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Nuclear News

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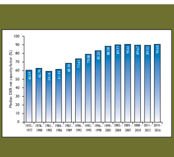

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Water jet peening crews from Mitsubishi Nuclear Energy Systems and AZZ/WSI observe the refuel pool from above as both peening tools perform the process inside the reactor vessel. (Photos: Scott Bolley/Wolf Creek Nuclear Operating Corporation)

Wolf Creek: Water jet peening of reactor vessel nozzles

Wolf Creek is the first U.S. nuclear power plant to implement this process, with the goal of mitigating primary water stress corrosion cracking in reactor vessel nozzles.

By Justin Daily

During the fall 2016 outage at the Wolf Creek nuclear power plant, Wolf Creek Nuclear Operating Corporation became the first U.S. nuclear plant operator to perform water jet peening on its reactor vessel nozzles. The goal was to mitigate the susceptibility to primary water stress corrosion cracking (PWSCC), which can occur in nickel-based Alloy 600 welds, and specifically in pressurized water reactor vessel welds because of the high operating temperatures. These alloys are used in the welding material that attaches the reactor vessel nozzles to the reactor vessel. In the case of Wolf Creek, a 1,200-MWe PWR near Burlington, Kan., there are eight inlet/outlet nozzles for the reactor coolant system and 58 bottom-mounted penetration nozzles.

The first stress corrosion cracking in nozzles was observed in Alloy 600 recirculation inlet nozzle safe ends at the Arnold plant, in Palo, Iowa, in 1978. Nickel-based alloy cracking of reactor pressure boundary components has been a worldwide concern for the past 30 years. Increased inspection frequencies, improved inspection practices, and increased licensee vigilance continue to help in the identification of nickel-based alloy cracking in vessel penetrations and various components of the primary coolant loop.

Worldwide operating experience has shown that Alloy 600 and related weld filler materials Alloys 82 and 182 (referred to collectively as Alloy 82/182) are susceptible to stress corrosion cracking in the

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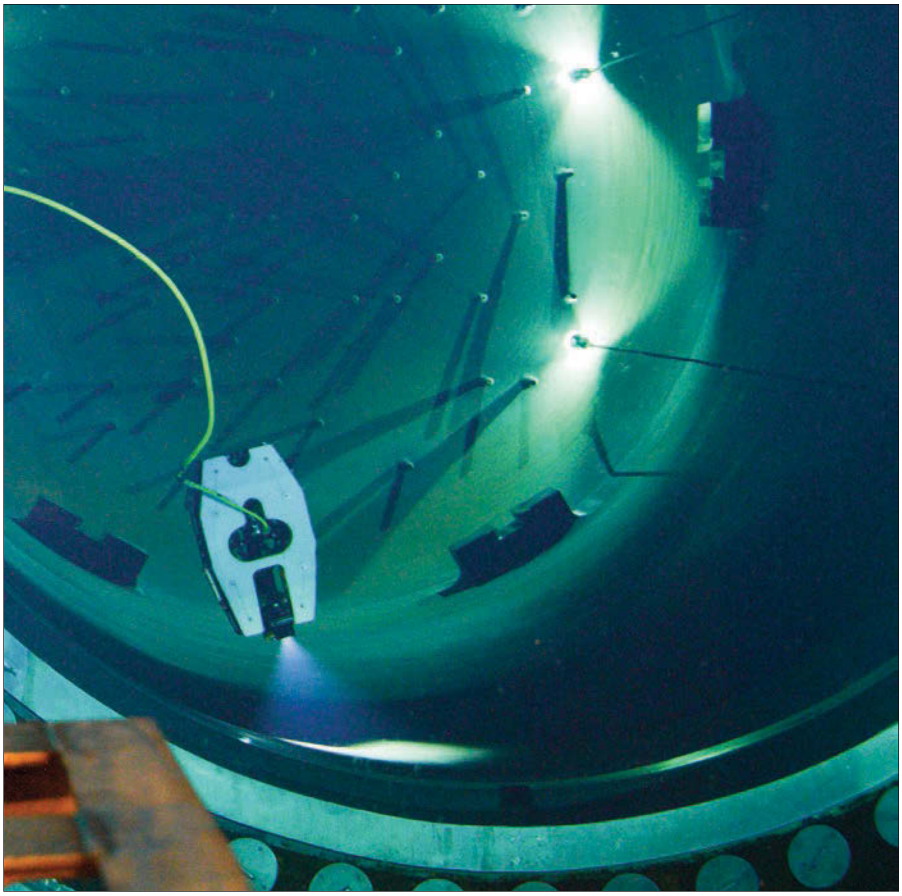
reactor coolant environment. As a PWR, due to the higher operating temperatures of the reactor coolant system, Wolf Creek was at a higher risk for PWSCC at the hot leg reactor vessel nozzle weld location than most other nuclear plants.

