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

July 9, 1997

NRC INFORMATION NOTICE 97-46: UNISOLABLE CRACK IN HIGH-PRESSURE INJECTION PIPING

Addressees

All holders of operating licenses or construction permits for nuclear power reactors.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to alert addressees to the discovery of a leaking cracked weld in an unisolable section of a combined makeup (MU) and high-pressure injection (HPI) line at Oconee Unit 2. 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

On April 22, 1997, at 12:50 p.m., Oconee Unit 2 was shut down because of unidentified reactor coolant system (RCS) leakage exceeding the technical specification limit of 1 gpm. From the time of initial leak indications on April 21, at approximately 10:45 p.m., until reactor pressure was sufficiently reduced, the leakage rate rose from approximately 2 gpm to a maximum leakage rate of approximately 12 gpm. A subsequent containment entry identified an unisolable leak in the MU/HPI line 2A1 from a through-wall crack in the weld connecting the MU/HPI pipe and the safe-end of the 2A1 reactor coolant loop (RCL) nozzle.

Discussion

The Oconee 2A1 MU/HPI nozzle assembly consists of the MU/HPI 2$\frac{1}{2}$ inch diameter pipe/safe-end/thermal sleeve (see Figure 1 - Original Design). The sleeve is attached by contact rolling to the inner surface of the safe-end. A 1-inch

diameter "warming" line taps into the bottom of the MU/HPI pipe immediately upstream of the pipe/safe-end weld where the through-wall crack was found. This line permits a small continuous MU flow (3 gpm) to reduce nozzle thermal transients due to changes in normal MU flow. All Oconee units have two combined MU/HPI lines and two additional HPI lines connected to the RCS. However, the thermal sleeve configuration in Oconee Unit 1 is different from that in Units 2 and 3.

Preliminary analysis indicates that crack initiation and propagation in the weld was caused by high-cycle fatigue due to a combination of thermal cycling and flow induced vibration. The

metallurgical examination of the weld determined that the crack consisted of a 360° inside surface flaw. The flaw depth increased gradually from about 30 percent into the wall until it became through-wall over a 77° arc length (see Figure 2). The examination found a gap in the contact area between the thermal sleeve and the safe end, indicative of loss of contact that caused the thermal sleeve in this line to be loose (see Figure 1). The thermal sleeve was found to be cracked, with portions missing from the end that extends into the RCS flow path. Significant wear damage was observed at both the upstream (the rolled end) and the downstream end. Cracking was also found in the pipe in the vicinity of the "warming" line nozzle. Video examinations of the other thermal sleeves of the HPI system showed no evidence of damage. Ultrasonic Testing (UT) and Radiographic Testing (RT) of the welds and the thermal sleeves in the other HPI nozzles showed no indications of cracking or loosening, or other signs of degradation. Figure 1 shows a comparison of the original and new thermal sleeve designs. The thermal sleeve in the 2A1 MU/HPI line was replaced during the current outage with the new design thermal sleeve.

Although the root cause of the cracking is not well understood, the licensee has identified a number of thermal/mechanical conditions that may have contributed to the crack propagation of the 2A1 pipe to safe-end weld. The precise contribution to cracking of each of these conditions is not presently known. However, the licensee has hypothesized that, in addition to the thermal cycling experienced at the nozzle during heat up/cool down and other plant transients, a likely contributor to the fatigue may have been the alternate heating and cooling of the weld by intermittent mixing of the hot reactor coolant leaking through the gap in the contact area between the loose thermal sleeve and the safe-end, and the cooler normal makeup water flowing through the associated MU/HPI line. Although the precise contribution of the gap is unknown, it is believed that a gap may be a prerequisite for cracking in the piping since the cracked pipes also had gaps between the thermal sleeve and the safe end.

This phenomenon was identified as the probable cause for similar safe-end

cracking observed at Crystal River and other B&W plants (including Oconee) in the early 1980's. This issue was previously addressed in Information Notice 82-09 and Generic Letter 85-20.

Recent re-examination of radiographs made in April 1996 of the Oconee 2A1 nozzle revealed that the licensee had failed to identify the gap which had developed in the safe-end/thermal sleeve contact area. The licensee also had failed to follow the original recommendations for augmented ultrasonic testing
(UT) as listed in NRC Generic Letter 85-20, "High Pressure Injection/Make-Up Nozzle Cracking in Babcock and Wilcox Plants," issued November 8, 1985. The licensee performed the recommended UT of the safe ends of the MU/HPI lines; however, they did not inspect the adjacent piping as recommended. In addition, the licensee failed to UT the weld between the safe-end and pipe, a discontinuity where cracking would be expected, and did, form. Also, NRC Bulletin 88-08, Supplement 1, "Thermal Stresses in Piping Connected to Reactor
Coolant Systems," issued August 4, 1988, emphasized that, because of the difficulty in identifying the types of cracks that were occurring due to thermal stresses, the need exists for enhanced UT and for experienced examination personnel to detect the cracks..

