New approach to internals inspections saves dose and time

An innovative method used during an aging management inspection of FENOC's Beaver Valley-1 produced significant results.

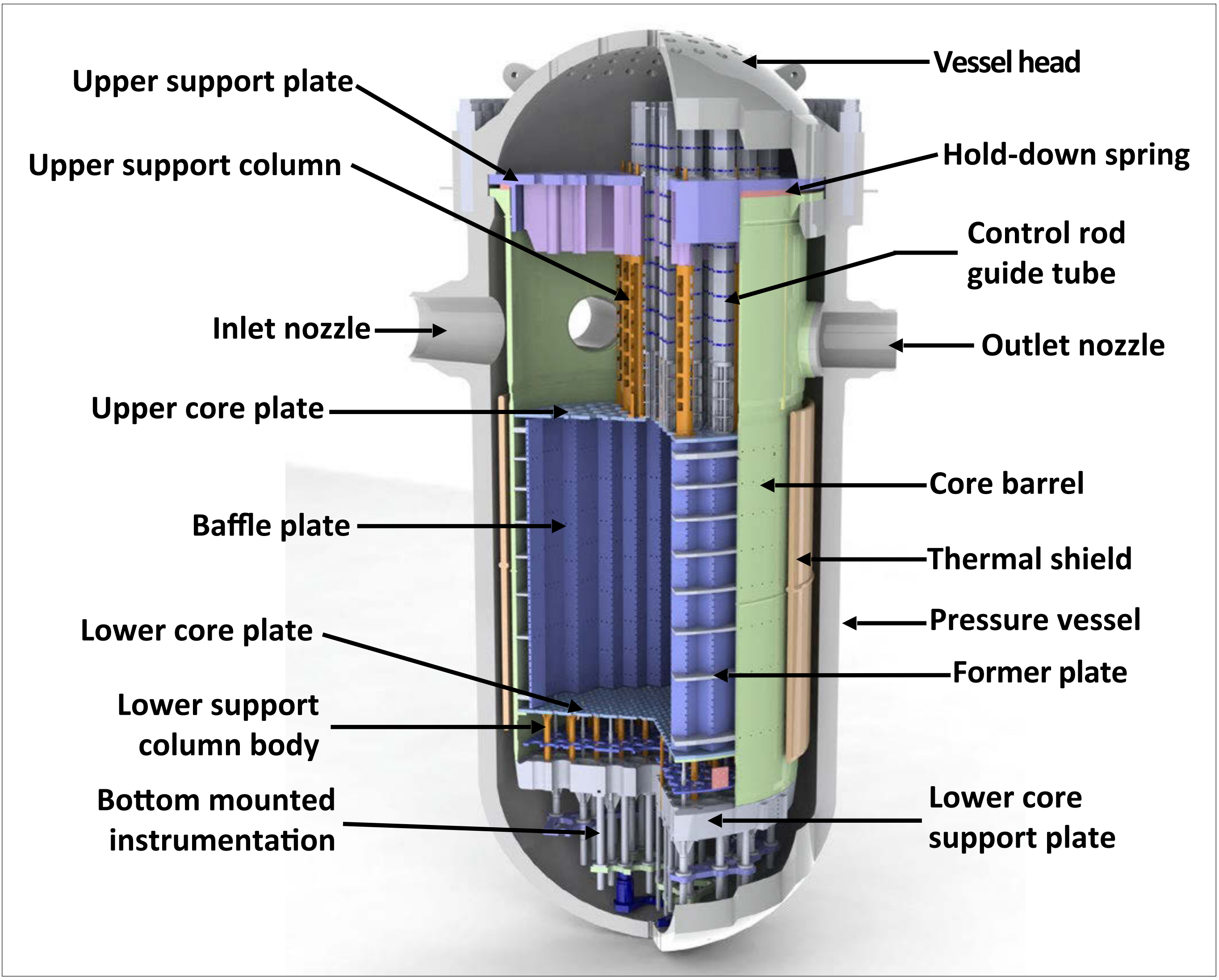
To assist utilities in managing aging in pressurized water reactor internals, including those utilities looking to extend their reactors' operating licenses to allow for longer-term operation, the Electric Power Research Institute's Materials Reliability Program (MRP) developed inspection and evaluation guidelines that plants have been implementing in various stages. *Pressurized Water Reactor Internals Inspection and Evaluation Guidelines* (MRP-227-A) supports the industry in developing PWR internals aging management programs, which are required to satisfy license renewal regulations.

