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

March 12, 2002

NRC INFORMATION NOTICE 2002-11: RECENT EXPERIENCE WITH DEGRADATION OF REACTOR PRESSURE VESSEL HEAD

Addressees

All holders of operating licenses for pressurized-water reactors (PWRs), except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to inform addressees about findings from recent inspections and examinations of the reactor pressure vessel (RPV) head at Davis-Besse Nuclear Power Station. 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 February 16, 2002, the Davis-Besse facility began a refueling outage that included inspection of the vessel head penetration (VHP) nozzles, which focused on the inspection of control rod drive mechanism (CRDM) nozzles, in accordance with the licensee's commitments to NRC Bulletin 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles," which was issued on August 3, 2001. These inspections identified axial indications in three CRDM nozzles, which had resulted in pressure boundary leakage. Specifically, these indications were identified in CRDM nozzles 1, 2, and 3, which are located near the center of the RPV head. These findings were reported to the NRC on February 27, 2002, and supplemented on March 5 and March 9, 2002. The licensee decided to repair these three nozzles, as well as two other nozzles that had indications but had not resulted in pressure boundary leakage.

The repair process for these nozzles included roll expanding the CRDM nozzle material into the surrounding RPV head material, followed by machining along the axis of the CRDM nozzle to an elevation above the indications in the nozzle material. On March 6, 2002, the machining process on CRDM nozzle 3 was prematurely terminated and the machining apparatus was removed from the nozzle. During the removal process, nozzle 3 was mechanically agitated and subsequently displaced in the downhill direction (i.e., tipped away from the top of the RPV head) until its flange contacted the flange of the adjacent CRDM nozzle.

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To identify the cause of the CRDM nozzle displacement, the licensee began an investigation into the condition of the RPV head surrounding CRDM nozzle 3. This investigation included removing the CRDM nozzle from the RPV head, removing boric acid deposits from the top of the RPV head, and performing ultrasonic thickness measurements of the RPV head in the vicinity of CRDM nozzles 1, 2, and 3. Upon completing the boric acid removal on March 7, 2002, the licensee conducted a visual examination of the area, which identified a large cavity in the RPV head on the downhill side of CRDM nozzle 3. Followup characterization by ultrasonic testing indicated wastage of the low alloy steel RPV head material adjacent to the nozzle. The wastage area was found to extend approximately 5 inches downhill on the RPV head from the penetration for CRDM nozzle 3, with a width of approximately 4 to 5 inches at its widest part. The minimum remaining thickness of the RPV head in the wastage area was found to be approximately ⅜ inch. This thickness was attributed to the thickness of the stainless steel cladding on the inside surface of the RPV head, which is nominally ⅜ inch thick.

<u>Background</u>

The Davis-Besse Nuclear Power Station has an RPV head that is constructed from low alloy steel, fabricated in accordance with the American Society of Mechanical Engineers (ASME) specification SA-533, Grade B, Class1, and clad on the inside surface with stainless steel. Of those 69 VHP nozzles, 61 are used for CRDMs, 7 are spare (empty) nozzles, and 1 is used for the RPV head vent piping. Each of the 69 nozzles is approximately 4 inches in outside diameter, with a wall-thickness of approximately ⅝ inch. Each is constructed of Alloy 600 and is attached to the RPV head by a partial-penetration, J-groove weld using Alloy 82 and 182. The distance from the center of one nozzle to the center of the next is approximately 12 inches.

The vessel head is insulated with metal reflective insulation, which is located on a horizontal plane slightly above the RPV head (i.e., it is not in direct contact with the head). The minimum distance between the RPV head and the insulation is approximately 2 inches at the center (top) of the head. The CRDM nozzles pass from the RPV head through the insulation and terminate at flanges to which the CRDM housings are attached.

The limited gap between the insulation and the RPV head does not impede the performance of a visual inspection of the CRDM nozzles, as described in Bulletin 2001-01. This is because the top of the RPV head is surrounded by a service structure that has 18 openings (referred to as “weep holes”) near the bottom of the structure, through which small cameras can be inserted to facilitate visual inspections of the RPV head.

During refueling outages in 1998 and 2000, the licensee performed visual inspections of the RPV head surface that was accessible through the service structure weep holes. The scope of these visual inspections covered the bare metal of the RPV head to identify the presence of boric acid deposits, which would be indicative of primary coolant leakage. These inspections also included checking for leakage from any of the CRDM flanges, located above the insulation, in response to Generic Letter 88-05, “Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components,” which the NRC issued on March 17, 1988.