Since 2000, more than a dozen instances of stress corrosion cracking have occurred at U.S. nuclear plants, each resulting in significant repair projects with multimillion-dollar price tags. Wolf Creek chose to explore a water jet peening technology that was developed in Japan by Mitsubishi Heavy Industries (MHI) as a proactive approach to ensuring the long-term health of the reactor vessel welds.

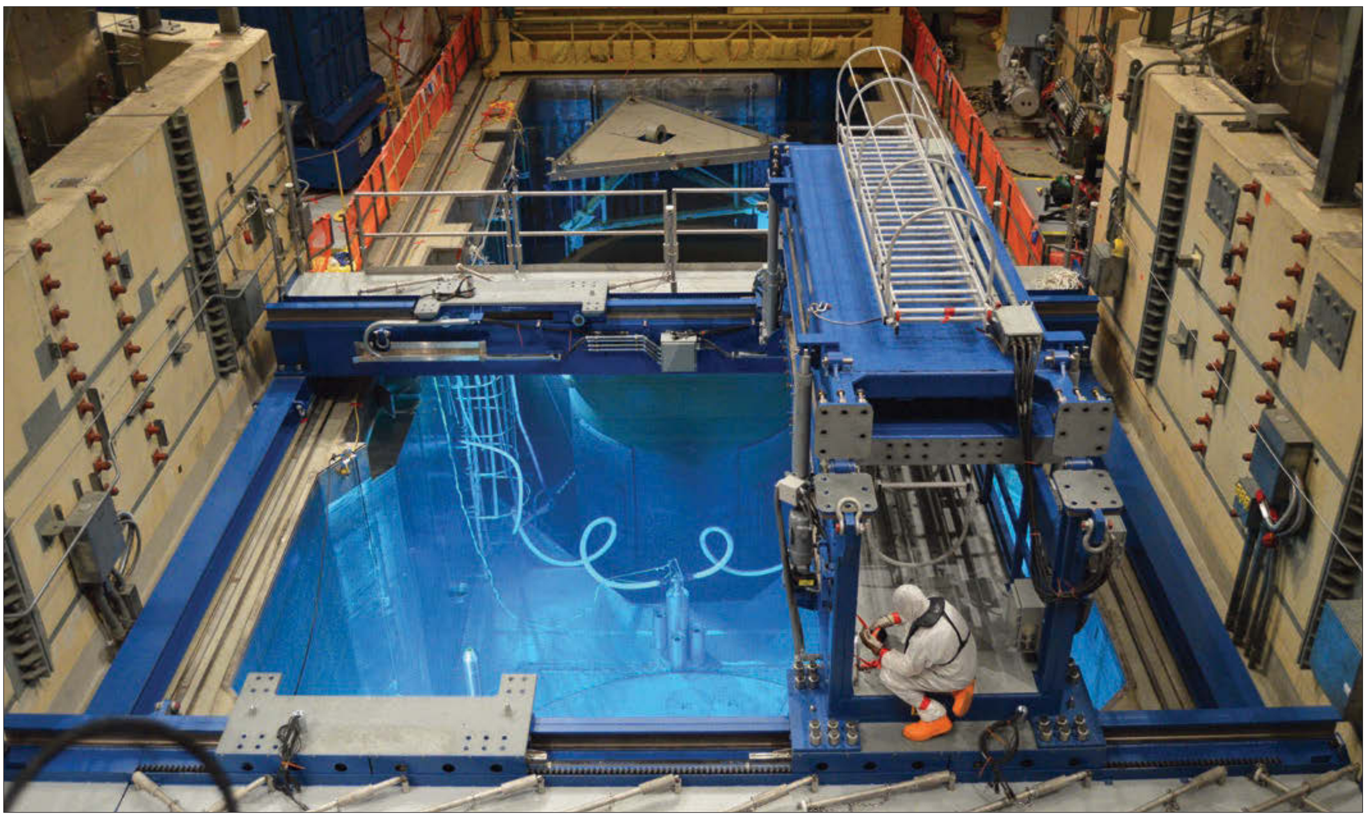
The technology has been deployed on Japanese reactors with proven results. In more than 15 years of performing water jet peening on 21 reactors in Japan, the process has proven 100 percent effective, with no post-application adverse indications. The process safely reduces tensile stress in weld material to effectively mitigate potential stress corrosion cracking.

