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

February 23, 1990

NRC INFORMATION NOTICE NO. 90-10: PRIMARY WATER STRESS CORROSION CRACKING (PWSCC) OF INCONEL 600

Addressees:

All holders of operating licenses or construction permits for pressurized water reactors (PWRs).

Purpose:

This information notice is intended to alert addressees to potential problems related to primary water stress corrosion cracking (PWSCC) of Inconel 600 that has occurred in pressurizer heater thermal sleeves and instrument nozzles at several domestic and foreign PWR plants. 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 do not constitute NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances:

During the 1989 refueling outage at Calvert Cliffs Unit 2 (CC-2), visual examination detected leakage in 20 pressurizer heater penetrations and 1 upper-level/pressure tap instrument nozzle. Leakage was indicated by the presence of boric acid crystals at the penetrations and on the nozzle. Nondestructive examinations (liquid penetrant and eddy current examinations) were performed on 28 thermal sleeves and 3 instrument nozzles. Crack indications were reported in 24 thermal sleeves, including the 20 originally identified to be leaking as well as the leaking nozzle. No crack indications were found in the two lower instrument nozzles. The examinations showed that all cracks in the sleeves and the nozzle were axially oriented with a maximum length not greater than 1.5 inches. The mode of failure for the thermal sleeves was identified as PWSCC.

The heater sleeves and the instrumentation nozzles were made of Inconel 600 tubing and bar materials, respectively, supplied by INCO. All thermal sleeves were made in a high strength heat (NX8878) with a reported yield strength of 63.5 ksi. No chemical contaminants were found on the sleeve fracture surfaces. A review of the fabrication records showed that all 120 thermal sleeves in CC-2 were reamed 3.5 inches from the top before welding and all but two were also

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reamed after welding to facilitate the insertion of the heater rods. All cracks in the sleeves were reported to be located inside the reamed region either above or below the J-groove weld.

All instrument nozzles were made from heat no. NX8297 and its yield strength was reported to be 36 ksi. The licensee indicated that four upper instrument nozzles, including the leaking one, had been extensively reworked when the faulty J-groove welds were repaired. Based on the results of the investigations, the licensee, Baltimore Gas and Electric (BG&E), postulated that the leaking in the pressurizer thermal sleeves and the instrumentation nozzle was due to PWSCC. The licensee is in the process of removing a metallurgical sample from the leaking instrument nozzle for failure analysis to identify the mode of failure.

On February 27, 1986, a small leak (about 0.15 gpm) was observed on a 3/4-inch-diameter upper pressurizer level instrument nozzle at San Onofre Nuclear Generating Station (SONGS) Unit 3 while the plant was in hot standby. An axial flaw about 5/8 inch in length was identified on the inside diameter surface of the nozzle. The flaw appeared to originate from the end of the nozzle inside the pressurizer and extended beyond the attachment weld (1/2 inch in depth) approximately 1/8 inch into the annulus area of the nozzle assembly. The flawed nozzle was cut out, including the entire attachment weld. The results of the metallurgical examination performed on the flawed nozzle assembly indicated that the cracking was PWSCC.

In spring 1989, leakage from instrument nozzles was observed in two foreign PWRs (one from each 1300-MW plant) when the hydrostatic pressure testing of the primary system was performed during the first refueling outage. The instrument nozzles were made of Inconel 600 material. The installation of the nozzles included mechanically rolling a portion of the nozzle into the pressurizer shell. Nondestructive examinations (NDEs) were performed on the leaking nozzles and found the cracks to be principally axial in orientation; however, some circumferential cracking was observed. Destructive examination of these two leaking nozzles to identify the root causes has not been completed. Additional NDEs were performed on all the instrument nozzles of five 1300-MW PWRs. Crack indications were found in 12 instrument nozzles.

Discussion:

Extensive laboratory testing has shown that intergranular stress corrosion cracking (IGSCC) requires the presence of the following three key elements: an aggressive environment, susceptible material, and sufficient tensile stresses for crack initiation and propagation. PWSCC refers to IGSCC in the primary water environment of PWRs. The laboratory demonstration of PWSCC in Inconel 600 was first reported by Coriou almost 30 years ago. The studies of PWSCC in Inconel 600 have been documented in numerous published reports. However, the mechanism for PWSCC in Inconel 600 is still not well understood. In PWRs, PWSCC of Inconel 600 was first reported in steam generator tubing.

