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

April 30, 2001

NRC INFORMATION NOTICE 2001-05: THROUGH-WALL CIRCUMFERENTIAL CRACKING OF REACTOR PRESSURE VESSEL HEAD CONTROL ROD DRIVE MECHANISM PENETRATION NOZZLES AT OCONEE NUCLEAR STATION, UNIT 3

Addressees

All holders of operating licenses for pressurized water nuclear power reactors except those who have 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 the recent detection of through-wall circumferential cracks in two of the control rod drive mechanism (CRDM) penetration nozzles and weldments at the Oconee Nuclear Station, Unit 3 (ONS3).

It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific actions or written response is required.

Description of Circumstances

On February 18, 2001, with ONS3 in Mode 5, Duke Energy Corporation (the licensee) performed a visual examination (VT-2) of the outer surface of the unit's reactor pressure vessel (RPV) head to inspect for indications of borated water leakage. This RPV head inspection was performed as part of a normal surveillance during a planned maintenance outage. The VT-2 revealed the presence of small amounts of boric acid residue in the vicinity of nine of the 69 CRDM penetration nozzles (Figures 1 and 2). Subsequent nondestructive examinations (NDEs) identified 47 recordable crack indications in these nine degraded CRDM penetration nozzles. The licensee initially characterized these flaws as either axial or below-the-weld circumferential indications, and initiated repairs of the degraded areas. NDEs of nine additional CRDM penetration nozzles from the same heat of material were conducted for "extent of condition" purposes, but did not detect recordable indications.[1]

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[1] Axial flaws are flaws that propagate along the inside or outside diameter length of the CRDM nozzle. Below-the-weld circumferential indications are apparent flaws oriented around the circumference of the nozzle, beneath the RPV head and below the area where the nozzle is welded to the RPV head. A recordable indication is one that exceeds the NDE acceptance criteria.

Subsequent dye-penetrant testing (PT) revealed additional indications in two of the nine degraded penetration nozzles. While affecting further repairs of these indications, the licensee identified that each nozzle had significant circumferential cracks in the nozzle above the weld. Further investigations and metallurgical examinations revealed that these cracks had initiated from the outside diameter (OD) of the CRDM penetration nozzles. The circumferential crack in the #56 CRDM nozzle was through-wall, and the #50 nozzle had pin hole through-wall indications. These cracks followed the weld profile contour, and were nearly 165° in length.

The licensee stated that pre-repair ultrasonic testing (UT) examinations had identified indications in these areas during the initial inspections, but these indications had been misinterpreted as craze cracking with unusual characteristics. The characterization for these two nozzle indications was revised after the initial post-repair PT examinations. The licensee concluded that the root cause for the CRDM penetration nozzle cracking was primary water stress corrosion cracking (PWSCC). This conclusion was based on metallurgical examinations, crack location and orientation, and finite element analyses.

Discussion

The 69 CRDM nozzles at ONS3 are approximately 5 feet long and are J-groove welded to the inner radius of the RPV head, with the lower end of each nozzle extending about 6 inches below the inside of the RPV head (see Figure 2). The nozzles are constructed from 4-inch OD Alloy 600 Inconel procured in accordance with the requirements of Specification SB-167, Section II to the 1965 Edition (including Addenda through Summer 1967) of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. During initial construction, each nozzle was machined to final dimensions to assure a match between the RPV head bore and the OD of the nozzle. The nozzles were shrink-fit by cooling to at least minus 140 degrees F, inserted into the closure head penetration, and then allowed to warm to room temperature (70 degrees F minimum). The CRDM nozzles were tack-welded and then permanently welded to the closure head using 182-weld metal (see Figure 2). The shielded manual metal arc welding process was used for both the tack weld and the J-groove weld. During weld buildup, the weld was ground and PT inspected at each 9/32 inch of the weld. The final weld surface was ground and PT inspected. The weld prep for installation of each nozzle in the RPV head was accomplished by machining and buttering the J-groove with 182-weld metal.