Water jet peening uses a high-pressure, high-velocity water jet to create cavitation. Microscopic bubbles in the water collapse against the metal surface, causing a peening effect, which is similar to striking a hammer against a metal surface, on a less destructive level.

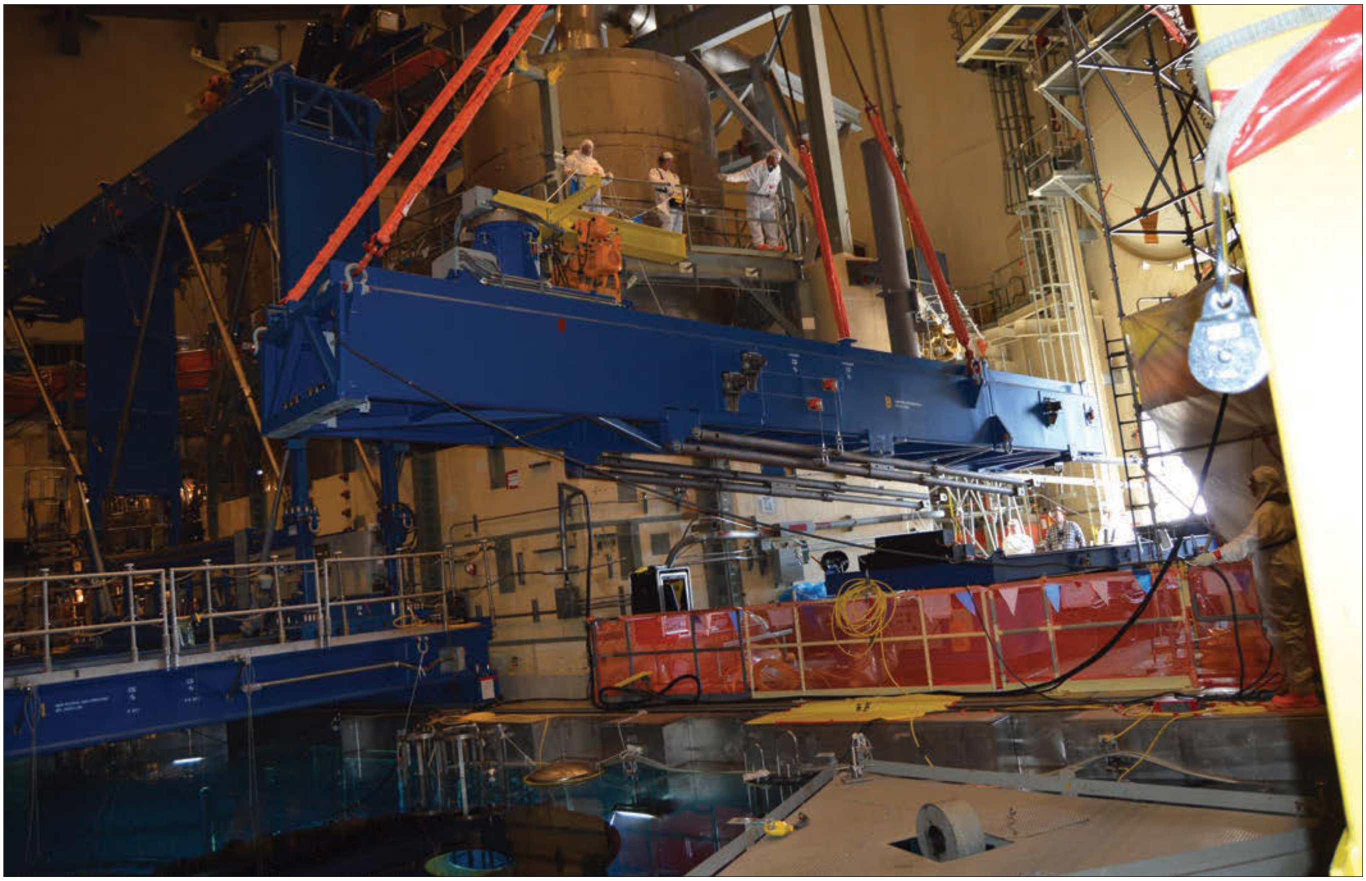
The collapse of a bubble creates shock pressure of more than 145,000 pounds per square inch on a local area of the surface of the metal. The collapse of thousands of