The visual inspections in 1998 showed an uneven layer of boric acid deposits scattered over the RPV head (including deposits near CRDM nozzle 3). The outside diameter of the CRDM nozzles had white streaks, which indicated to the licensee that the boric acid evident on the head flowed downward from leakage in the CRDM flanges.

During the refueling outage in 2000, the licensee also performed visual inspections of the CRDM flanges and nozzles. Above the RPV head insulation, those inspections revealed five CRDM flanges with evidence of leakage, including one flange that was the principal leakage point. Boric acid deposits on the vertical faces of three of these five flanges and the associated nozzles confirmed leakage from the flanges. Similarly, one of the other two leaking CRDM flanges had boric acid deposits between the flange and the insulation, which indicated leakage from the flange. All of these leaking flanges were repaired by replacing their gaskets. The faces of the flange that was the principal leakage point were also machined to ensure a better seal.

Visual inspections performed below the RPV head insulation during the 2000 refueling outage indicated some accumulation of boric acid deposits on the RPV head. These deposits were located beneath the leaking flanges, with clear evidence of downward flow from the flange area. No visible evidence of CRDM nozzle leakage (i.e., leakage from the gap between the nozzle and the RPV head) was detected. The licensee described that the RPV head area was cleaned with demineralized water to the greatest extent possible, while trying to maintain the dose as low as reasonably achievable (ALARA). Subsequent video inspection of the partially cleaned RPV head and nozzles was performed for future reference.

A subsequent review of the 1998 and 2000 inspection videotapes in 2001 confirmed that there was no evidence of leakage from the RPV head nozzles, although many areas of the RPV head were not accessible because of persistent boric acid deposits that the licensee did not clean because of ALARA issues (including the region around nozzle 3).

The inspections in 2002 did not reveal any visual evidence of flange leakage from above the RPV head. However, as discussed above, three CRDM nozzles had indications of cracking (identified by ultrasonic testing of the nozzles), which could result in leakage from the RPV to the top of the RPV head.

Discussion

The following documents describe reactor operating experience with boric acid corrosion of ferritic steel reactor coolant pressure boundary components in PWR plants:

- Information Notice 86-108, “Degradation of Reactor Coolant System Pressure Boundary Resulting from Boric Acid Corrosion,” issued December 29, 1986

- Information Notice 86-108, Supplement 1, “Degradation of Reactor Coolant System Pressure Boundary Resulting from Boric Acid Corrosion,” issued April 20, 1987

- Information Notice 86-108, Supplement 2, “Degradation of Reactor Coolant System Pressure Boundary Resulting from Boric Acid Corrosion,” issued November 19, 1987

- Information Notice 86-108, Supplement 3, “Degradation of Reactor Coolant System Pressure Boundary Resulting from Boric Acid Corrosion,” issued January 5, 1995

- Generic Letter 88-05, “Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants,” issued March 17, 1988

Several instances of boric acid corrosion discussed in these generic communications are associated with corrosion of the RPV head. NRC Information Notice 86-108, Supplement 1, for example, described an instance in which boric acid had severely corroded three of the RPV flange bolts, the control rod drive shroud support, and an instrument tube seal clamp. Similarly, NRC Information Notice 86-108, Supplement 2, described an instance in which boric acid resulted in nine pits in the surface of the RPV head, ranging in depth from 0.9 to 1 cm [approximately 0.4 inch] and ranging in diameter from 2.5 to 7.5 cm [1 to 3 inches].

As discussed in Information Notice 86-108, Supplement 2, the primary effect of boric acid leakage onto the ferritic steel RPV head is wastage or general dissolution of the material. Pitting, stress corrosion cracking (SCC), intergranular attack, and other forms of corrosion are not generally of concern in concentrated boric acid solutions at elevated temperatures such as those that may occur on the surface of the RPV head. The rate of general corrosion (wastage) of ferritic steel from boric acid varies and depends on several conditions, including whether the boric acid is dry or in solution. If the boric acid is dry (i.e., boric acid crystals), the corrosion rate is less severe; however, boric acid crystals are not completely benign to carbon steel. During operation, the temperature of the RPV head is sufficiently high that any leaking primary coolant would be expected to flash to steam, leaving behind dry boric acid crystals.

