System Inspects Nuclear Reactor Drain Lines for Corrosion

The Susquehanna plant of PPL Corp. demonstrated an EPRI-developed remotely operated ultrasound evaluation system for the detection of flow-accelerated corrosion.

To facilitate corrosion detection in difficult-to-access locations such as boiling water reactor drain lines, the Palo Alto, Calif.-based, Electric Power Research Institute (EPRI) worked with PPL Corp., an electric utility based in Allentown, Pa., to develop and demonstrate a remotely operated ultrasound evaluation system. The tool has been successfully field tested during outages at PPL’s Susquehanna plant in spring 2007 and 2008.

Preventing Corrosion Failures

Damage to power plant piping from flow-accelerated corrosion (FAC) can result in costly outages and repairs that affect reliability and safety. FAC is a corrosion mechanism in which a normally protective oxide layer on a metal surface dissolves in a fast-flowing fluid. The underlying metal corrodes to re-create the oxide, initiating a cycle in which the metal loss continues. Chemistry conditions play a role, as does the fluid velocity.

Flow-accelerated corrosion leads to metal loss on the inside walls of steel piping exposed to flowing water or wet steam. If undetected and unmitigated, this damage mechanism can result in thinning and weakening of the pipe wall, and could culminate in a leak or break.

Because of their configuration and the operating chemistry and flow conditions, the carbon steel drain lines of boiling water reactors may be susceptible to FAC. Inspecting the drain line for FAC damage, however, is challenging. The line is surrounded by the control rod drive mechanism tubular penetrations and other components that limit access. Adding to the inspection challenge, the boiling water reactor drain line can include 90-deg elbows and diameter changes in the susceptible piping section targeted for FAC inspection.

While boiling water reactor drain lines may be susceptible to FAC, no FAC damage has been reported to date due to the dif-

difficulty accessing and inspecting the pipe location. The potential consequences of FAC damage are serious, however, because leaks or breaks in the line cannot be isolated. While easily managed by the plant safety systems, such a break would result in significant economic consequences to restore the plant to normal operation.

Once the drain line’s susceptibility to FAC was recognized, industry representatives and EPRI established a plan of action that included estimating possible corrosion rates, ranking boiling water reactor plants according to level of susceptibility, and developing an inspection technology to verify the in-place condition of the drain line in the fleet. EPRI’s Nondestructive Evaluation (NDE) Center led the inspection technology development efforts, and PPL agreed to host the first use of the technology at its Susquehanna plant.

Technology to Inspect FAC

For more than two decades, EPRI has worked with the nuclear power industry on a broad-based initiative to detect and mitigate FAC before it causes costly failures. EPRI formed a tool design team with East Hanover, N.J.-based, Nova Technology (www.novatechnologync.com), while PPL (www.pplweb.com) provided detailed piping configuration input and design review.

The project team conceived and constructed a remotely operated tool that could be delivered via pole past the obstructions of the drain line environment at the bottom of the reactor pressure vessel — Fig. 1. Once secured and aligned on the top of the drain line, the tool employs two ultrasonic transducers to measure pipe wall thickness. A geared wheel rotates the transducers around the pipe circumference, while a second gear provides the motion along the elbow curvature — Fig. 2. The transducers are equipped to permit proper tracking of the surface.

The system also includes ultrasonic data acquisition units, a motion controller to execute positioning instructions, and video units to monitor the alignment, position, and motion of the tool and transducers.

Full-Scale Mockup

The project team demonstrated the new tool to PPL using a full-scale mockup of the reactor bottom including wooden repli-
The demonstration enabled the project team to assess the tool’s performance, gave PPL staff hands-on experience with the system, and identified issues to be addressed prior to field deployment. The demonstration showed that the tool placement procedure was satisfactory, and that ultrasonic measurements of pipe wall thickness tracked closely with data obtained manually with the mockup. The demonstration produced one false reading, which the project team traced to improper transducer inclination in the vicinity of the pipe weld; a refined positioning procedure addressed the problem.

Susquehanna Field Trial

PPL and EPRI field tested the system at Susquehanna Unit 2 during the 2007 spring outage — Figs. 4–6. Following sensor calibration, the team placed the unit on the drain line, accompanied by a video camera to view the drain line and the tool. The team evaluated the drain line by mapping the wall thickness using a grid pattern with a spacing of ½ in. (12.7 mm). This pattern translated to eight data points around the circumference per grid ring. Upon completing the elbow assessment, the downstream pipe segment was examined in three stages for a distance of 6 in. (152.4 mm).

Results and Conclusions

PPL reviewed the wall thickness data collected by the inspection tool and determined that the drain line met the requirements for safe operation. Because a measurement at one location had a value below the nominal wall thickness, PPL will monitor this area at a future outage for possible degradation. The project reached the following conclusions:

◆ The technology provided satisfactory access to the drain line to perform thickness measurements for piping configurations representative of the boiling water reactor design at Susquehanna.
◆ Measurement accuracy with the inspection tool is comparable to that obtained with manual techniques.
◆ Video camera support is necessary for proper system operation.
◆ Careful video tracking of the transducer inclination angle is essential because improper surface tracking may lead to false readings.

Further Development

PPL successfully deployed the technology a second time during Unit 1’s spring 2008 outage. To further extend the applicability of this technology, EPRI is adapting the tool for use in plants with piping configurations representative of other boiling water reactor designs.

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