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UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF INSPECTION AND ENFORCEMENT
WASHINGTON, D.C. 20555

December 29, 1986

IE INFORMATION NOTICE NO. 86-108: DEGRADATION OF REACTOR COOLANT SYSTEM PRESSURE BOUNDARY RESULTING FROM BORIC ACID CORROSION

Addressees:

All pressurized water reactor (PWR) facilities holding an operating license or a construction permit.

Purpose:

This notice is to alert recipients of a severe instance of boric acid induced corrosion of ferritic steel components in the reactor coolant system (RCS). Recipients are expected to review the information for applicability to their facilities and consider actions, if appropriate, to preclude similar problems occurring at their facilities. However, suggestions contained in this information notice do not constitute NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances:

In October 1986, the Arkansas Nuclear One, Unit 1 (ANO-1) Plant was in cold shutdown and was performing nondestructive testing of the high pressure injection (HPI) nozzle thermal sleeves. An HPI nozzle is attached directly on the side of each of the four RCS cold legs. The metallic insulation was removed from the "A" HPI nozzle to allow radiographic examination. Removal of this insulation revealed severe corrosion wastage on the exterior of the HPI nozzle and some wastage on the RCS cold leg pipe. The corrosion apparently was caused by reactor coolant leakage from an HPI isolation valve located about 8 feet above the nozzle as shown in the attached Figure 1.

The wastage began adjacent to where the 3-1/2 inch OD stainless steel safe-end is welded to the carbon steel HPI nozzle. The safe-end is located between the stainless steel HPI line and the carbon steel HPI nozzle. The wastage was approximately 1/2 inch at its deepest location (adjacent to the stainless-to-carbon steel weld). The HPI nozzle (including cladding) is approximately 3/4 inch thick at this point. At the transition weld between the safe-end and the carbon steel nozzle, the wastage extended approximately 20 percent around the circumference of the nozzle in the form of several trenches. From this point, the wastage narrowed to two separate trenches that became shallower as they progressed more than 10 inches along the bottom of the HPI nozzle towards the RCS cold leg. The two trenches then continued down the cold leg for approximately 6 inches. The depth of the trenches on the cold leg were less than 1/4 inch.

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The HPI nozzle is constructed of ferritic (ASTM, A-105, grade 2) steel. The cold leg also is constructed of ferritic (ASTM, A-106, grade C) steel. The HPI nozzle and the cold leg are clad on the inside with stainless steel of 3/16 inch nominal thickness.

Leakage from the HPI isolation valve was first noted in August 1985, through RCS leak detection methods. The measured leakage was approximately 0.08 gallons per minute (gpm). The leakage was attributed to a valve body-to-bonnet leak. The valve's seal ring and yoke clamp were replaced in September 1985. A leakage of 0.09 gpm was again detected from this valve 8 days later during plant startup. This leak rate continued until subsequent repair of the valve in February 1986. The insulation was not removed at the time of these repairs. After the damaged HPI nozzle was discovered, a reddish stain, resulting from the leaching out of iron oxide corrosion products, was found on the exterior of the insulation near the damaged area.

Discussion:

There have been a number of reported incidents of boric acid corrosion wastage of ferritic steels. In 1981 Calvert Cliffs, Unit 2, experienced boric acid corrosion wastage on an RCS cold leg near the suction to a reactor coolant pump (RCP). This corrosion wastage was from 1/8 to 1/4 inch in depth and extended about 20 percent around the circumference of the RCS pipe. This RCS piping is fabricated from ferritic (ASME, SA 516, grade 70) steel.

Most incidents, however, have been wastage of threaded fasteners. In June 1982, IE Bulletin 82-02, "Degradation of Threaded Fasteners In The Reactor Coolant Pressure Boundary OF PWR Plants," was issued. The closeout of this bulletin was addressed in NUREG-1095, May 1985. The affected threaded fasteners were of a low alloy, high strength, ferritic steel. A generic issue, "Bolting Degradation or Failures in Nuclear Power Plants," is currently under review by the NRC staff to determine if additional actions are necessary. One of the main concerns in this issue is boric acid corrosion. The 1983 edition of the ASME Code, Section XI, was revised to provide for more restrictive requirements for visual examinations of systems containing borated water. Part of these requirements is an inspection of insulation at the joints for evidence of leaks. This revision is contained in Section IWA-5242(a), Insulated Components.

Boric acid corrosion has been found to be most active where the metal surface is cool enough so that it is wetted. If the metal is sufficiently hot, then the surface will stay dry and this loss of electrolyte will slow the corrosion rate. At ANO-1, borated water leaked from the HPI isolation valve in the form of a liquid and then ran down the HPI piping on the inside of the insulation to the HPI nozzle. As the leakage approached the cold leg, the increased piping temperatures caused evaporation of the water, thus increasing the boric acid concentration and lowering the PH of the solution. It is believed that the close tolerance between the HPI nozzle and the insulation, aided by boric acid crystallization, caused pooling of the solution at the nozzle. This pool of highly acidic solution wetted the nozzle and resulted in accelerated corrosive attack. Experience has shown that even relatively hot metal can be sufficiently cooled on the surface by the flow of the leakage so that the surface stays wetted and boric acid corrosion is promoted. In addition, periods during which a metal surface is below normal operating temperature may allow corrosion in areas that would not otherwise be expected. Boric acid corrosion rates in excess of 1 inch depth per year in ferritic steels have been experienced in plants and duplicated in laboratory tests where low quality steam from borated reactor coolant impinged upon a surface and kept it wetted.

Additional information is contained in EPRI-NP-3784, "A Survey of the Literature on Low Alloy Steel Fastener Corrosion in PWR Power Plants," December 1984, and NUREG/CR-2827, "Boric Acid Corrosion of Ferritic Reactor Components," July 1982.

Followup:

The damaged HPI nozzle has been repaired by grinding out all indications of corrosion and rebuilding by welding in those areas with less than the minimum required wall thickness. Repair to the cold leg required only grinding out the corrosion. All repairs were in accordance with ASME codes. The other HPI nozzles were inspected and no evidence of corrosion wastage was found. The licensee continues to evaluate methods and procedures to minimize recurrence of this type of event. The primary defense is to minimize leaks, detect and stop leaks soon after they start, and promptly clean up any boric acid residue. Detection of leaks will be enhanced by an evaluation of any iron oxide stains on insulation.

No specific action or written response is required by this information notice. If you have questions about this matter, please contact the Regional Administrator of the appropriate NRC regional office or this office.

E L Jordan

Edward L. Jordan, Director
Division of Emergency Preparedness
and Engineering Response
Office of Inspection and Enforcement

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Attachments:
1. Figure 1: ANO-1 HPI Line/Nozzle Configuration
2. List of Recently Issued IE Information Notices

Figure 1: ANO-1 HPI Line/Nozzle Configuration