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

August 21, 2003

NRC BULLETIN 2003-02: LEAKAGE FROM REACTOR PRESSURE VESSEL LOWER HEAD PENETRATIONS AND REACTOR COOLANT PRESSURE BOUNDARY INTEGRITY

Addressees

All holders of operating licenses for pressurized-water nuclear power reactors (PWRs) with penetrations in the lower head of the reactor pressure vessel (RPV), except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor pressure vessel.

All other holders of operating licenses for nuclear power plants will receive a copy of this bulletin for information.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this bulletin to:

(1) advise PWR addressees that current methods of inspecting the RPV lower heads may need to be supplemented with additional measures (e.g., bare-metal visual inspections) to detect reactor coolant pressure boundary (RCPB) leakage,

(2) request PWR addressees to provide the NRC with information related to inspections that have been or will be performed to verify the integrity of the RPV lower head penetrations, and

(3) require PWR addresses to provide a written response to the NRC in accordance with the provisions of Section 50.54(f) of Title 10 of the *Code of Federal Regulations* (10 CFR 50.54(f)).

Background

PWR RPV upper heads have a number of penetrations, including penetrations for control rod drive mechanisms (CRDMs). These penetrations are typically made of nickel-based Inconel Alloy 600. The penetrations are welded to the inside of the RPV head with nickel-based Inconel Alloy 82/182 materials. Most PWRs also have penetrations in the RPV lower heads for in-core nuclear instrumentation. The same Inconel materials are typically used in the lower head penetrations and welds. The primary coolant water and the operating conditions of PWR plants have caused cracking of nickel-based alloys in upper head penetrations through a process called primary water stress corrosion cracking (PWSCC).

As part of the response to issues associated with degradation of the RPV upper head at the Davis-Besse Nuclear Power Station, the NRC issued Bulletin 2002-01, "Reactor Pressure Vessel Head Degradation and Reactor Coolant Pressure Boundary Integrity," dated March 18, 2002. This bulletin requested information about the condition and inspections of RPV upper heads and about licensee's boric acid corrosion control (BACC) programs. The NRC subsequently issued Bulletin 2002-02, "Reactor Pressure Vessel Head and Vessel Head Penetration Nozzle Inspection Programs," dated August 9, 2002. This bulletin was issued to address staff concerns regarding the adequacy of visual examinations as a primary inspection method for the RPV upper head and RPV upper head penetrations. By NRC Order EA-03-009, dated February 11, 2003, the NRC required specific inspections of RPV upper heads, CRDM penetrations, and associated welds in addition to the inspections required by Section XI of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code).

After evaluating the responses received in response to Bulletin 2002-01, the NRC staff issued requests for additional information (RAIs) to PWR licensees in order to obtain more detailed information regarding licensee BACC programs. The NRC staff summarized its review of the responses to Bulletin 2002-01 and the associated RAIs in Regulatory Issue Summary (RIS) 2003-13, "NRC Review of Responses to Bulletin 2002-01, 'Reactor Pressure Vessel Head Degradation and Reactor Coolant Pressure Boundary Integrity,'" dated July 29, 2003. The NRC noted in RIS 2003-13 that most licensees do not perform inspections of Alloy 600/82/182 materials beyond those required by Section XI of the ASME Code to identify potential cracked and leaking components. For the RPV lower head, the ASME Code specifies that a visual examination, called a VT-2 examination, be performed during system pressure testing. Licensees may meet the ASME Code requirement for a VT-2 inspection by performing an inspection of the RPV lower head without removing insulation from around the head and penetrations. It is the NRC staff's understanding that many licensees perform the ASME Code-required inspections without removing insulation and, therefore, may not be able to detect the amounts of through-wall leakage expected from potential flaws due to PWSCC or other cracking mechanisms.

The lower head and bottom mounted instrumentation (BMI) penetrations of the South Texas Project Unit 1 (STP Unit 1) RPV were visually inspected on April 12, 2003, as a routine part of the unit's refueling outage. The lower head of the reactor is surrounded by an insulating box structure with no insulation directly in contact with the lower head. The inspection was accomplished by removing three of the insulation panels forming the insulating box. Three different vantage points were used to inspect all 58 BMI penetrations in the vessel lower head. The inspection found small amounts of white residue around two of the 58 BMI penetrations (numbers 1 and 46) at the junction where the penetrations met the lower reactor vessel head. The residue at penetrations 1 and 46 was collected for laboratory analysis to determine the source of the residue material. Approximately 150 milligrams and 3 milligrams were collected from penetrations 1 and 46, respectively. The analysis of the sample for lithium demonstrated that the lithium was approximately 99.9 percent lithium-7, which indicated that the reactor coolant system was the source of the residue. The analysis of the sample for cesium indicated that the average age of the residue collected was between 3 and 5 years. The licensee for STP Unit 1 indicated that these residues were not visible during the previous inspection on November 20, 2002.