Given the wide range of conditions around reactor primary coolant leakage sites and the wide variation in boric acid corrosion rates, the deleterious effects of boric acid on ferritic steel components indicate the importance of minimizing boric acid leakage, detecting and correcting leaks in a timely manner, and promptly cleaning any boric acid residue.

The investigation of the causative conditions surrounding the degradation of the RPV head at Davis-Besse is continuing. Boric acid or other contaminants could be contributing factors. As discussed above, factors contributing to the degradation might also include the environment of the head during both operating and shutdown conditions (e.g., wet/dry), the duration for which the RPV head is exposed to boric acid, and the source of the boric acid (e.g., leakage from the CRDM nozzle or from sources above the RPV head such as CRDM flanges).

<u>Related Generic Communications</u>

Bulletin 2001-01, “Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles,” August 3, 2001.

Bulletin 82-02, “Degradation of Threaded Fasteners in the Reactor Coolant Pressure Boundary of PWR Plants,” June 2, 1982.

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 Nozzles and Other Vessel Closure Head Penetrations,” April 1, 1997.

Information Notice 80-27, “Degradation of Reactor Coolant Pump Studs,” June 11, 1980.

Information Notice 82-06, “Failure of Steam Generator Primary Side Manway Closure Studs,” March 12, 1982.

Information Notice 86-108, “Degradation of Reactor Coolant System Pressure Boundary Resulting from Boric Acid Corrosion,” December 29, 1986.

Information Notice 86-108, Supplement 1, “Degradation of Reactor Coolant System Pressure Boundary Resulting from Boric Acid Corrosion,” April 20, 1987.

Information Notice 86-108, Supplement 2, “Degradation of Reactor Coolant System Pressure Boundary Resulting from Boric Acid Corrosion,” November 19, 1987.

Information Notice 86-108, Supplement 3, “Degradation of Reactor Coolant System Pressure Boundary Resulting from Boric Acid Corrosion,” January 5, 1995.

Information Notice 90-10, “Primary Water Stress Corrosion Cracking of INCONEL 600,” February 23, 1990.

Information Notice 94-63, “Boric Acid Corrosion of Charging Pump Casing Caused by Cladding Cracks,” August 30, 1994.

Information Notice 96-11, “Ingress of Demineralizer Resins Increases Potential for Stress Corrosion Cracking of Control Rod Drive Mechanism Penetrations,” February 14, 1996.

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,” April 30, 2001.

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 one of the technical contacts listed below or the appropriate project manager in the NRC’s Office of Nuclear Reactor Regulation (NRR).

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Attachment: List of Recently Issued NRC Information Notices

Information Notice 86-108, "Degradation of Reactor Coolant System Pressure Boundary Resulting from Boric Acid Corrosion," December 29, 1986.

Information Notice 86-108, Supplement 1, "Degradation of Reactor Coolant System Pressure Boundary Resulting from Boric Acid Corrosion," April 20, 1987.

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LIST OF RECENTLY ISSUED
NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
2002-10	Nonconservative Water Level Setpoints on Steam Generators	03/07/2002	All holders of operating licenses for nuclear power reactors, except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor.
2002-09	Potential for Top Nozzle Separation and Dropping of Certain Type of Westinghouse Fuel Assembly	02/13/2002	All holders of operating licenses for nuclear power reactors, and non-power reactors and holders of licenses for permanently shutdown facilities with fuel onsite.
2002-08	Pump Shaft Damage Due to Excessive Hardness of Shaft Sleeve	01/30/2002	All holders of operating licenses for nuclear power reactors, except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor.
2002-07	Use of Sodium Hypochlorite for Cleaning Diesel Fuel Oil Supply Tanks	01/28/2002	All holders of operating licenses for nuclear power except those who have ceased operations and have certified that fuel has been permanently removed from the reactor vessel.
2002-06	Design Vulnerability in BWR Reactor Vessel Level Instrumentation Backfill Modification	01/18/2002	All holders of operating licenses or construction permits for boiling water reactors (BWRs).
2002-05	Foreign Material in Standby Liquid Control Storage Tanks	01/17/2002	All holders of licenses for nuclear power reactors.
2002-04	Wire Degradation at Breaker Cubicle Door Hinges	01/10/2002	All holders of operating licenses for nuclear power reactors.

OL = Operating License
CP = Construction Permit