Axial cracking in pressurized water reactor (PWR) CRDM nozzles has been previously identified, evaluated, and repaired. Numerous small-bore Alloy 600 nozzles and pressurizer heater sleeves have experienced leaks attributed to PWSCC. Generally, these components are exposed to temperatures of 600 degrees F or higher and to primary water, as are the ONS3 CRDM nozzles. However, circumferential cracks above the weld from the OD to the inside diameter (ID) have not been previously identified in the U.S.

An action plan was implemented by the NRC staff in 1991 to address PWSCC of Alloy 600 vessel head penetrations (VHPs) at all U.S. PWRs. This action plan included a review of the safety assessments by the PWR owners groups (Westinghouse Owners Group, Combustion

Engineering Owners Group, and Babcock & Wilcox Owners Group) submitted for staff review on June 16, 1993, by the Nuclear Management and Resource Council (NUMARC, now the Nuclear Energy Institute [NEI]).

After reviewing the industry's safety assessments and examining the overseas inspection findings, the NRC staff concluded, in a safety evaluation (SE) dated November 19, 1993, that PWR CRDM nozzle and weld cracking was not an immediate safety concern. The bases for this conclusion were that if PWSCC occurred (1) the cracks would be predominately axial in orientation, (2) the axial cracks would result in detectable leakage before catastrophic failure, and (3) the leakage would be detected during visual examinations performed as part of surveillance walkdown inspections before significant damage to the RPV head would occur. However, the NRC staff noted concerns about potential circumferential cracking (which would need to be addressed on a plant-specific basis), high residual stresses from initial manufacture and from tube straightening sometimes done after welding, and the need for enhanced leakage monitoring.

By letter dated March 5, 1996, NEI submitted a white paper entitled "Alloy 600 RPV Head Penetration Primary Stress Corrosion Cracking," which reviewed the significance of PWSCC in PWR VHPs, described how the PWR licensees were managing the issue. NEI assumed that the issue was primarily an economic issue rather than a safety issue, and described an economic decision tool to be used by PWR licensees to evaluate the probability of a VHP developing a crack or a through-wall leak during a plant's lifetime. This information would then be used by a PWR licensee to evaluate the need to conduct a VHP inspection at their plant.

To verify the conclusions in the industry’s safety assessments, sampling inspections were performed at three PWR units in 1994. The results of these domestic inspections were consistent with the February 1993 analyses by the PWR owners groups, the staff’s November 19, 1993, SE, and the PWSCC found in European reactors. On the basis of the results of the first five inspections of U.S. PWRs, the PWR owners groups' analyses, and the European experience, the NRC staff determined that it was probable that CRDM penetrations at other plants contained similar axial cracks, but that such cracking did not pose an immediate- or near-term safety concern. Further, the NRC staff recognized that the scope and timing of inspections may vary for different plants, depending on their individual susceptibility to this form of degradation. In the long term, however, the staff determined that degradation of the CRDM and other RPV head penetrations is an important safety consideration because of the possibility of (1) exceeding the ASME Code safety margins if the cracks are sufficiently deep and continue to propagate during subsequent operating cycles and (2) eliminating a layer of defense in depth for plant safety.

On April 1, 1997, NRC issued Generic Letter (GL) 97-01, “Degradation of Control Rod Drive Mechanism Nozzle and Other Vessel Closure Head Penetrations,” which requested addressees to inform the staff of their inspection activities related to VHPs. Based on the industry’s GL 97-01 response, which took credit for periodic inspections of the RPV head, the staff agreed that the conclusions in its November 19, 1993, SE remained valid.

The recent identification of significant circumferential cracking of two CRDM nozzles at ONS3 raises concerns about a potentially risk-significant generic condition affecting all domestic PWRs. RPV head penetrations, including CRDM nozzles, provide the function of maintaining the reactor coolant system (RCS) pressure boundary. Cracking of CRDM nozzles and welds is a degradation of the primary RCS boundary. Industry experience has shown that Alloy 600 is susceptible to stress corrosion cracking (SCC). Further, the environment in the CRDM housing annulus will likely be far more aggressive after any through-wall leakage, because potentially highly concentrated borated primary water will become oxygenated, increasing crack growth rates.