Ultrasonic inspections (using circumferential, axial, and zero degree probes) of 57 BMI penetration tubes at STP Unit 1 were completed in May 2003, along with the visual inspections of the surfaces of the 58 J-groove welds which attach the BMI penetration tubes to the RPV lower head. In addition, eddy current testing (ECT) was used to examine the J-groove weld and inside diameter surfaces of some BMI penetration tubes. Axial cracks were found in penetration tubes 1 and 46. The largest of these cracks was entirely through-wall and extended above and below the J-groove weld. No evidence of cracking was found in any other penetration. BMI penetrations 1 and 46 have been repaired. The licensee is continuing to investigate the cause of the cracks. The investigation has not, to date, identified any manufacturing practice or operating condition that is unique to the affected penetrations or to the RPV at STP Unit 1. The design of the area beneath the RPV at STP Unit 1 and the inspection methods used by the licensee enabled the discovery of the leaking penetrations. From the NRC staff reviews described in RIS 2003-13, the NRC staff concluded that leakage such as that observed at STP Unit 1 would likely not have been detected during inspections performed at many other PWRs.

Discussion

The RPV and its head penetrations are an integral part of the RCPB, and their integrity is important to the safe operation of the plant. The recent identification of cracking and leakage from two BMI penetrations at STP Unit 1 raises questions about potential degradation mechanisms which may be active in this area. In addition, licensee responses to the Bulletin 2002-01 followup RAIs raised questions about the adequacy of inspections performed by licensees to detect leakage from RPV lower head penetrations.

As indicated above, the investigation of the degradation mechanism involved in the cracking of the two penetrations at STP Unit 1 is continuing. However, an evaluation of the available information leads to several observations. First, although the root cause of the cracking experienced at STP Unit 1 is not yet understood, the investigation to date has not identified potential root causes which would be unique to the affected penetrations at STP Unit 1.

Second, the licensee for STP Unit 1 uses a method of inspecting the RPV lower head penetrations that permits visual examination of the external metal surfaces of the vessel lower head and its penetrations, unimpeded by the surrounding insulation. In comparison to the previously discussed VT-2 examinations specified in Section XI of the ASME Code, which do not require the removal of insulation and must be performed at normal operating pressure conditions once each refueling outage, the inspections conducted by the STP Unit 1 licensee are superior for the purpose of finding evidence of leakage like that observed at STP Unit 1. In fact, the NRC staff has concluded that the VT-2 examinations required by Section XI of the ASME Code would not be effective at finding deposits like those discovered at STP Unit 1.

Third, the circumstances of the STP Unit 1 findings indicate that the cracking and the onset of leakage may have occurred several years prior to the discovery of leakage. The licensee's prior inspections of STP Unit 1 lower head were capable of finding the deposits observed in April 2003. However, no evidence of leakage had been noted as the result of any inspections conducted prior to April 2003. Therefore, a one-time inspection of an RPV lower head area may not provide adequate assurance that degradation is not occurring similar to that observed in the BMI penetrations at STP Unit 1.

The small amount of leakage from the cracks discovered at STP Unit 1 did not represent an immediate safety problem due to the size and orientation of the cracks. In addition, safety systems included in plant designs and required to be available during plant operation would be able to mitigate the effects of more significant leaks, including a gross rupture of an RPV lower head penetration. Although unlikely, a significant leak from an RPV lower head penetration could introduce operational and safety concerns since it would require operation of safety systems for an extended period and complicate longer term efforts to stabilize the plant. To maintain the overall defense-in-depth philosophy incorporated into the design and operation of nuclear power plants, licensees should take appropriate actions to ensure the integrity of the RPV lower head penetrations.

The NRC staff believes it is appropriate for licensees to assess their current inspection practices to periodically ensure that there are no leaks from RPV lower head penetrations. This conclusion is based on the safety concerns associated with a significant leak from the RPV lower head and the uncertainties associated with the ability of some current inspection practices to identify cracks and resultant small leaks from RPV lower head penetrations.

Inspections capable of detecting through-wall leakage from any RPV lower head penetration, beginning at the next refueling outage, would provide additional confidence in the integrity of the RPV lower head penetrations. If visual inspections are performed to detect evidence of possible leakage, such inspections should include an inspection of 100% of the circumference of each penetration as it enters the RPV lower head.