The inspection and evaluation guidelines provided in MRP-227-A were derived from available data and from industry experience in materials aging, which has been used to develop a generic, systematic approach to the inspections. Operational history, actual as-built plant design, and the plant's design basis shape each plant's specific approach. Compliance with MRP-227-A can be achieved by focusing on three key areas: establishing an aging management program, developing a pre-inspection engineering package (PIEP), and conducting the field inspections.

A plant's aging management program considers variations in plant design; plant-specific operating history; schedules for refueling, in-service inspections, and plant modifications for more efficient scheduling of MRP-227–related inspections; and plant-specific regulatory commitments. It also demonstrates alignment with the plant's license renewal commitment. Such plans typically require approximately a year to develop.

The PIEP is developed through a process that considers inspection detection targets and acceptance criteria for reactor vessel internals components, which must be developed in line with the applicable regulatory criteria. Utilities seeking license renewal rely on the inspection and evaluation guidelines in MRP-227-A to address the effects of aging on the reactor vessel internals, as required by 10 CFR Part 54, *Requirement for Renewal of Operating Licenses for Nuclear Power Plants,* Section 21(a)(3). The PIEP process determines the criteria that permit return to service for the entire inspection cycle—typically 10 years—and also return to service for one fuel cycle with certain inspection results. Being prepared with an inspection response allows dispositioning of the inspection finding without having an impact on the outage during which the inspection took place. The overall PIEP consists of component inspection details, acceptance criteria, required spare parts, and the inspection response plan.

The primary components for which field inspections are required vary by plant. They typically include the control rod guide tube assembly (the guide cards and lower flange welds), core barrel welds, baffle-former assembly and bolting, alignment and interfacing of the reactor vessel components, reactor vessel hold-down spring, and, at some units, the thermal shield flexure assembly. To assist utilities



Graphic: Westinghouse

A cutaway view of the internals of a pressurized water reactor showing many of the primary components for which field inspections are required.

in complying with MRP-227-A, EPRI's MRP developed *Inspection Standard for Pressurized Water Reactor Internals* (MRP-228), which provides procedure standards for demonstrated, documented examination techniques. These techniques can be applied to effectively examine susceptible components to help ensure their structural integrity.

As part of the aging management program for Beaver Valley-1, FirstEnergy Nuclear Operating Company scheduled certain required MRP-227-A inspections of its reactor vessel internals during the unit's spring 2018 outage, and it hired Westinghouse Electric Company's wholly owned subsidiary WesDyne International to perform the inspections. The specific inspections completed during that outage were of the guide tube flange welds in the upper internals and the core barrel cylindrical welds and thermal shield flexures in the lower internals.

The WesDyne team had originally proposed seven days to complete the inspections, but in order to meet Beaver Valley-1's goal of completing the entire outage in less than 26 days, the outage manager and each of the teams that would be working in containment scrutinized all of the containment refuel floor work. Through a detailed pre-work planning process that began almost a year before the outage, the teams looked for schedule savings that would allow them to complete the inspections in five days. This included integrating all of the projects' work scopes into one very detailed flow chart to better visualize and determine which work could be streamlined or done in conjunction with other work.

The core barrel lift team, the lower internals support structure (LISS) team, the refueling team, the manipulator crane upgrade team, and the inspection team together studied and discussed the work processes in intricate detail. Through innovative planning, they were able to reduce the required critical path duration by a projected 48 hours. Clear interactions and interwork of the teams were crucial to the planning process and would also be critical to the successful execution of the highly coordinated, choreographed work in containment.

An important piece of the planning process included a first-of-a-kind inspection method for Beaver Valley-1 that had the benefit of keeping dose much lower than it normally would be for inspections of the core barrel. Unit 1 has a single-level reactor cavity, which means that if the core barrel had to be placed in the lower internals storage stand for an inspection, dose would be very high, since approximately 5 feet of the core barrel would be above the water once it was removed from the reactor vessel and placed in the stand.

