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

April 22, 2004

NRC INFORMATION NOTICE 2004-08: REACTOR COOLANT PRESSURE BOUNDARY LEAKAGE ATTRIBUTABLE TO PROPAGATION OF CRACKING IN REACTOR VESSEL NOZZLE WELDS

Addressees:

All holders of operating licensees for nuclear power boiling-water reactors (BWRs), 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 to alert addressees to cracking identified in the nozzle-to-cap weld of control rod drive (CRD) return line penetration N10 at Pilgrim Nuclear Power Station (Pilgrim Station). The NRC expects recipients to review the information in this notice 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 and, therefore, do not require any specific action or written response.

Description of Circumstances:

During a planned outage on September 30, 2003, the licensee for Pilgrim Station began performing drywell inspections to identify and make necessary repairs to reduce drywell leakage. On October 1, 2003, the licensee's drywell inspections revealed leakage from the nozzle-to-cap weld area of penetration N10. The licensee concluded that the leakage was a contributor to the unidentified drywell leakage.

The licensee used a Performance Demonstration Initiative (PDI) qualified manual ultrasonic testing (UT) technique to determine that the N10 nozzle-to-cap weld contained an unacceptable flaw that was approximately 4.45cm (1.75 inches) long in the circumferential direction. Observations by the nondestructive examination (NDE) inspector suggested that the flaw initiated at the inner diameter (ID) of the weld, in the area of previous weld repairs. The through-wall location appeared to be close to the centerline of the weld.

Root Cause

The reactor pressure vessel (RPV) nozzle is made of SA-508, Class 2 low-alloy steel, while the CRD return line cap is made of Alloy 600. The subject weld is fabricated with Alloy 82/182 material, and the nozzle side of the weld is buttered with Alloy 182 material.

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Section 2.2.1.2 of the BWR Vessel and Internals Project report BWRVIP-49, "Instrument Penetration Inspection and Flaw Evaluation Guidelines," states that there has been extensive laboratory and field experience with stress corrosion cracking (SCC) of nickel based alloy, including wrought Alloy 600, Alloy 82 and Alloy 182 weld metal. Both Alloy 600 and Alloy 182 are potentially susceptible to SCC under normal water chemistry conditions in the BWR environment. Alloy 600 is more resistant than Alloy 182 to crack initiation regardless of prior fabrication history or metallurgical condition, particularly in the uncreviced condition. Consistent with its higher chromium and lower carbon content, Alloy 82 weld metal is more resistant to SCC than Alloy 182. Stress corrosion cracking in the base material is referred to as intergranular SCC (IGSCC), while SCC in the weld material is referred to as interdendritic SCC (IDSCC) because of the nature of the elongated grains (or dendrites) in the weld. Both degradation mechanisms refer to essentially the same phenomenon in the base metal and weld metal.

The licensee concluded that the root cause of the cracking in the nozzle-to-cap weld of CRD return line penetration N10 was IDSCC, given that the flaw was completely contained within the weld. The licensee asserted that the IDSCC was induced by a combination of a crevice condition and weld repair stresses resulting from previous local weld repairs.

The licensee reviewed industry experience as part of its root cause evaluation. General Electric (GE) and utility personnel who comprised the root cause team for a 1997 event at Hope Creek concluded that the through-wall leak in the core spray nozzle to safe-end weld was attributable to IDSCC in the Alloy 182 material. The root cause team also concluded that the crack growth rate was influenced by the presence of fabrication defects and weld repair stresses (i.e. the leak was in the area of a previous local repair using Alloy 182).

Corrective Action

The Pilgrim Station licensee performed a weld overlay repair to stop the leakage. The licensee's repair technique is an alternative to the requirements in Section XI, IWA-4000, of the Boiler and Pressure Vessel Code promulgated by the American Society of Mechanical Engineers (ASME). The repair was based on the use of Code Case N-504-2, "Alternative Rules for Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping" (with modifications), and Code Case N-638, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique." (See ADAMS Accession No. ML032870328.)

Background:

The N10 nozzle is a 10-cm (4-inch) diameter RPV penetration that was previously used to return CRD system flow to the reactor vessel. In 1977, the licensee modified the N10 nozzle to prevent cracking attributable to the cyclic thermal stresses resulting from the return of cooler water to the reactor vessel from the CRD system. That modification consisted of cutting and isolating the existing CRD system return line to nozzle N10 and rerouting the CRD return line to the CRD cooling water header. The modification also included removing the safe end and thermal sleeve from nozzle N10 and installing an Alloy 600 cap. The final configuration of the

nozzle was composed of an Alloy 82/182 nozzle-to-cap butt weld from the forged steel nozzle to the Alloy 600 cap. Radiographic examination following the modification identified defects in the weld, which the licensee subsequently repaired. The final testing of the modification was performed in 1977 using NDE and hydrostatic testing.