The industry's Materials Reliability Program (MRP) has made recommendations for PWR licensees to perform bare-metal visual inspections of RPV lower head penetrations during the current or next refueling outage. The recommendations were included in a letter from Leslie Hartz, MRP Senior Representative, dated June 23, 2003 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML031920395). The MRP is an industry program, coordinated by EPRI, to address material-related issues associated with PWRs.

The NRC is aware that preexisting conditions at some facilities may prevent licensees from performing bare-metal visual inspections of some RPV lower head penetrations during their next refueling outage. For these plants, such inspections of the RPV lower head penetrations may not be possible, for example, until after plant modifications, cleaning, and completion of other tasks provide access and a clean surface for baseline and future inspections. For the plants unable to perform inspections as recommended above, additional confidence in the integrity of the RPV lower head penetrations may be obtained by licensees (1) developing an inspection plan to examine as many of the RPV lower head penetrations as is practical, and (2) taking the necessary steps to enable the performance of inspections as above for each penetration during subsequent refueling outages. In conducting inspections or other activities on the RPV lower head, licensees should recognize that entry into and work in cavities under PWR reactor vessels present very high radiation hazards. Access controls to these areas should require, among other things, close communication between plant operations and radiation protection staff on the status of the highly activated components (e.g., thimble retraction from the core into the reactor cavity) so that required reactor cavity access controls and oversight can be fully implemented before very high radiation levels are created. More information on these under-vessel hazards is provided in Appendix B of Regulatory Guide 8.38, "Control Of Access To High And Very High Radiation Areas In Nuclear Power Plants."

The NRC staff is working with the industry and other stakeholders to revise the ASME Code and NRC regulations to address inspection of RCPB locations susceptible to cracking, including RPV penetrations. These activities will not be completed for several years, so the NRC is issuing this bulletin to address the immediate concerns identified following the reviews of the responses to Bulletin 2002-01 and followup RAIs and the discovery of leaks from BMI penetrations at STP Unit 1. The NRC has posted and will continue to post information about these subjects on its Web site (www.nrc.gov).

Applicable Regulatory Requirements

The NRC has acknowledged that the existing regulatory requirements may need to be supplemented in order to ensure required inspections of RPV lower head penetrations are adequate to identify potential penetration leakage. However, several provisions of the NRC regulations and plant operating licenses (technical specifications) pertain to RCPB integrity and the issues addressed by this bulletin. The general design criteria (GDC) for nuclear power plants (Appendix A to 10 CFR Part 50), or, as appropriate, similar requirements in the licensing basis for a reactor facility, the requirements of 10 CFR 50.55a, and the quality assurance criteria of Appendix B to 10 CFR Part 50 provide the bases and requirements for NRC staff assessment of the potential for, and consequences of, degradation of the RCPB.

The applicable GDCs include GDC 14 (Reactor Coolant Pressure Boundary), GDC 31 (Fracture Prevention of Reactor Coolant Pressure Boundary), and GDC 32 (Inspection of Reactor Coolant Pressure Boundary). GDC 14 specifies that the RCPB be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture. GDC 31 specifies that the probability of rapidly propagating fracture of the RCPB be minimized. GDC 32 specifies that components which are part of the RCPB have the capability of being periodically inspected to assess their structural and leaktight integrity.

NRC regulations in 10 CFR 50.55a state that ASME Class 1 components (which includes the RCPB) must meet the requirements of Section XI of the ASME Code. Various portions of the ASME Code address RCPB inspection. For example, Table IWB-2500-1 of Section XI of the ASME Code provides examination requirements during system leakage testing of all pressure-retaining components of the RCPB and references IWB-3522 for acceptance standards. IWB-3522.1(c) and (e) specify that conditions requiring correction include the detection of leakage from insulated components and discoloration or accumulated residues on the surfaces of components, insulation, or floor areas that may be evidence of borated water leakage, with leakage defined as the through-wall leakage that penetrates the pressure retaining membrane. Therefore, 10 CFR 50.55a, by reference to the ASME Code, does not permit through-wall degradation of the RPV lower head penetrations. For through-wall leakage identified by visual examinations in accordance with the ASME Code, acceptance standards for the identified degradation are provided in IWB-3142. Specifically, supplemental examination (by surface or volumetric examination), corrective measures or repairs, analytical evaluation, and replacement provide methods for determining the acceptability of degraded components. Criterion V (Instructions, Procedures, and Drawings) of Appendix B to 10 CFR Part 50 states that activities affecting quality shall be prescribed by documented instructions, procedures, or drawings of a type appropriate to the circumstances and shall be accomplished in accordance with these instructions, procedures, or drawings. Criterion V further states that instructions,

procedures, or drawings shall include appropriate quantitative or qualitative acceptance criteria for determining that important activities have been satisfactorily accomplished. Visual and volumetric examinations of the RCPB are activities that should be documented in accordance with these requirements.