To better facilitate the visual inspections and the tooling required to conduct them, while also significantly reducing the potential for airborne contamination and radiological dose rates, the inspection team used a Westinghouse-designed structure—the LISS—to conduct the lower internals inspections. This unique structure supports the lower internals directly above

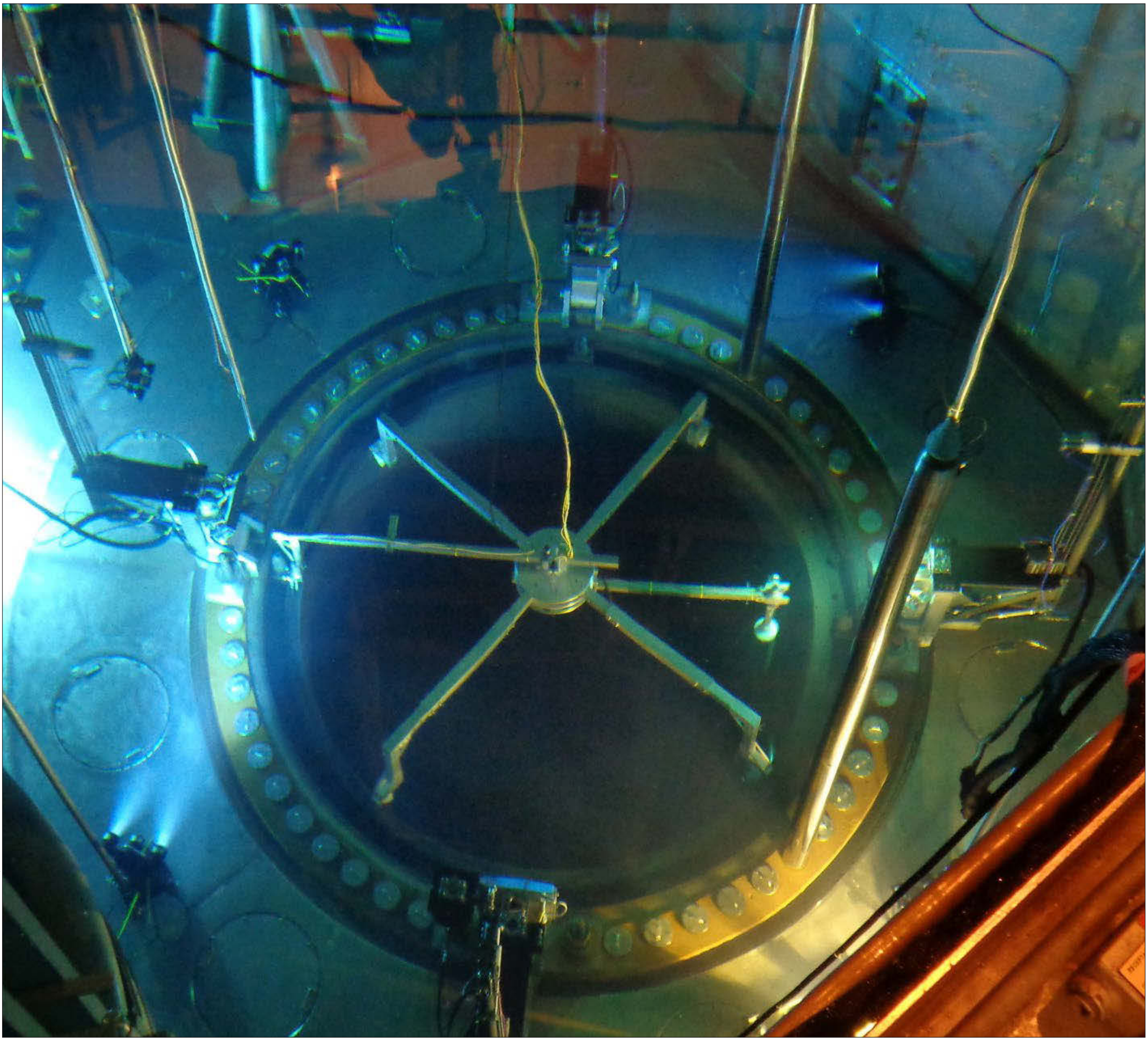


Photo: James Cannon/Beaver Valley/FENOC

The Magellan tool inspecting the upper core barrel girth weld, with the core barrel seated in the reactor vessel and the four LISS arms placed in the retracted position surrounding the core barrel.

the reactor vessel, allowing the entire core barrel to remain submerged during the inspections. Westinghouse also provided an auxiliary bridge with a pipe gantry crane for use with the LISS and to support the lifting and maneuvering of the inspection tooling.