A submersible, remotely controlled camera is used to perform visual inspection inside the reactor pressure vessel, and the images are used to establish the material condition prior to the water jet peening operation. The images are also used after the work is completed to examine the results.



The peening bridge is unpacked and then bolted to supports around the reactor refuel pool. The two support structures arrived folded and packed in crates, and were then hydraulically unfolded once they were in place.



The gantry portion of the bridge, which sits on top of the support structures that unfold, is hoisted by crane through the equipment hatch. At the lower left of the photo is an assembled gantry bridge.

bubbles results in a peening effect on the entire wetted surface of the material that is susceptible to cracking. The water jet peening process changes the stress condition that contributes to stress corrosion cracking, putting the metal in "biaxial compression," which is what prevents cracking. While the process does not fix existing cracks, it has been proven to prevent the initiation of new ones.

The science behind the technology provides a significant measure of confidence in the reliability of the reactor vessel welds. Water jet peening of reactor vessel components susceptible to PWSCC will ensure that future unanticipated costs for crew mobilization, engineering, and repair methods are mitigated, potentially saving Wolf Creek millions of dollars in unplanned emergent repair costs and extended outage durations.

Prep and execution

Wolf Creek contracted with MHI's subsidiary, Mitsubishi Nuclear Energy Systems (MNES), to perform water jet peening of the reactor vessel components susceptible to PWSCC during the plant's 21st refueling outage in the fall of 2016. Overall project management, logistics, and field oversight were performed by the Wolf Creek team.

While Mitsubishi's water jet peening process had been used in similar Japanese nuclear plant applications by Mitsubishi personnel, Wolf Creek's implementation was performed by U.S. personnel for the first time using equipment and tooling designed and fabricated specifically for use in the U.S. nuclear industry.

The Wolf Creek project team worked with MNES and its subcontractors for four years on the translation and revision of the Japanese processes and procedures to meet U.S. regulatory requirements. This included the review and approval of all MNES procedures, engineering basis documents, and training materials required for special process qualifications.

To ensure that the U.S. project team—which had no previous experience working with this technology—was proficient in all assigned activities, mock-up training was performed for several weeks during the summer preceding the Wolf Creek outage. The training was conducted at a specially constructed facility in Pennsylvania that included a 20-foot by 20-foot stainless steel–lined pit that was 25 feet deep, allowing to-scale reactor vessel nozzle and bottom-mounted nozzle mock-ups to be submerged to simulate reactor vessel working conditions.

The water jet peening equipment required considerable physical space inside the reactor containment building to support staging, setup, testing, and repairs. Due to site limitations, all equipment had to be placed inside the containment building. To overcome plant component obstructions around the reactor cavity, the Wolf Creek project team designed and fabricated a temporary work platform that was installed on the north side of the reactor cavity, above the digital rod position indication boxes.