The repair activities at ONS3 were extensive. The licensee stated that all flaws would be removed entirely from both weld material and nozzle base metal and repaired prior to plant restart. The licensee plans to perform a thorough visual inspection of the Unit 2 RPV head penetrations during the next outage and is investigating the eventual replacement of the RPV heads on all three units to prevent recurrence of this event. Foreign PWRs in France and Japan have already replaced a number of their RPV heads.

The NRC held a public meeting with the Electric Power Research Institute (EPRI) Materials Reliability Project (MRP) personnel on April 12, 2001, to discuss CRDM nozzle circumferential cracking issues. During the meeting, the industry representatives said that they were developing a generic safety assessment, recommendations for revisions of near-term inspections, and long-term inspection and flaw evaluation guidelines.

The ONS3 cracking reinforces the importance of examining the upper PWR RPV head area (e.g., visual under-the-insulation examinations of the penetrations for evidence of borated water leakage or volumetric examinations of the CRDM nozzles) and of using appropriate NDE methods (e.g., UT, ET, PT, etc.) to adequately characterize cracks. Presently, licensees are not required to remove RPV head insulation to visually inspect the head penetrations; however, some licensees have recently performed expanded VT-2 examinations by using cameras to inspect between the CRDM nozzles and the insulation.

The NRC has recently developed a Web page to keep the public informed of generic activities on PWR Alloy 600 weld cracking (http://www.nrc.gov/NRC/REACTOR/MRP/index.html). The NRC will update this Web page and assess the need for further generic action as new information becomes available.

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.

Related Generic Communications

- Generic Letter 88-05, “Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants,” March 17, 1988
- Generic Letter 97-01, “Degradation of Control Rod Drive Mechanism Nozzle and Other Vessel Closure Head Penetrations,” April 1, 1997
- Information Notice 90-10, “Primary Water Stress Corrosion Cracking of INCONEL 600,” February 23, 1990
- Information Notice 96-11, ”Ingress of Demineralizer Resins Increases Potential for Stress Corrosion Cracking of Control Rod Drive Mechanism Penetrations,” February 14, 1996
- NUREG/CR-6245, ”Assessment of Pressurized Water Reactor Control Rod Drive Mechanism Nozzle Cracking,” October 1994

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Attachments:
1. Figure 1: Oconee Reactor Pressure Vessel Head Map
2. Figure 2: Oconee CRDM Nozzle Penetration (Typical)
3. List of Recently Issued NRC Information Notices

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Figure 1: Oconee Reactor Pressure Vessel Head Map