With plans in place, including how to accommodate three platforms—the manipulator crane, the auxiliary bridge, and the Beaver Valley–supplied platform—in the confined containment area, along with their shared use of the rails to complete the various activities, the inspections could begin.

Under the new, more integrated plan, the inspection team conducted the MRP-227-A inspections of the upper internals off critical path in parallel with the fuel offload from the core. This was possible due to the platform/crane movement and interaction studies the teams conducted during the planning process, as well as the special tooling the inspection team used to inspect the control rod guide tube column-to-flange and enclosure welds and their adjacent areas—three-quarters of an inch on either side of each weld, as required by MRP-227-A.

Once the fuel was offloaded, the teams again worked to the new plan in parallel. While the inspection team conducted its first two lower internals core barrel cylindrical weld inspections, the LISS team—which would lift and reset the core barrel in place directly above the reactor vessel for the final two weld inspections and the thermal shield flexure inspections—began installing the LISS. This work was originally planned to be done in series. The teams worked in constant communication, with real-time—and sometimes minute-to-minute—adjustments to the plan being made as needed to keep all work safe and on track.

The inspection team used the WesDyne-designed Magellan inspection tool, which is configured to allow the core barrel and reactor vessel internals to remain underwater during the inspections of the first two core barrel welds. Due to the size of the tool, which mounts to the circumference of the top flange of the core barrel, it was lifted by crane and lowered into place. A remotely driven trolley runs along the Magellan tool holding a radiation-hardened, high-resolution camera that provides the necessary access for the visual inspection of the first two inner-diameter cylindrical welds—the upper core barrel flange weld just below the top of the barrel, and the upper core barrel girth weld just above the thermal shield.

