UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, DC 20555-0001

December 11, 2006

NRC INFORMATION NOTICE 2006-27: CIRCUMFERENTIAL CRACKING IN THE STAINLESS STEEL PRESSURIZER HEATER SLEEVES OF PRESSURIZED WATER REACTORS

ADDRESSEES

All holders of operating licenses or construction permits for pressurized water reactors (PWRs), except those who have permanently ceased operations 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 (IN) to describe a recent experience in which a licensee attributed a circumferentially-oriented crack to intergranular stress corrosion cracking (IGSCC) in a stainless steel pressurizer heater sleeve in a PWR reactor coolant environment. The NRC expects that addressees will review the information for applicability to their facilities and consider actions, as appropriate, to identify and address similar problems. However, suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

DESCRIPTION OF CIRCUMSTANCES

During the spring 2006 outage at Braidwood, Unit 1, Exelon Generation Company (the licensee) found boron deposits in the pressurizer surge line area during insulation removal. The licensee determined that the leakage originated from the number 52 pressurizer heater (heater number 52) at the upper weld between the pressure tube and heater coupling. The licensee based this determination on deposit patterns, deposit chemical analysis, and rouging (i.e., rust) found in the convection cover insulation sleeve for heater number 52. Rouging could be caused by steam impingement on the stainless steel material. The licensee visually inspected all 78 pressurizer heaters to determine the extent of the condition and determined that heater number 52 was the only source of boric acid leakage from the pressurizer.

The licensee removed leaking coupling for heater number 52 from the system and plugged the tube. The licensee shipped the coupling to a testing facility to determine the cause of the failure. The results of the laboratory examinations to date suggest that the observed cracking in the sleeve occurred due to circumferentially-oriented IGSCC in the heat affected zone

approximately 0.090 inch above the toe of the sleeve-to-coupling upper fillet weld. The cracking initiated at the inside diameter surface and progressed radially outward resulting in a through wall leak. The licensee indicated that the cracks extended approximately 150 degrees around the circumference with about 20 degrees having a crack depth greater than 95 percent. The heater sleeve tubes have a wall thickness of 0.11 inch and an inside diameter of 0.905 inch. If the circumferential crack were allowed to grow, it could reach the critical crack length of 212 degrees around the circumference as determined by the licensee and potentially result in sleeve separation, sleeve ejection, and loss of reactor coolant.

The crack propagated through the heat affected zone of the pressure tube, which was heavily sensitized during fabrication of the multi-pass socket weld. The blunted crack tip morphology and the crack deposits near the outside diameter surface suggest a slow rate of crack growth, a long duration of leakage, or both.

As a corrective action, the licensee plans to detect boron deposits by visually inspecting the bare metal in the annulus region and at heater sleeve welds during every outage of each of its Braidwood and Byron units, pending more definitive industry guidance (e.g., from the PWR Owners Group).

Braidwood, Unit 1, represents the only known occurrence of IGSCC-induced circumferential cracking in a PWR pressurizer heater sleeve. A Westinghouse Electric Company assessment of this event noted that there are at least 12 Westinghouse-designed plants in operation with the same configuration of welded stainless steel heater sleeves, with a total of 936 such sleeves in service. These plants range in age from 20–25 years old. With no other occurrences of leakage in this large population of stainless steel heater sleeves with an average of 20 years of operating experience, this data suggests an extremely low probability of occurrence of cracking. The licensee provided details regarding the event, including the Westinghouse assessment, in its July 17, 2006, letter to NRC (Agencywide Documents Access and Management System, Accession Number ML062500219).

BACKGROUND

The NRC staff reviewed previously documented industry experiences and did not identify any similar events at the other Westinghouse-designed plants. All previous events involving pressurizer heater sleeve cracking occurred at plants designed by Combustion Engineering that exhibited primary water stress corrosion cracking of nickel alloy materials and have been the subject of numerous previous INs.

Electric Power Research Institute (EPRI) literature indicates that sensitized 300 series stainless steel can be susceptible to IGSCC in stagnant or dead-end PWR coolant environments that contain oxygen. Using qualitative energy dispersive spectroscopy evaluations that identified a high oxygen content in the crack deposit, EPRI noted that the crevice region where the cracking initiated was exposed to an oxygenated environment.

NRC requirements related to the pressurizer heater sleeve cracking issue include the technical specification limits for reactor coolant system operational leakage (e.g., no pressure boundary leakage and 1 gallon per minute unidentified leakage). Additionally, Section XI of the American Society of Mechanical Engineers *Boiler and Pressure Vessel Code* (ASME Code) requires that all PWR licensees inspect for reactor coolant leakage. Licensees may also have plant-specific commitments in their response to Generic Letter 88-05, "Boric Acid Corrosion of Carbon Steel Reactor Coolant Boundary Components in PWR Plants."

DISCUSSION

The Braidwood, Unit 1 event challenges the previously held belief that stainless steel pressurizer heater sleeves in PWRs were not susceptible to IGSCC. NRC will continue considering the safety and regulatory aspects of the event.

GENERIC IMPLICATIONS

IGSCC is a material failure mode driven by material characteristics (e.g., alloy used, annealing process), weld residual and applied stresses, and environmental factors (e.g., local water chemistry). Other plants have pressurizer heater sleeves made of similar material that are exposed to similar environmental conditions as the Braidwood, Unit 1, heater sleeve and, therefore, may also be susceptible to IGSCC. NRC has initiated discussions with the PWR Owners Group address generic implications of the Braidwood event. Specifically, these discussions involve other susceptible plants and licensee decisions to conduct additional periodic analyses, tests, and inspections of their stainless steel pressurizer heater sleeves.

CONTACTS

This information notice requires no specific action or written response. Please direct any questions about this matter to the technical contact listed below.

/RA/

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ADAMS Accession Number: ML062490396

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