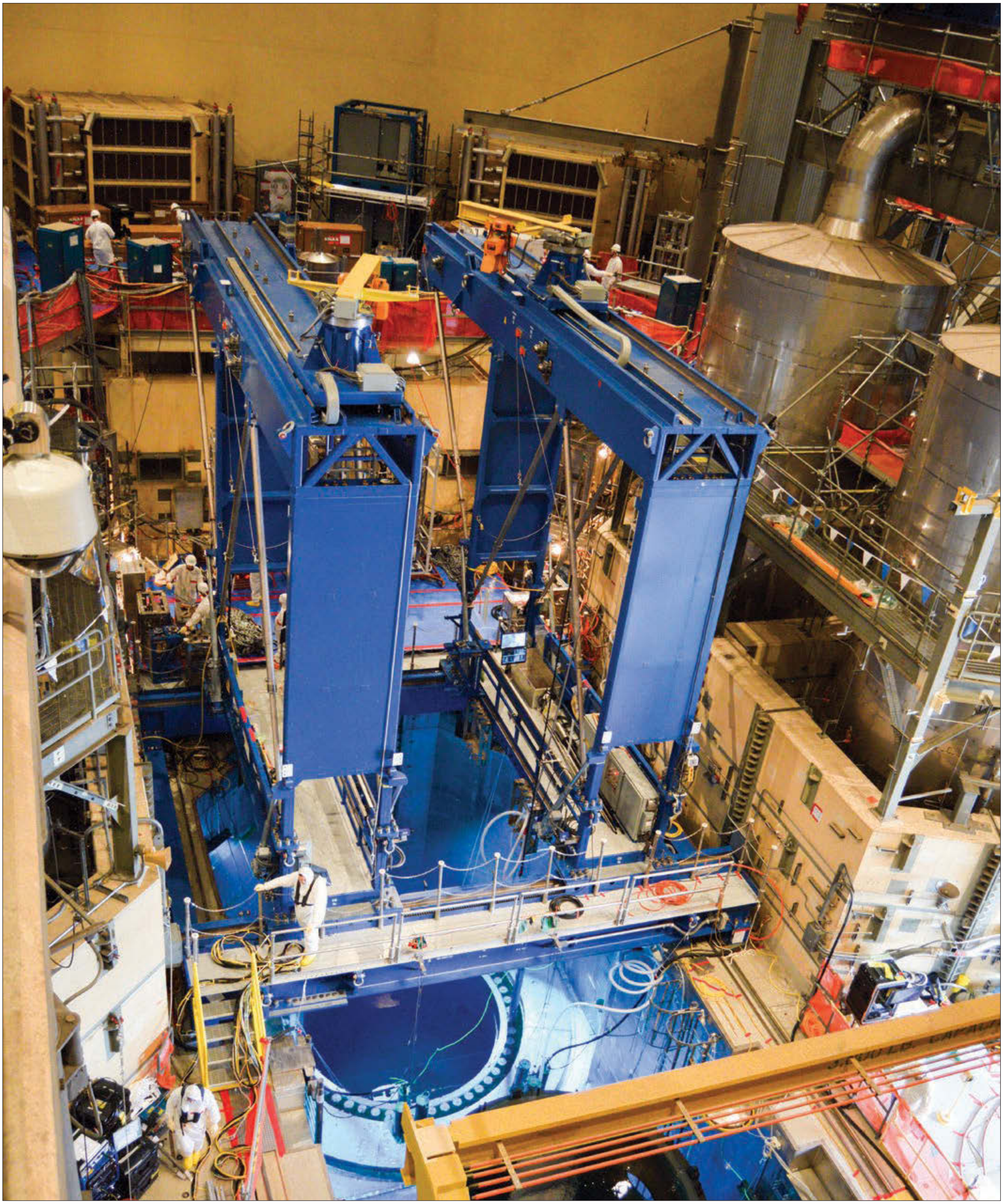
To minimize polar crane use over the cavity during the peening operation, the Wolf Creek team worked with MNES and contractor AZZ/WSI LLC to design and fabricate a water jet peening bridge structure. The modular, 90-ton bridge was assembled and tested over the reactor refueling canal after the core barrel was removed and placed in its storage location. The bridge allowed one reactor vessel nozzle peening tool and one bottom-mounted nozzle peening tool to be used simultaneously, minimizing the overall peening duration. During previous operations in Japan, the two tools had never been used in parallel. Besides minimizing the time required to perform the peening, the bridge also allowed the polar crane to support other critical path outage activities unimpeded.