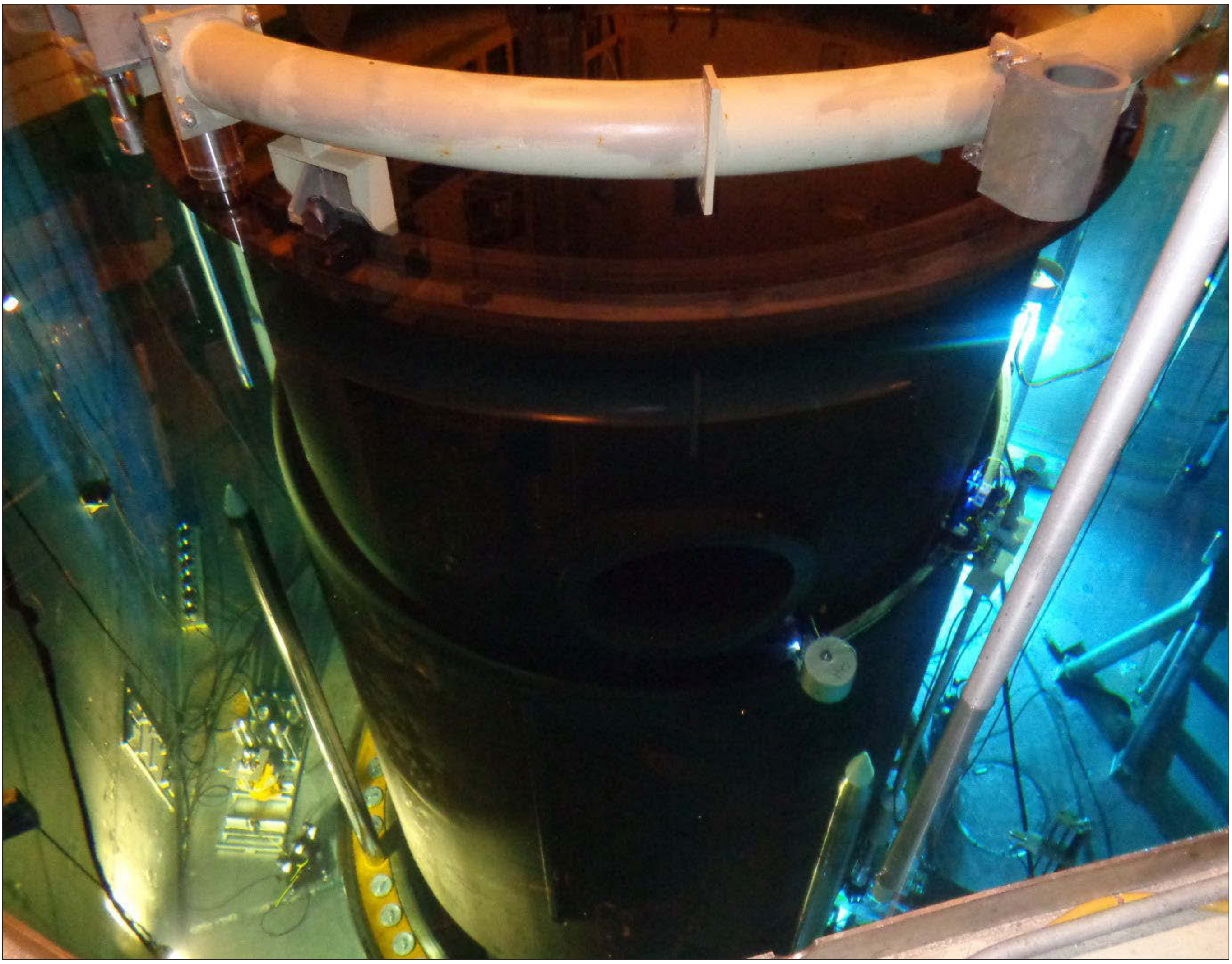


Photo: James Cannon/Beaver Valley/FENOC

The Enterprise tool examining the thermal shield flexures with the core barrel raised and seated on the LISS (arms extended and under the core barrel), just inches below the water level.

The teams worked in careful coordination while the LISS team lifted and placed each of the four legs of the LISS into place. Each leg is fitted with a hydraulic arm assembly and then lowered into the four defined places along the circumference of the core barrel. The inspection team had to work precisely, as the LISS team was on critical path, and it was imperative that the in-parallel work of the inspection team did not cause any delay in the preparation for the core barrel lift with the LISS. This required all of the skills of the highly trained teams, including those of the analyst who was remotely reviewing the images from the high-resolution camera.

Continuing to work synchronously, the inspection team finished the first two weld inspections and removed the tooling while the LISS team tightened the LISS hardware in preparation for lifting the 245,000-pound core barrel so that the hydraulic assemblies could be rotated and their arms extended underneath the core barrel.

Once the core barrel was lifted and set on the arms of the LISS, the top of the core barrel remained approximately 8 inches underwater, with room for the inspection of the third and fourth welds and the thermal shield flexures. At Beaver Valley-1, the third weld—the lower core barrel cylinder girth weld—is behind the thermal shield. The team conducted the inspection with the WesDyne-designed Enterprise tool. This tool clamps to the thermal shield and holds a one-of-a-kind, high-resolution fiberscope specifically designed to inspect this weld. It is delivered in the annulus between the core barrel and the thermal shield.

The third weld is located approximately 8 feet below the top of the thermal shield, and inspecting it required maneuvering the fiberscope through a series of passages between the thermal shield support lugs, jacking bolts, and upper internals alignment pins. The minimum inspection coverage requirement of this weld is 75 percent; the actual coverage at Beaver Valley-1 was 82.3 percent.

The same tool was used to inspect the fourth and final weld of the lower internals, including the thermal flexures. To inspect the lower core barrel flange weld and thermal flexures, the fiberscope was replaced with a pole and camera designed to be manipulated around the various obstructions, including the LISS, and was used without the need to install foreign materials exclusion covers, which would have inhibited the inspection.

The teams' determination to meet Beaver Valley-1's goals with precise planning and innovative approaches to the work made this inspection process unique not only to Beaver Valley-1 but also to the industry. The radiological dose achieved was 1,776 mrem—just 37 percent of the planned 4,737 mrem—and the overall schedule savings was approximately 48 hours. These savings were achieved while all work in containment was done safely and efficiently, meeting all applicable MRP-227-A requirements.

Innovation in field work is an important part of helping utilities continue to find more cost-effective methods for maintaining the safe and efficient operation of their plants. NN