (NRC) emphasize that neutron flux monitoring must be part of a comprehensive safety strategy.

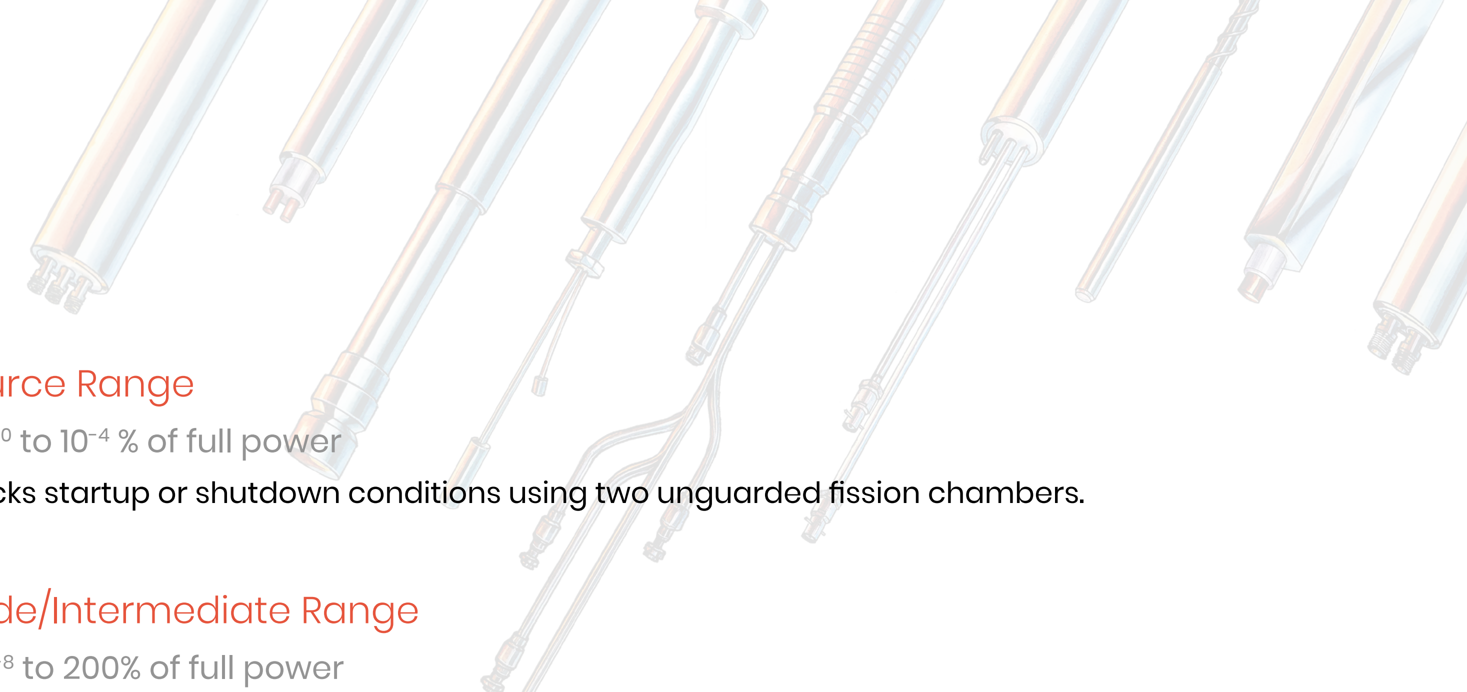
Neutron flux monitoring also helps control neutron exposure levels and ensures that shielding measures effectively reduce radiation risks.

The International Atomic Energy Agency (IAEA) and the U.S. Nuclear Regulatory Commission (NRC) emphasize that neutron flux monitoring must be part of a comprehensive safety strategy that includes redundancy in detection systems to ensure continued reactor stability, even during sensor failures.

The U.S. NRC mandates that nuclear facilities implement rigorous calibration and testing procedures to ensure the long-term performance of neutron flux monitoring equipment.

Given NFMS's critical role in reactor safety and efficiency, understanding its evolution highlights the importance of continued innovation in nuclear technology.

History of the Gamma Metrics NFMS



The Gamma Metrics NFMS has provided nuclear operators with a reliable, high-precision neutron flux measurement system for decades. This system has been widely adopted in research, testing, and training reactors, offering an indispensable tool for scientific research, reactor modeling, and operator training.

The product line was developed to address the need for accurate and reliable neutron flux monitoring in nuclear reactors. Its origins trace back to the mid-20th century, when the nuclear industry rapidly expanded, and the demand for advanced instrumentation was at an all-time high.

Thermo Fisher, a leader in scientific instrumentation, developed the Gamma Metrics NFMS as a state-of-the-art solution. The system employs ex-core fission chamber detectors capable of covering a wide range of neutron flux levels, from the source range through the intermediate range to the power range. These detectors are designed to operate without significant loss of sensitivity over 40 years, making them reliable and cost-effective.

The system uses a single fission chamber-based detector assembly to monitor neutron flux over 12-decades and across all reactor power levels.