Criterion IX (Control of Special Processes) of Appendix B to 10 CFR Part 50 states that special processes, including nondestructive testing, shall be controlled and accomplished by qualified personnel using qualified procedures in accordance with applicable codes, standards, specifications, criteria, and other special requirements.

Criterion XVI (Corrective Action) of Appendix B to 10 CFR Part 50 states that measures shall be established to assure that conditions adverse to quality are promptly identified and corrected. For significant conditions adverse to quality, the measures taken shall include root cause determination and corrective action to preclude repetition of the adverse conditions. For degradation of the RCPB, the root cause determination is important for understanding the nature of the degradation present and the required actions to mitigate future degradation. These actions could include proactive inspections and repair of degraded portions of the RCPB.

Plant technical specifications (TS) pertain to this issue insofar as they do not allow operation with through-wall reactor coolant system pressure boundary leakage.

Requested Information

(1) All subject PWR addressees are requested to provide the following information. The responses for facilities that will enter refueling outages before December 31, 2003, should be provided within 30 days of the date of this bulletin. All other responses should be provided within 90 days of the date of this bulletin.

(a) A description of the RPV lower head penetration inspection program that has been implemented at your plant. The description should include when the inspections were performed, the extent of the inspections with respect to the areas and penetrations inspected, inspection methods used, the process used to resolve the source of findings of any boric acid deposits, the quality of the documentation of the inspections (e.g., written report, video record, photographs), and the basis for concluding that your plant satisfies applicable regulatory requirements related to the integrity of the RPV lower head penetrations.

(b) A description of the RPV lower head penetration inspection program that will be implemented at your plant during the next and subsequent refueling outages. The description should include the extent of the inspections which will be conducted with respect to the areas and penetrations to be inspected, inspection methods to be used, qualification standards for the inspection methods, the process used to resolve the source of findings of boric acid deposits or corrosion, the inspection documentation to be generated, and the basis for concluding that your plant will satisfy applicable regulatory requirements related to the structural and leakage integrity of the RPV lower head penetrations.

(c) If you are unable to perform a bare-metal visual inspection of each penetration during the next refueling outage because of the inability to perform the necessary planning, engineering, procurement of materials, and implementation, are you planning to perform bare-metal visual inspections during subsequent refueling outages? If so, provide a description of the actions that are planned to enable a bare-metal visual inspection of each penetration during subsequent refueling outages. Also, provide a description of any penetration inspections you plan to perform during the next refueling outage. The description should address the applicable items in paragraph (b).

(d) If you do not plan to perform either a bare-metal visual inspection or non-visual (e.g., volumetric or surface) examination of the RPV lower head penetrations at the next or subsequent refueling outages, provide the basis for concluding that the inspections performed will assure applicable regulatory requirements are and will continue to be met.

(2) Within 60 days of plant restart following the next inspection of the RPV lower head penetrations, the subject PWR addressees should submit to the NRC a summary of the inspections performed, the extent of the inspections, the methods used, a description of the as-found condition of the lower head, any findings of relevant indications of through-wall leakage, and a summary of the disposition of any findings of boric acid deposits and any corrective actions taken as a result of indications found.

Required Response

In accordance with 10 CFR 50.54(f), the subject PWR addressees are required to submit written responses to this bulletin. This information is sought to verify licensees' compliance with the current licensing basis for the subject PWR addressees. The addressees have two options:

(1) addressees may choose to submit written responses providing the information requested above within the requested time periods, or

(2) addressees who choose not to provide the information requested or cannot meet the requested completion dates are required to submit written responses within 15 days of the date of this bulletin. The responses must address any alternative course of action proposed, including the basis for the acceptability of the proposed alternative course of action.

The required written responses should be addressed to the U.S. Nuclear Regulatory Commission, ATTN: Document Control Desk, 11555 Rockville Pike, Rockville, Maryland 20852, under oath or affirmation under the provisions of Section 182a of the Atomic Energy Act of 1954, as amended, and 10 CFR 50.54(f). In addition, a copy of a response should be submitted to the appropriate regional administrator.