The cracking to date in the thermal sleeves and the instrument nozzles of the domestic PWRs has been reported as being only axially oriented. The safety implication of an axial crack is not considered a significant threat to the structural integrity of the components and most likely will result in a small leak. However, limited circumferential cracking was reported in the instrument nozzles of several foreign PWRs. The difference in the cracking morphology has been attributed to the different type of mechanical working (rolling vs. reaming) being performed on these nozzles and thermal sleeves. The appearance of the crack in the rolled instrument nozzle is consistent with that observed in the roll-expanded region of steam generator tubing. Circumferential cracking poses a more serious safety concern because if it were to go undetected it could lead to a structural failure of a component rather than to a limited leak.

The reported cracking of the pressurizer thermal sleeves and the instrument nozzle at Calvert Cliffs Unit 2 and the instrument nozzle at SONGS Unit 3 are the most current PWSCC events for Inconel 600 in domestic PWRs besides the cracking problem associated with the steam generator tubing and plugs. The pressurizer thermal sleeves in Calvert Cliffs Unit 1 (CC-1) were also made of the same heat of susceptible material, but the recent inspection of the CC-1 pressurizer did not reveal any leaking or cracking of the thermal sleeves. The licensee indicated that the major difference in the fabrication of thermal sleeves between CC-1 and CC-2 is that the pre-installation reaming operation was not performed on CC-1 sleeves. The Combustion Engineering Owners Group (CEOG) performed an evaluation of pressurizer heater sleeve susceptibility to PWSCC for plants designed by Combustion Engineering. The CEOG recommended a visual inspection program for the thermal sleeves. The inspection program for the thermal sleeves varied, depending on the degree of susceptibility of the sleeve materials. The sleeve susceptibility was rated by the elements described above. The staff notes that at CC-2 the yield strength of the thermal sleeve material is higher than that of the instrument nozzle material. However, PWSCC occurred in both heats of materials. This circumstance may indicate that the yield strength of the material is not necessarily a reliable screening criterion for PWSCC susceptibility. The CEOG is performing additional work to address PWSCC of Inconel 600. The CEOG programs include the following activities: evaluations to gain better understanding of the cracking mechanism in pressurizer thermal heater sleeves and instrument nozzles; an analytical determination of a temperature profile for the heater sleeves; review of the fabrication history of all Inconel 600 penetrations in the primary system components; conduct of a test that is primarily a system leakage test on a mock-up of the flawed components; and improvement of NDE methods for cracking evaluation.

PWSCC of Inconel 600 is not a new phenomenon. However, very little special attention has been given to the inspection for PWSCC in Inconel 600 applications other than that associated with the steam generator tubing. As a result of the recently reported instances of PWSCC in the pressurizer heater thermal sleeves and instrument nozzles in several domestic and foreign PWRs, it may be prudent for licensees of all PWRs to review their Inconel 600 applications in the primary coolant pressure boundary, and when necessary, to implement an augmented inspection program.

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 NRR project manager.

Charles E. Rossi

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Information Notice No.	Subject	Date of Issuance	Issued to
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88-30, Supp. 1	Target Rock Two-Stage SRV Setpoint Drift Update	2/2/90	All holders of OLs or CPs for nuclear power reactors.
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88-23, Supp. 2	Potential for Gas Binding of High-Pressure Safety Injection Pumps During a Loss-of-Coolant Accident	1/31/90	All holders of OLs or CPs for PWRs.
90-07	New Information Regarding Insulation Material Performance and Debris Blockage of PWR Contain-ment Sumps	1/30/90	All holders of OLs or CPs for nuclear power reactors.
90-06	Potential for Loss of Shutdown Cooling While at Low Reactor Coolant Levels	1/29/90	All holders of OLs or CPs for nuclear power reactors.
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OL = Operating License
CP = Construction Permit

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