The bridge components were delivered to Wolf Creek in specially designed 30-foot metal crates. To accommodate loading and unloading of these boxes inside the containment building equipment hatch, Wolf Creek used a pipe modular lift system and a nine-line remote-operated cart capable of moving all outage support equipment—including the bridge boxes, which weighed up to 45,000 pounds—into the containment refueling floor elevation. This system, procured and operated by Precision Surveillance Corporation, alleviated the crane operating restrictions during high-wind conditions that are commonplace in Kansas.

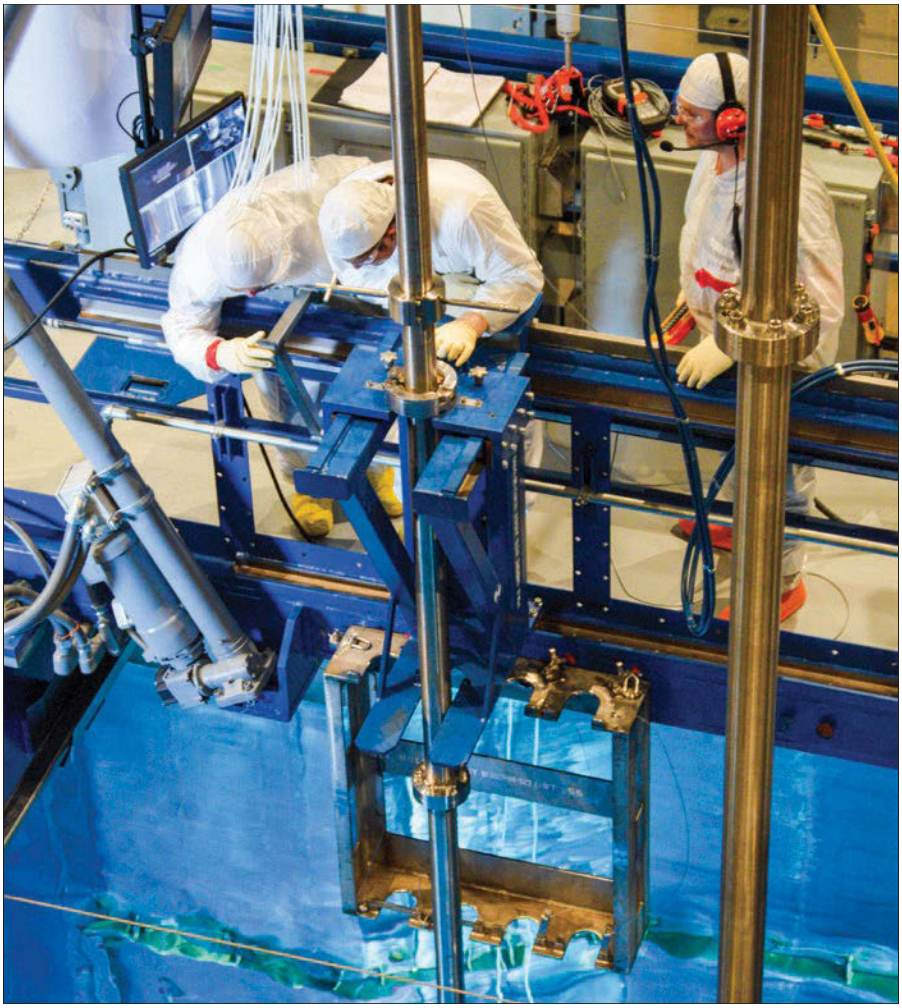
All targeted welds on the reactor vessel hot- and cold-leg nozzles and on all 58 bottom-mounted nozzles were inspected for pre-existing cracks (none were found), and then were peened to prevent any future occurence of PWSCC.

Mission accomplished

During the peening operation, all project safety and radiological goals were met. The project team logged more than 18,700 person-hours while performing water jet peening. Also, through proficiencies gained during mock-up training and engagement at all levels of the project



An overall view of the work area, once the bridge and work platform were in place.