Source Range

~10^{-10} to 10^{-4} % of full power

Tracks startup or shutdown conditions using two unguarded fission chambers.

Wide/Intermediate Range

~10^{-8} to 200% of full power

Manages increasing power levels during start-up and decreasing power levels during shutdown. Combines two signal processing techniques using fission chambers for pulse counting (~10^{-8} to 10^{-2} %) and Mean Square Voltage (MSV, also referred to as Campbells Theorem) (~10^{-3} to 200%).

Power Range

Ensures continuous normal full-power operations.

This system is also qualified per U.S. NRC Reg Guide 1.97 for Post-Accident Monitoring (PAM) operations. This Wide Range channel approach ensures that neutron flux monitoring remains accurate and responsive throughout all phases of reactor operation, from startup to full-power and PAM conditions using a single detector assembly.

Thermo Fisher played a leading role in developing and enhancing NFMS technology. By leveraging its expertise in nuclear instrumentation, the company refined neutron detection methodologies, making NFMS more accurate, reliable, and adaptable to a wide range of reactor environments.

Thermo Fisher has since shifted away from direct support of nuclear instrumentation, resulting in an urgent need for a long-term strategy to sustain NFMS technology to avoid potential obsolescence and supply chain disruptions.

The transition of the NFMS product line needed to be managed by a company with extensive expertise in nuclear safety and instrumentation - **that's where Paragon comes in.**

Paragon Energy Solutions (Paragon) is a leading provider of innovative solutions for the nuclear industry and a reliable partner for nuclear facilities seeking high-quality instrumentation and reactor monitoring solutions. Paragon recognized the importance of neutron flux monitoring for the nuclear industry and assumed ownership of the Gamma Metrics NIS products and NFMS product line.

Paragon Energy Solutions acquires NFMS technology

In January 2023, Paragon entered into a licensing agreement with Thermo Fisher to ensure the continued availability of neutron flux monitoring technology and to solidify its leadership in the industry.

This agreement includes transferring its intellectual property, manufacturing processes, and support infrastructure. It also grants Paragon full responsibility for product support, including spare parts, upgrades, and new systems. The acquisition reduces risks related to technology obsolescence by establishing a dedicated team responsible for maintaining and enhancing NFMS technology.

Paragon Energy Solutions pursued this acquisition with three strategic goals:

- Mitigating obsolescence risk by maintaining NFMS availability.
- Ensuring access to spare parts, upgrades, and technical assistance.
- Advancing NFMS technology through research and development.

Paragon is committed to preserving the current NFMS functionality and modernizing the system to align with next-generation nuclear reactors, including Small Modular Reactors.

As with all nuclear power-related products, regulatory compliance remains a key priority for Paragon. **The qualification of NFMS components will be maintained under nuclear industry standards, including:**

IEEE 497-2002 Specifies reliability requirements for nuclear instrumentation, including redundancy and qualification testing.

IEC 61513 Provides requirements for the total instrumentation and control architecture for systems important to safety in nuclear power plants.

10 CFR 50 Appendix R Fire protection program specifications and remote/alternative shutdown requirements.

NRC Regulatory Guide 1.97 Post-accident monitoring requirements, including loss of coolant accidents and main steam line breaks.

By ensuring that its NFMS technology remains compliant with these standards, Paragon is reinforcing its commitment to upholding nuclear safety regulations.

Above: Reuter-Stokes' facility in Twinsburg, Ohio

Paragon partners with Reuter-Stokes

Reuter-Stokes is a renowned leader in neutron and gamma flux monitoring technology since 1956. With 70 years of experience in the nuclear industry, Reuter-Stokes brings unparalleled expertise to manufacturing radiation detectors for NFMS.

In March 2023, Paragon and Reuter-Stokes signed a teaming agreement encompassing joint marketing and project development in the growing Small Modular Reactor (SMR) and advanced reactor markets for NFMS.

Reuter-Stokes' commitment to quality and innovation aligns with Paragon's mission to sustain and enhance neutron flux monitoring solutions.

Combining Paragon's industry knowledge and customer focus with Reuter-Stokes' radiation detector design and manufacturing excellence ensures nuclear facilities can access high-quality neutron flux detectors and support systems for years to come.

Paragon and Reuter-Stokes are well-positioned to set new standards in neutron flux monitoring by fostering industry partnerships and investing in research and development.

Scope of work

Previously, Reuter-Stokes supplied the fission chambers themselves to Thermo Fisher, not the detector assembly.

Now, Reuter-Stokes manufactures and supplies the integrated detector assemblies to Paragon- consisting of the fission chambers, moderator, external housing, cabling, and connectors.

During installation, plant technicians will connect the Reuter-Stokes detector assembly connector to the input port of the pre-amplifier supplied by Paragon.

Along with the amplifier, Paragon supplies all downstream signal-processing equipment and is responsible for sales, support, and logistics for the Gamma Metrics NFMS, with field service support for detector installation and commissioning as necessary.

