

UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
OFFICE OF NUCLEAR REACTOR REGULATION  
WASHINGTON, D.C. 20555-0001

July 24, 1998

**NRC INFORMATION NOTICE 98-27: STEAM GENERATOR TUBE END CRACKING**

Addressees

All holders of operating licenses for pressurized-water reactors (PWRs) except those who have permanently ceased operation and have certified that fuel has been permanently removed from the reactor vessel.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to inform licensees of instances of steam generator tube-end cracking. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

Entergy, the licensee for Arkansas Nuclear One, Unit 1 (ANO-1), conducted leak testing on each once-through steam generator (OTSG) during the spring 1998 refueling outage to identify the source of primary-to-secondary leakage measured during the previous operating cycle. The leak testing revealed a small leak in one tube of each OTSG. The leak in each tube was in flaws in the tube hardroll just below the upper tubesheet seal weld. Subsequent eddy current inspections identified primary-water stress-corrosion cracking (PWSCC) in each of the two tubes. The through-wall flaws in the tubes were oriented both axially and circumferentially in the tubes. Examinations of all upper tubesheet seal weld areas in both OTSGs revealed possible flaws in 1896 additional tubes. For these tubes, the licensee installed an additional hard roll in the upper tubesheet, thus redefining the reactor coolant pressure boundary.

Eddy current inspections completed at Davis-Besse Nuclear Power Station in April 1998 identified five tubes with "tube end anomalies" believed to be related to the flaws identified at ANO-1. Duke Power Co. recently completed an assessment to determine if its Babcock and Wilcox-designed, operating units, Oconee Nuclear Station, Units 1 and 3, were affected by tube-end cracking. The licensee concluded that 372 indications in the Unit 1 OTSGs and 61 indications in the Unit 3 OTSGs exceeded the repair criteria in the Oconee Technical Specifications. Tube-end cracking has also been reported for the steam generators at Prairie Island Nuclear Generating Plant.

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Steam generator tubes are secured into tubesheets using both mechanical expansion and welding. In general, each tube protrudes slightly beyond the tubesheet. A seal weld provides a leak-tight configuration. The mechanical expansion and seal welding processes introduce high residual stresses in the ends of each tube. In addition, the high temperatures associated with welding alter the metallurgical characteristics of the tube material in the heat-affected zone. Although the tubes in the ANO-1 OTSGs were heat treated prior to operation (which should have improved the material's resistance to stress-corrosion cracking), the licensee's preliminary conclusion is that the rolling and welding processes contributed to the development of PWSCC in the tubes at the seal weld. The licensee is currently conducting a root-cause evaluation to determine any future corrective measures necessary to prevent recurrence or to mitigate the consequences of this mode of degradation.


### Discussion

One of the safety functions of steam generators is to maintain a barrier against fission product release. Tube-to-tubesheet seal welds in steam generators minimize the potential for primary-to-secondary leakage under normal-operating and postulated-accident conditions. The development of PWSCC tube cracking in the vicinity of these welds may degrade the leak-tight barrier between the primary and secondary coolant systems. Although the primary-to-secondary leakage during normal operation from a single tube-end flaw is likely to be small relative to the limit specified in plant technical specifications, the combined leakage from tube-end flaws could become significant if a large number of tubes have through-wall cracks.

PWR technical specifications require tubes containing defects with depths that exceed the repair criteria (typically 40 percent of nominal wall thickness) to be removed from service. The repair criteria often require licensees to consider the entire tube in determining whether tubes are degraded or defective. Defects located in any area of a tube are evaluated against the repair criteria unless the area is specifically excluded from the surveillance requirements. Upon confirming the presence of tube-end flaws at ANO-1, the licensee utilized an industry-approved repair method to install an additional hard roll in the upper tubesheet, thus redefining the reactor coolant pressure boundary. The tubes in most recirculating steam generator designs are fully expanded within the tubesheet and do not offer the option of this type of repair. While fully-expanded designs inherently provide considerable resistance to bypass leakage, licensee technical specifications may still require licensees to consider flaws near tube-end seal welds in dispositioning tubes as acceptable for continued service.

Steam generator tube-end cracking may not be limited to OTSGs. All PWR steam generators contain similar welds that may be equally susceptible to the development of PWSCC in the heat-affected zone of the tube. Due to the location of flaws associated with tube seal welds, the use of traditional inspection techniques and analysis procedures may not be entirely effective in detecting and characterizing this mode of degradation. The licensee for the Oconee units found it necessary to perform supplemental eddy current inspections on mockup test samples to adequately address tube-end cracking.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

*for*   
Jack W. Roe, Acting Director  
Division of Reactor Program Management  
Office of Nuclear Reactor Regulation

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98-24	Stem Binding in Turbine Governor Valves in Reactor Core Isolation Cooling (RCIC) and Auxiliary Feedwater (AFW) Systems	7/08/98	All holders of operating licenses for nuclear power reactors except those who have permanently ceased operation and have certified that fuel has been permanently removed from the reactor vessel

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OL = Operating License  
CP = Construction Permit

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