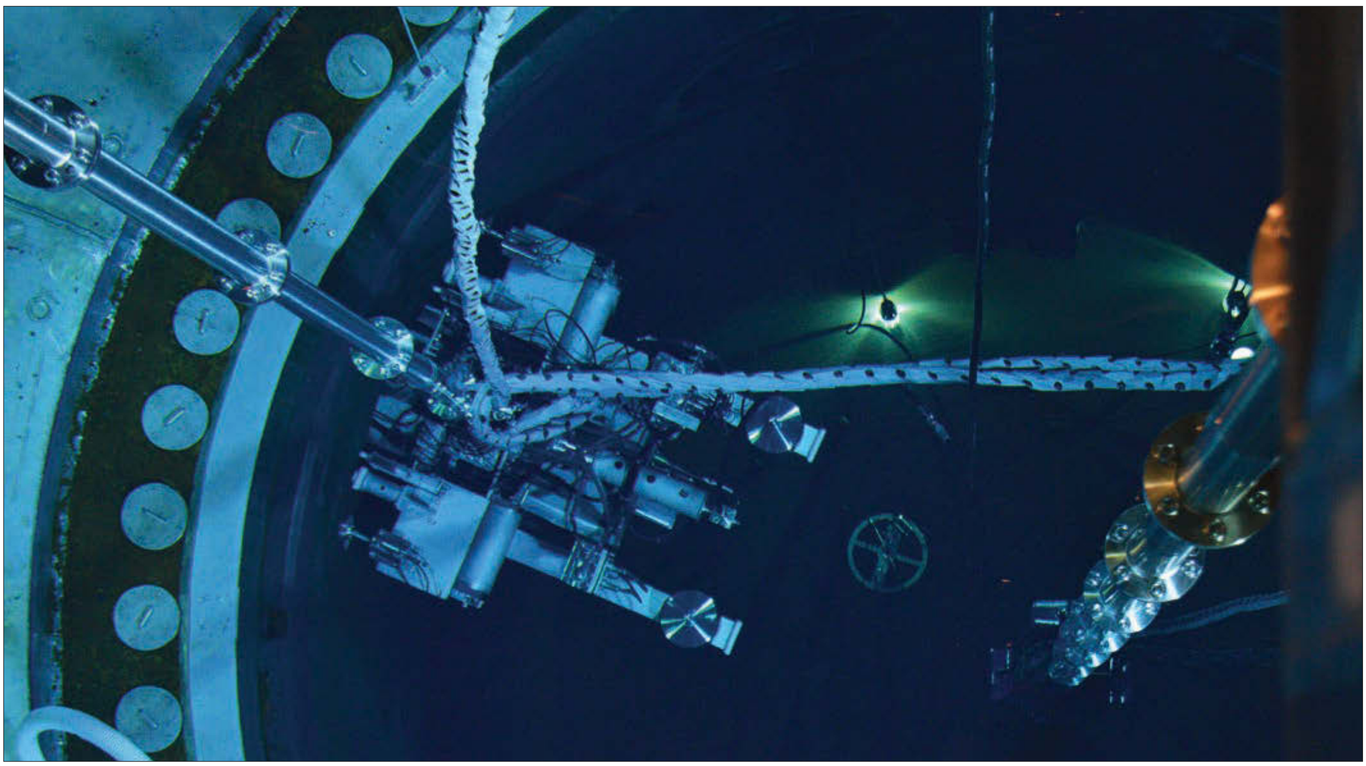
Workers lower the peening tools into the reactor vessel via metal extension rods, positioning them to begin peening a particular area.

team, the peening project was successfully completed with excellent industrial safety performance: There were no first aid or Occupational Safety and Health Administration–recordable injuries.