The licensee also reviewed the 1996 radiographs of the safe-ends in Oconee Unit 3. The 3A1 MU/HPI line was found to have a gap in the safe-end/thermal sleeve contact area. As a result of the gap in the 3A1 safe-end, Oconee Unit 3 was shut down on May 2, 1997. UT examinations identified apparent cracking in the 3A1 safe-end. This safe-end has been removed and is presently being metallurgically examined, but a visual examination has also revealed cracks in
the thermal sleeve. Minor gaps in the other safe-end/thermal sleeve contact areas were determined not to have grown, the rolled area of the thermal sleeve
was acceptable, and UT examinations of the other Oconee Unit 3 HPI nozzle assemblies revealed no cracking.

The Oconee Unit 1 nozzles have a double thermal sleeve design (Figure 3). Radiographic inspection in the period from 1983 to 1989 indicated that no gap existed in three of the four thermal sleeves. The thermal sleeve in the 1B2 (HPI) line had a gap; but, the gap had not grown during the inspection period.
Advantages of the double thermal sleeve as stated by the licensee include: (1) greater stiffness; (2) greater thermal resistance; and (3) reduced flow area, with corresponding increased flow velocity.

General Design Criterion 14 of Appendix A to Part 50 of Title 10 of the Code of Federal Regulations requires that the reactor coolant pressure boundary be designed so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture. The related generic communications listed below discuss several other similar events, and the actions that licensees were requested to take to reduce the probability of additional similar events occurring.

Similar Recent Events

On December 14, 1996, a non-isolable leak on piping connecting the safety injection system to the reactor coolant system was found in Dampierre Unit 1 in France. The damaged pipe length was examined and a through wall crack located on an uninterrupted portion of straight piping (not on a stressed area
such as a weld or a bend). The licensee has not identified the root cause of the cracking, but concluded that the most probable cause was temperature variations produced by cold water coming from leaking valves located upstream in the safety injection system. The licensee also concluded that the presence
of a through-wall defect on a straight portion of a pipe is likely to raise questions about previous assumptions made regarding the root cause of the cracking.

Related Generic Communications

NRC INFORMATION NOTICE 82-09, "CRACKING IN PIPING OF MAKEUP COOLANT LINES AT B&W PLANTS," dated March 31, 1982.

NRC GENERIC LETTER 85-20, "RESOLUTION OF GENERIC ISSUE 69: HIGH PRESSURE INJECTION/MAKEUP NOZZLE CRACKING IN BABCOCK AND WILCOX PLANTS," dated November
11, 1985.

NRC BULLETIN NO. 88-08, "THERMAL STRESSES IN PIPING CONNECTED TO REACTOR COOLANT SYSTEMS," dated June 22, 1988.

NRC BULLETIN NO. 88-08, Supplement 1, "THERMAL STRESSES IN PIPING CONNECTED TO
REACTOR COOLANT SYSTEMS," dated June 24, 1988.

NRC BULLETIN NO. 88-08, Supplement 2, "THERMAL STRESSES IN PIPING CONNECTED TO
REACTOR COOLANT SYSTEMS," dated August 4, 1988.

NRC BULLETIN NO. 88-08, Supplement 3, "THERMAL STRESSES IN PIPING CONNECTED TO
REACTOR COOLANT SYSTEMS," dated April 11, 1989.

NRC INFORMATION NOTICE 97-19, "SAFETY INJECTION SYSTEM WELD FLAW AT SEQUOYAH NUCLEAR POWER PLANT, UNIT 2," dated April 18, 1997

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.

signed by S.H. Weiss for

Marylee M. Slosson, Acting Director

Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Technical contacts: Barry Elliot, NRR
301-415-2709
E-mail: bje@nrc.gov

Eric Benner, NRR
301-415-1171
E-mail: ejb1@nrc.gov

Kamal Manoly, NRR
301-415-2765
E-mail: kam@nrc.gov

Mark Hartzman, NRR
301-415-2755
E-mail: mxh@nrc.gov

Attachments:
1. Figure 1 - Thermal Sleeve
2. Figure 2 - Warming Line Flow
3. Figure 3 - Unit 1 Thermal Sleeve
4. List of Recently Issued NRC Information Notices

Page Last Reviewed/Updated Wednesday, February 16, 2011