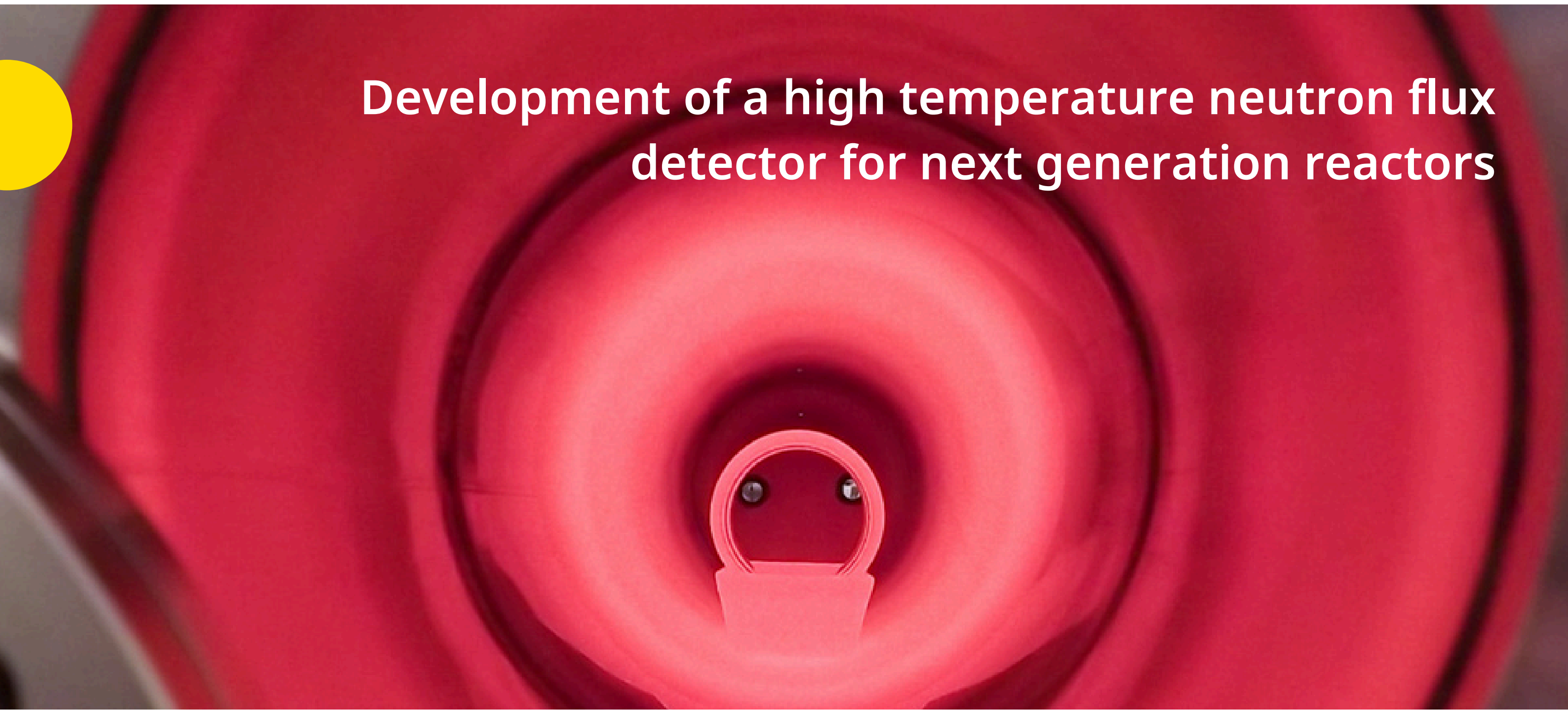
ULTRA | Energy

CURTISS-WRIGHT

Development of a high temperature neutron flux detector for next generation reactors



Context

Neutron flux detectors operate in extremely challenging environments

Neutron flux instrumentation is present in all nuclear power plants. It provides near real-time insight into core reactivity, enabling reactor control systems to manage fission intensity and therefore power generation, as well as safety at the facility.

An essential component of this instrumentation are neutron flux detectors (NFD). These are sited in or around the reactor core and create a very small but measurable electronic signal in response to neutron flux. Given their location, they are often exposed to extreme conditions, including high heat, pressure, and radioactivity, as well as factors that cause material corrosion.

Ultra Energy has a long-established track record in designing and manufacturing safety-critical neutron flux instrumentation such as NFDs, and is a key supplier to the industry, including the UK's Advanced Gas cooled Reactor (AGR) fleet.

Challenge

Next generation reactor environments are significantly more extreme

Many next generation reactors currently under development will have reactor cores that operate at much higher temperatures than established types. Some will also create significantly more corrosive environments. Existing NFDs are not designed for these conditions so developers can't buy off the shelf or make relatively simple adaptations to existing solutions. A new generation of devices is required for the next generation of reactors to operate safely and effectively.

NFDs sense atomic-level effects and convert them into electronic signals that they send from within the reactor core to receiving instrumentation in non-radioactive areas within the power plant. Despite the extreme conditions found in traditional nuclear power plants, NFDs must be capable of functioning reliably for many years before needing to be replaced. This achievement is a significant engineering feat.

NFDs operating in next generation rectors will be exposed to far more extreme conditions, creating unprecedented challenges to their ongoing performance. Devices able to meet these challenges have until now not been successfully developed to the point of commercial availability.