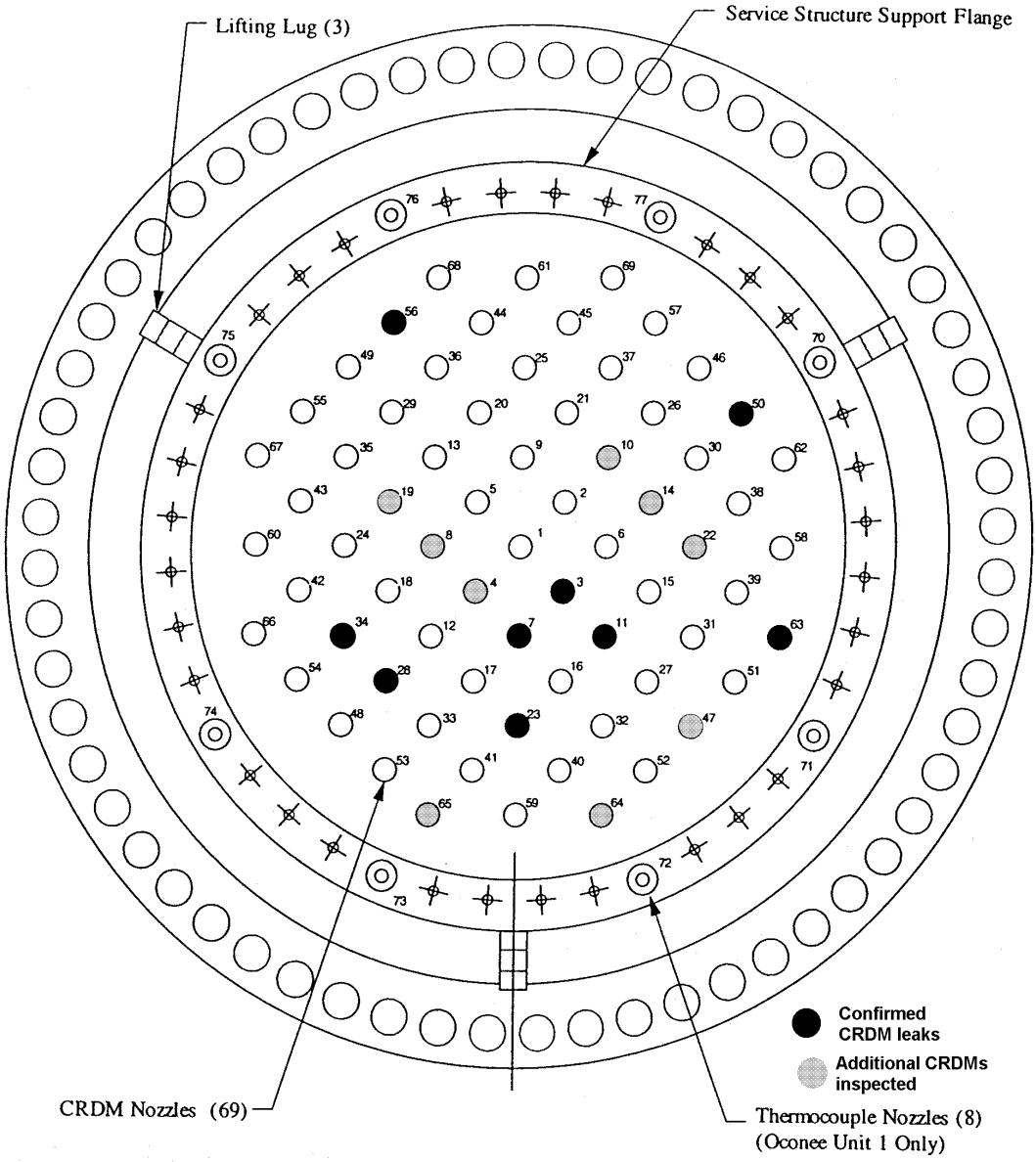
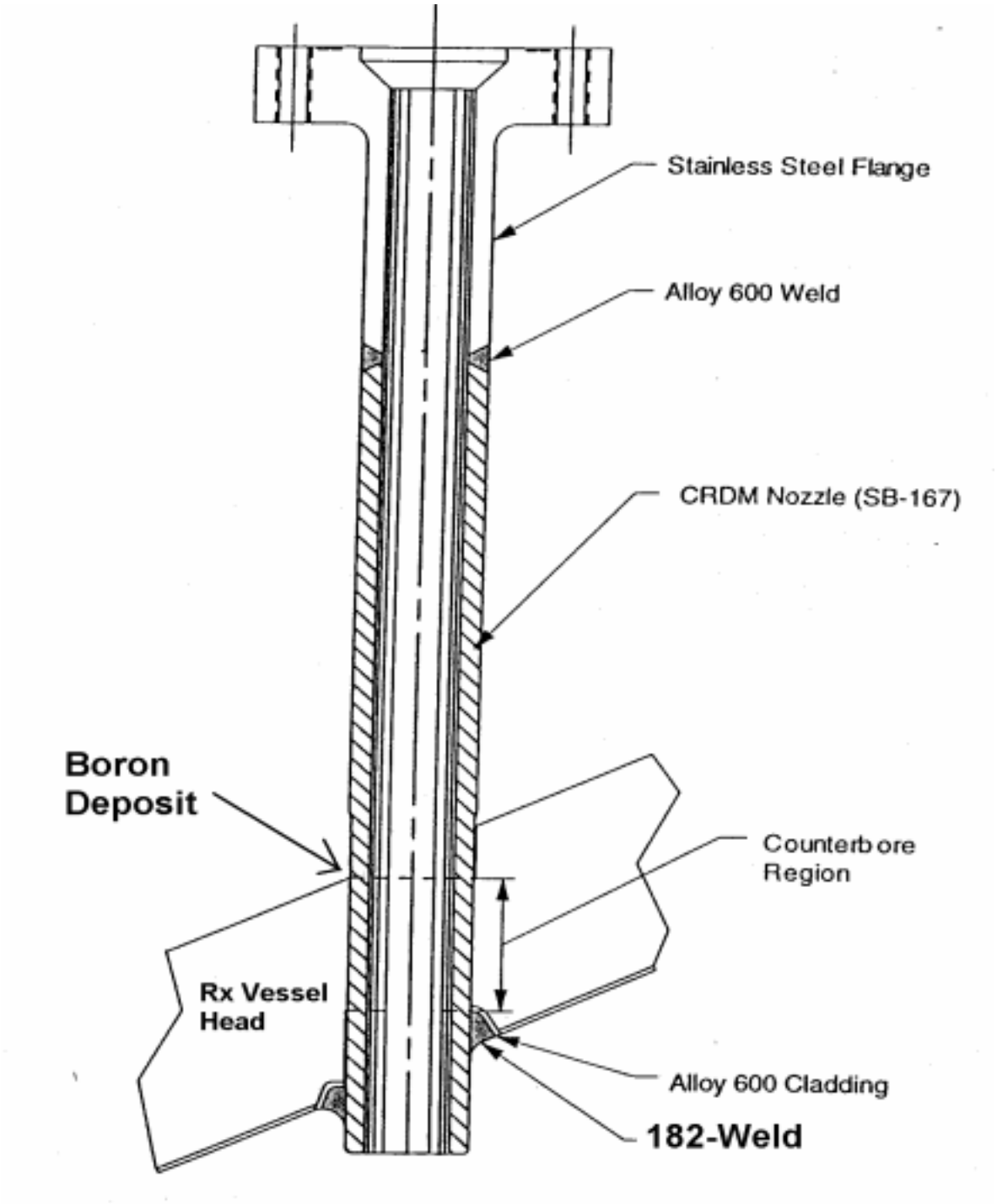