Reasons for Information Request

NRC regulatory requirements and plant TS requirements preclude operation with through-wall leakage from the RCPB. Requirements in the ASME Code, NRC regulations, and plant TS are intended to make licensees perform inspections to maintain an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture. The current inspection

techniques used at many PWRs may not detect small leaks such as those discovered at STP Unit 1. Uncertainty exists about the root cause of the cracking and resultant leakage at STP Unit 1, and whether other PWRs with RPV lower head penetrations could have similar problems. A detailed assessment of the risks associated with this issue is hampered by the uncertainties associated with the degradation mechanisms which may be active in RPV lower head penetrations, plant conditions (especially for those plants that have not performed the recommended inspections), and the course of events given a significant leak from the lower head. Improved inspections of the RPV lower head penetrations will resolve some of these uncertainties and could identify and allow correction of conditions before they become a significant safety concern.

This information request is necessary to permit the NRC staff to verify compliance with existing regulations and plant-specific licensing bases. The information being requested by this bulletin focuses on RPV lower head penetrations in more detail than previous generic communications and, therefore, is not currently available to the NRC staff. The NRC staff will use the information to assess the acceptability of current licensee lower vessel head inspection programs to identify BMI penetration leakage, and to determine the need for, and guide the development of, any additional regulatory actions (e.g., generic communications, orders, or rulemaking) to address the integrity of the RCPB. Such regulatory actions could include regulatory requirements for augmented inspection programs under 10 CFR 50.55a(g)(6)(ii). The NRC staff will review the responses to this bulletin to determine whether the PWR addressees' inspections provide reasonable assurance that existing applicable regulations are met. If concerns are identified, the NRC staff will contact each affected addressee.

Related Generic Communications

Regulatory Issue Summary 2003-13, "NRC Review of Responses to Bulletin 2002-01, 'Reactor Pressure Vessel Head Degradation and Reactor Coolant Pressure Boundary Integrity,' July 29, 2003 (ADAMS Accession No. ML032100653)

Information Notice 2003-11 "Leakage Found on Bottom-Mounted Instrumentation Nozzles," August 13, 2003 (ADAMS Accession No. ML032250135)

Bulletin 2002-02, "Reactor Pressure Vessel Head and Vessel Head Penetration Nozzle Inspection Programs," August 9, 2002 (ADAMS Accession No. ML022200494)

Bulletin 2002-01, "Reactor Pressure Vessel Head Degradation and Reactor Coolant Pressure Boundary Integrity," March 18, 2002 (ADAMS Accession No. ML020770497)

Generic Letter 88-05, "Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants," March 17, 1988 (ADAMS Accession No. ML031130424)

Backfit Discussion

Under the provisions of Section 182a of the Atomic Energy Act of 1954, as amended, and 10 CFR 50.54(f), this bulletin transmits an information request for the purpose of verifying compliance with existing applicable regulatory requirements (see the Applicable Regulatory Requirements section of this bulletin). Specifically, the required information will enable the NRC staff to determine whether current inspection and maintenance practices for the detection of degradation of the RCPB at reactor facilities (similar to the degradation observed at STP

Unit 1) provide reasonable assurance that RCPB integrity is being maintained. No backfit is either intended or approved by the issuance of this bulletin, and the staff has not performed a backfit analysis.

Federal Register Notification

A notice of opportunity for public comment on this bulletin was not published in the *Federal Register* because the NRC staff is requesting information from power reactor licensees on an expedited basis for the purpose of assessing compliance with existing applicable regulatory requirements and the need for subsequent regulatory action. This bulletin was prompted by the discovery of leaks from BMI penetrations at STP Unit 1 and by the NRC staff's assessment of responses to Bulletin 2002-01. As the resolution of this matter progresses, the opportunity for public involvement will be provided. Nevertheless, comments on the actions requested and the technical issues addressed by this bulletin may be sent to the U.S. Nuclear Regulatory Commission, ATTN: Document Control Desk, Washington, DC 20555-0001.

Small Business Regulatory Enforcement Fairness Act

The NRC has determined that this action is not subject to the Small Business Regulatory Enforcement Fairness Act of 1996.

Paperwork Reduction Act Statement

This bulletin contains an information collection that is subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.). This information collection was approved by the Office of Management and Budget, clearance no. 3150-0012, which expires August 31, 2006. The burden to the public for this mandatory information collection is estimated to average 110 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the information collection. Send comments regarding this burden estimate or any other aspect of this information collection, including suggestions for reducing the burden, to the Records Management Branch (T-6 E6), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by Internet electronic mail to INFOCOLLECTS@NRC.GOV; and to the Desk Officer, Office of Information and Regulatory Affairs, NEOB-10202, (3150-0012), Office of Management and Budget, Washington, DC 20503.

Public Protection Notification

The NRC may not conduct or sponsor, and a person is not required to respond to, an information collection unless the requesting document displays a currently valid OMB control number.

If you have any questions about this matter, please contact one of the persons listed below or the appropriate Office of Nuclear Reactor Regulation project manager.

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