Solution

A range of devices able to operate reliably in more extreme conditions

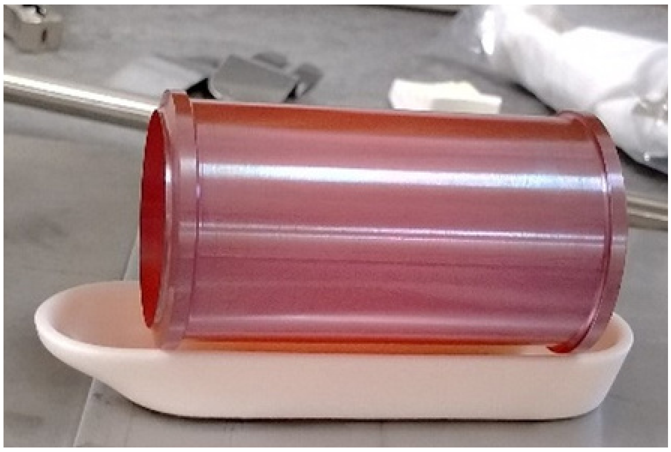
Ultra Energy recently completed the design and manufacture of a safety critical NFD that is suitable for use in the hostile environments that will be found in next generation reactors. The functional characteristics of this NFD are based on the detectors we manufacture for the UK AGR fleet. However, the new device has been designed to operate at temperatures up to 800°C, which means developers of next generation reactors now have the instrumentation they need to progress their overall designs.

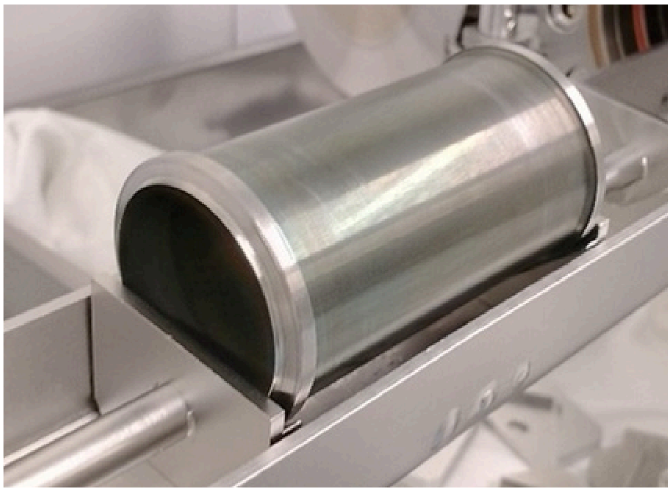
Our senior nucleonics specialist lead the project team, which included physicists, mechanical engineers, production engineers and machinists, all of whom have deep experience and expertise in developing nuclear instrumentation. The design of the NFD provides flexibility to our customers by enabling the development of a range of devices based on the same design. It is also focused on simplicity, reducing the number of possible causes of failure, as well as machining and manufacturing input, to support the industry's focus on reducing costs and timescales.

The project team started work in early 2020 and the finished design was presented at a conference in Toronto in October 2022. Using lessons learned from the NFDs that we build for the UK's AGR power plants, we conducted an iterative, agile prototyping project in which designs were built, trialled, tested and improved to create the final prototype, which will be one of a family of detectors based on the same design. The new NFD family is able to connect to our existing safety electronics, which therefore don't need to be changed.

Materials used in the device were carefully selected. Inconel 625 is the principal metal used for the chamber and containment assemblies due to its corrosion resistance and mechanical performance at high temperature.

235U coating detects incoming neutrons. Electrical isolation between the anode and cathode are achieved with magnesium oxide material and a metal-ceramic seal that uses aluminium oxide ceramic. We use an 850°C rated mineral insulated (MI) cable of triaxial construction, consisting of a copper centre conductor, copper screen and stainless-steel jacket, with each layer separated by a magnesium oxide insulant, to transmit the signal from the core to the non-core environment. Many of these materials can be substituted to meet the requirements of different environments found in specific reactor types.





Ultra has a state-of-the-art manufacturing and testing facility that includes a gamma test cell and neutron generator. This facility also has ovens and furnaces that can test devices of various sizes at temperatures of up to 1000°C. Validation of the new NFD was achieved by performing a series of tests under varying external environments. The performance under each of these conditions allows extrapolation of the device performance to the full power conditions, based on operational experience and historic testing of detectors. Initial measurements were performed at room temperature before proceeding to high temperature testing. High temperature testing was performed from 550°C to 800°C.

Benefits

Enables progress with new reactors designs at lower cost and time input

The primary benefit of our new NFD is that it enables developers of next generation reactors to progress their overall designs thanks to the availability of suitable instrumentation.

Additional to this, its purposefully simple design reduces time and cost to manufacture by around 30% in relation to previous generations of NFDs. Further costs can be taken out of development and build programmes as the device is available in a range of forms, enabling designers to create savings across systems due to the design choices that opens up to them. Finally, future cost savings are passed to operators as the NFD are expected to be capable of delivering uninterrupted service for 40 years, minimizing the number of refresh cycles during the reactor's lifetime.

Future

Reactor testing and qualification by the end of 2024

Looking further ahead, we will undertake further tests of the device, including long duration temperature cycling to prove its durability and reactor testing in partnership with a customer and Oak Ridge National Laboratory. We expect to have the whole range qualified for use before the end of 2024.

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About Ultra Energy

Organisations working with nuclear technologies have a responsibility to safeguard people, the environment and infrastructure. We provide solutions that give our customers complete, long-term protection and control of safety critical systems, while helping them increase the net value derived from nuclear investments over their total lifespan.

Part of Curtiss-Wright, Ultra Energy has worked with nuclear customers for over 60 years. We're embedded in strategic national infrastructure and helping organisations develop future nuclear applications. We support continuous operation of nuclear sites with protection and control solutions that monitor and manage factors such as radiation, neutrons, temperature and pressure within safety critical systems.

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