Innovations shaping the future

The next generation of neutron flux monitoring is headed towards integrated digital technologies, data analysis driven by artificial intelligence (AI), and wireless neutron sensors to enhance reactor monitoring efficiency and automation.

Artificial intelligence is expected to grow in neutron flux monitoring by enabling real-time anomaly detection and predictive analytics. Wireless neutron sensors will enhance monitoring flexibility and reliability in IoT-based reactor control systems.

Researchers are developing machine-learning algorithms to analyze neutron flux patterns in real-time, enabling predictive maintenance and early anomaly detection in nuclear reactors.

These advancements align with Paragon and Reuter-Stokes' mission to enhance NFMS capabilities, ensuring that nuclear reactors benefit in the future from improved data accuracy, early anomaly detection, and greater operational efficiency.

Strategic benefits to the nuclear industry

Reuter-Stokes brings manufacturing excellence and extensive experience tailoring neutron detection systems for the nuclear industry.

Paragon's acquisition from Thermo Fisher ensures a stable, high-quality NFMS production process in the future.

Customers have uninterrupted access to support, spare parts, and product upgrades, ensuring the longevity and reliability of their NFMS.

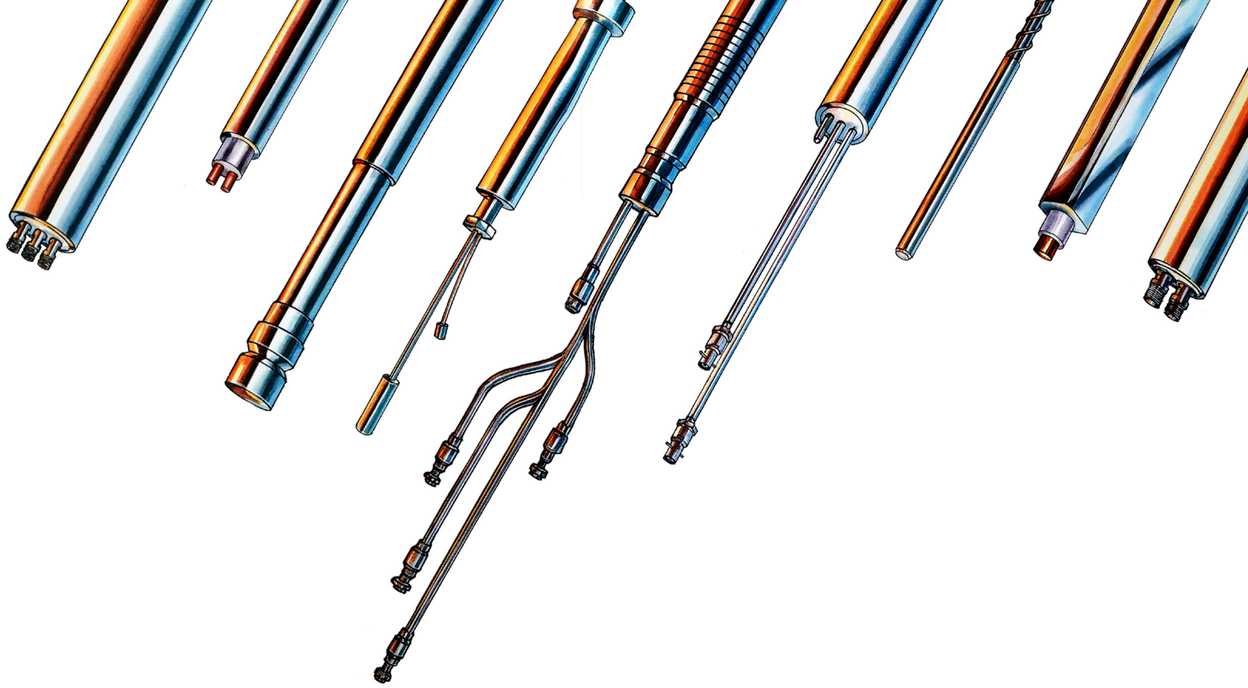
More cost-effective solutions through improved packaging, stable supply chains, and reliable lead times.

Continuous improvement through R&D to enhance system accuracy, integrate digital control features, and support next-generation reactor designs.

Paragon has replicated the original NFMS design to avoid impacting the product's Nuclear Equipment (Environmental and Seismic) Qualifications.

Part numbers will remain the same to simplify the transition process for customers.

Paragon will continue to certify previous revisions of Thermo Fisher drawings and certify the original Qualification Reports.



Conclusion

The acquisition of Thermo Fisher's Gamma Metrics Neutron Flux Monitoring Systems (NFMS) by Paragon Energy Solutions represents a significant advancement in the neutron flux monitoring market.

The Paragon and Reuter-Stokes strategic collaboration ensures continued reliability, effectively safeguarding a critical component of nuclear safety while addressing challenges such as technological obsolescence and supply chain disruptions.

As nuclear power evolves, Paragon and Reuter-Stokes remain dedicated to enhancing reactor monitoring solutions, integrating cutting-edge technologies, and pioneering innovations that will shape the future of next-generation reactor monitoring.

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