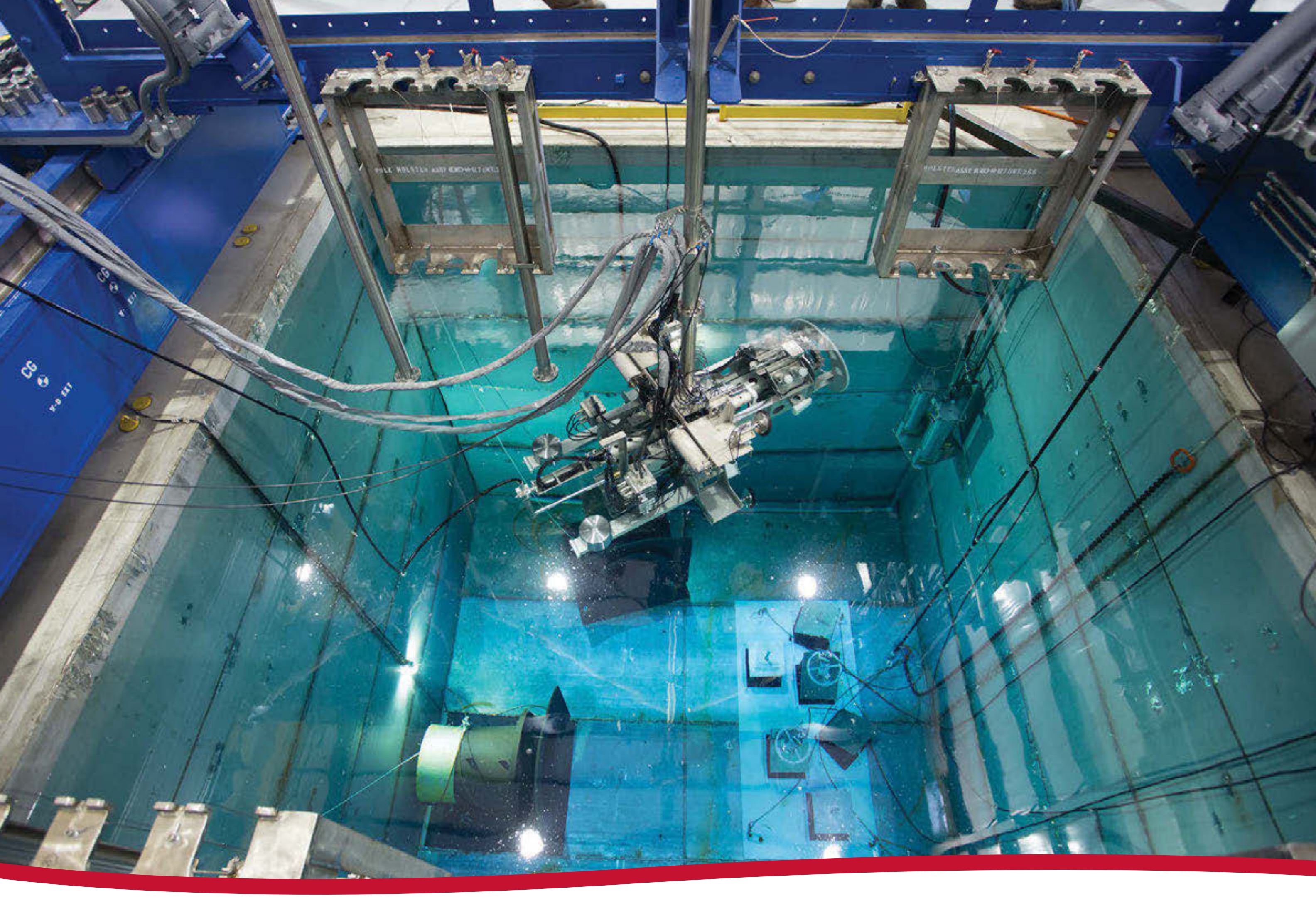
Radiological safety performance was equally impressive. Prior to the outage and based on Japanese water jet peening experience, a dose goal of 4.416 rem was projected. By reinforcing site expectations for radiation worker practices during mock-up training and ownership of contamination and dose by each individual during the outage, actual project dose was limited to just 1.886 rem, more than 57 percent below the estimate. Despite numerous wet tool movements in and out of the reactor vessel, the project team completed the work with no personnel contamination events.

Overall project costs finished below the planned budget, with 2016 project costs for Wolf Creek ending nearly 10 percent below projections. The entire outage peening scope was successfully performed and documented, protecting the reactor vessel asset for the remaining life of the plant.

The lessons learned and technology process improvements identified during the Wolf Creek water jet peening project phases will prove advantageous to plants looking to use the technology in the future as a PWSCC mitigation strategy. Ameren's Callaway station has already scheduled the process into a future refueling outage, and Wolf Creek is working closely with the Callaway team to share its operating experience. NN



The bridge allowed one reactor vessel nozzle peening tool, attached to the wall of the vessel (at left), and one bottom nozzle peening tool (at right) to be used simultaneously, minimizing the overall peening duration.



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