The NRC subsequently issued Generic Letter (GL) 88-01, "NRC Position on IGSCC in BWR Austenitic Stainless Steel Piping," to address the subject of IGSCC cracking in BWR piping. During that same time period, GE recommended that BWR owners inspect nozzle-to-safe-end welds containing Alloy 182 or a combination of Alloy 182 and Alloy 82 and, wherever practical, these inspections should be performed using automated UT scanning. Past inspections of dissimilar metal piping welds at Pilgrim Station were completed using the guidance in GL 88-01, which was superseded by guidance in BWRVIP-75, "Technical Basis for Revisions to Generic Letter 88-01 Inspection Schedules." (See ADAMS Accession Nos. ML003688842 and ML021350645.) In accordance with BWRVIP-75, the N10 nozzle-to-cap weld was classified as a Category D weld, meaning that it is made of susceptible materials that have not been treated with an IGSCC remedy and in which cracks have not been reported. The N10 nozzle is located 2.1m (84 inches) above the top of the active fuel and is not protected by hydrogen water chemistry (HWC). (The purpose of HWC is to protect components from SCC.) Category D welds have a 6-year inspection frequency. Prior to the Fall 2003 inspection, the licensee performed its last inspection of the N10 nozzle-to-cap weld during the Spring 1999 refueling outage. As part of that inspection, Inservice Inspection/ Nondestructive Examination personnel reviewed data sheets, but did not discover any recordable indications of SCC.

Other related generic communications involving weld inspections and degradation in BWR systems include the following NRC information notices (INs):

IN 1990-30: "Ultrasonic Inspection Techniques for Dissimilar Metal Welds"

IN 1992-50: "Cracking of Valves in the Condensate Return Lines of a BWR Emergency Condenser System"

IN 1998-44: "Ten-year Inservice Inspection (ISI) Program Update For Licensees That Intend to Implement Risk-Informed ISI of Piping"

Discussion:

The licensee's root cause for the cracking in nozzle N10 is consistent with the available evidence and industry experience. The weld metal is susceptible to IDSCC, and there is minimal protection (i.e., no HWC) from SCC mechanisms because of the location of the nozzle cap and stagnant flow conditions.

In conducting the Spring 1999 inspection, the licensee used manual ultrasonic inspection techniques with qualified inspectors. The 2003 examinations were performed to the updated requirements of Appendix VIII to Section XI of the ASME Code and the PDI program. Enhanced ultrasonic examinations using PDI-qualified inspectors have improved the capability to detect flaws related to SCC mechanisms, including those that occur entirely within the weld metal.

With respect to future inspections of this weld, after the qualified ISI examination of the nozzle N10 weld, which is scheduled for the 2009 outage, the weld will be examined in accordance with the schedule for Category E welds in BWRVIP-75. BWRVIP-75 defines Category E welds as those that have weld overlay repairs made with an IGSCC-resistant, nickel-based alloy (such as Alloy 52) and have received one qualified ISI since the initial post-overlay examination. After the initial examination, Category E welds with weld overlays are successively examined in accordance with BWRVIP-75, and related NRC comments, in order to ensure that there is no new cracking or crack growth. The Category E welds are then examined at a rate of 25 percent of the population every 10 years for normal water chemistry.

The staff and the licensee discussed expanding the scope of the Fall 2003 inspection to include all other Category D welds. The licensee used the following factors to consider this expanded scope based on the attributes of the cracked N10 weld:

- weld at a reactor vessel nozzle
- Category D weld
- low HWC protection
- dissimilar metal weld (Alloy 82/182)
- significant weld repair during original installation
- ID grinding and/or radiographic defects

The other Category D welds were, for example, protected by HWC, had improved inspections in the past (i.e., automated UT, rather than manual UT), had no weld repairs, and had no radiographic defects. Therefore, the licensee did not expand the scope of the inspection.

The leakage from the penetration N10 nozzle-to-cap weld and other leak sources in the drywell was less than the limit allowed by the plant's technical specifications (TS) for unidentified leakage and total leakage (combined unidentified and identified). The staff found that the licensee had mitigating procedures, routine inspection activities, operable leakage detection equipment and TS requirements designed to detect low levels of leakage from the reactor coolant system (RCS) and minimize the potential that a flaw could remain undetected. On that basis, the staff determined, qualitatively, that the N10 pressure boundary leakage was of very low safety significance.

Generic Implications:

Based on the information currently available, such as other capped BWR CRD return lines and prior industry experience with IDSCC, the degradation that occurred at Pilgrim Station may be relevant to other BWR facilities. The licensee for Pilgrim Station used guidance from BWRVIP-75 to determine the appropriate inspection method and frequency for this weld.

This information notice does not require any specific action or written response. If you have any questions about the information in this notice, please contact the technical contact identified below or the appropriate project manager in the NRC's Office of Nuclear Reactor Regulation (NRR).

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Information Notice No.	Subject	Date of Issuance	Issued to
2004-07	Plugging of Safety Injection Pump Lubrication Oil Coolers with Lakeweed	04/07/2004	All holders of operating licenses or construction permits for nuclear power reactors, except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.
2004-06	Loss of Feedwater Isokinetic Sampling Probes at Dresden Units 2 and 3	03/26/2004	All holders of operating licensees for nuclear power reactors except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.
2004-05	Spent Fuel Pool Leakage to Onsite Groundwater	03/03/2004	All holders of operating licensees for nuclear power reactors (except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel) and for research and test reactors, and all holders of fuel storage licenses and construction permits.
2004-04	Fuel Damage During Cleaning at a Foreign Pressurized Water Reactor	02/24/2004	All holders of operating licenses for light-water reactors, except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor.

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