Figure 2:Oconee CRDM Nozzle Penetration (Typical)



LIST OF RECENTLY ISSUED
NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
2001-04	Neglected Fire Extinguisher Maintenance Causes Fatality	04/11/01	All holders of licenses for nuclear power, research, and test reactors and fuel cycle facilities
2001-03	Incident Reporting Requirements for Radiography Licensees	04/06/01	All industrial radiography licensees
2001-02	Summary of Fitness-for-Duty Program Performance Reports for Calendar Years 1998 and 1999	03/28/01	All holders of operating licenses for nuclear power reactors, and licensees authorized to possess or use formula quantities of strategic special nuclear material (SSNM) or to transport formula quantities of SSNM
2001-01	The Importance of Accurate Inventory Controls to Prevent the Unauthorized Possession of Radioactive Material	03/26/01	All material licensees
2000-17, Supp. 2	Crack in Weld Area of Reactor Coolant System Hot Leg Piping at V.C. Summer	02/28/01	All holders of operating licenses for nuclear power reactors except those who has ceased operations and have certified that fuel has permanently removed from reactor vessel
2000-22	Medical Misadministrations Caused by Human Errors Involving Gamma Stereotactic Radiosurgery (GAMMA KNIFE)	12/18/00	All medical use licensees authorized to conduct gamma stereotactic radiosurgery treatments
2000-21	Detached Check Valve Disc not Detected by Use of Acoustic and Magnetic Nonintrusive Test Techniques	12/15/00	All holders of OLs for nuclear power reactors except those who have ceased operations and have certified that fuel has been permanently removed from the reactor

OL = Operating License
CP = Construction Permit