# DAVIS-BESSE LESSONS LEARNED TASK FORCE RECOMMENDATIONS REGARDING STRESS CORROSION CRACKING

| TAC No. | Description |
|---|---|
| MB2916 | Non plant-specific activities for Bulletin 2001-01 |
| MB3567 | VHP Action Plan (Coordination and Administration) |
| MB3954 | Development of CRDM NUREGs (Bulletin 2001-01) |
| MB4495 | Lead PM Activities for Bulletin 2002-01 |
| MB4603 | Non plant-specific activities for Bulletin 2002-01 |
| MB5465 | Lead PM Activities for Bulletin 2002-02 |
| MB6218 | Inspection TI for Bulletin 2002-02 |
| MB6220 | Review of NEI/MRP Crack Growth Rate Report (MRP-55) |
| MB6221 | Development of Alternate (to ASME Code) RPV Head and VHP Inspection Requirements |
| MB6222 | Review of NEI/MRP RPV Head and VHP Inspection Plan (MRP-75) |
| MB7182 | Orders for Interim Inspection Guidelines |
| MB9522 | Review of Bulletin 2002-01 Responses |
| MB8915 | Generic Activities for Lower Head Inspection |
| MB9891 | Develop Bulletin 2003-02 |
| MC0590 | Develop Technical Issues Related to Incorporating RCPB Inspection Requirements into 50.55a |
| MC1036 | Develop/Revise Inspection Guidance for ISI and BACC |

Last Update: 02/01/08
Lead Division: DPR
Supporting Divisions: DE, DSS, & DIRS
Supporting Offices: RES & Regions

| Milestone | Date (T=Target) (C=Complete) | Lead | Support |
|---|---|---|---|
| **Part I - Reactor Pressure Vessel Head Inspection Requirements** | | | |
| 1. Collect and summarize information available worldwide on Alloy 600, Alloy 690 and other nickel based alloy nozzle cracking for use in evaluation of revised inspection requirements. [LLTF 3.1.1(1)-High] | 03/04 (C) ML040920026 | RES/DET | DE |
| 2. Critically evaluate existing SCC models with respect to their continuing use in the susceptibility index. [LLTF 3.1.4(1)-Medium] | 07/03 (C) ML032461221 | RES/DET | DE |
| 3.a Complete initial evaluation of individual plant inspections in response to Bulletins and Orders. | 05/04 (C) ML041560306 | DE | DLPM Regions |
| 3.b Continue to review future inspection results until permanent guidelines are issued. | Ongoing | DCI | DORL Regions |

| Milestone | Date (T=Target) (C=Complete) | Lead | Support |
|---|---|---|---|
| 4. Incorporate Order EA-03-009 requirements into 10 CFR 50.55a | Note (2) | | |
| a. Develop technical basis | 04/04 (C) ML040920628 ML040920638 | DE | DRIP |
| b. Develop rulemaking plan | 07/04 (C) ML041610180 | DRIP | DE |
| c. Commission decision | 08/04 (C) ML042190072 | | |
| 5. Monitor and provide input to industry efforts to develop revised RPV Head inspection requirements (ASME Code Section XI). [LLTF 3.3.4(8)-High] | 06/05 (C) Note (1) | DE | RES/DET<br>DSSA<br>Regions<br>Industry |
| 6. Participate in meetings and establish communications with appropriate stakeholders (e.g., MRP, ASME). [LLTF 3.3.4(8)-High] | Ongoing | DCI | RES/DET<br>PGCB<br>DPR<br>DSS<br>Industry |
| 7. Review and evaluate revised ASME Code requirements when issued. [LLTF 3.3.4(8)-High] | 06/06 (C) ML061800439 | DCI | RES/DET |
| 8. If revised ASME Code requirements are acceptable, establish schedule to incorporate by reference into 10 CFR 50.55a. [LLTF 3.3.4(8)-High] | 06/08 (T) | DCI | DPR<br>DIRS<br>DSS<br>RES/DET<br>Industry<br>Public |
| 9. Publish a NUREG report summarizing findings from Part I, Items 1 and 2, and Part II, Item 1. | 03/05 (C) NUREG-1823 ML050690012 | RES/DET | DE |
| 10. Propose a course of action and implementation schedule to address the results of the analysis of Part I, item 1, and Part II, item 1. [LLTF 3.1.1(1)-High] | 10/04 (C) ML043010675 | DE | RES/DET |

| Milestone | Date (T=Target) (C=Complete) | Lead | Support |
|---|---|---|---|
| **Part II - Boric Acid Control** | | | |
| 1. Collect and summarize information available worldwide on boric acid corrosion of pressure boundary materials for use in evaluation of revised inspection requirements. [LLTF 3.1.1(1)-High] | 10/04 (C) ML043000274 | RES/DET | DE |
| 2.a Evaluate individual plant responses to Bulletin 2002-01 regarding Boric Acid Inspection Programs (60-day responses and necessary follow-up) | 06/03 (C) ML031760568 | DE | DLPM |
| 2.b Issue public document to summarize evaluation of plant responses. | 07/03 (C) ML032100653 | DE | DLPM DRIP |
| 3. Participate in meetings and establish communications with appropriate stakeholders (e.g.,MRP, ASME). | Ongoing | DCI | RES/DET PGCB DPR DSS Industry |
| 4. Evaluate need to take additional regulatory actions and determine appropriate regulatory tool(s). | 06/03 (C) ML031760568 | DE | DLPM DRIP DIPM DSSA Regions |
| 5. Issue Bulletin 2003-02 on Reactor Vessel Lower Head inspection. | 08/03 (C) ML032320153 | DE | DLPM |
| 6. Develop milestones for additional regulatory actions, as necessary. | 07/03 (C) | DE | DLPM DSSA DRIP |
| 7. Complete and evaluate the results of ongoing research on materials degradation, engage external stakeholders and develop a plan to implement a proactive approach to manage degradation of the RCPB. | 06/08 (T) | DCI | RES |
| 8. Review and evaluate the adequacy of revised ASME Code Requirements for Pressure Testing/Leakage Evaluation being developed by the ASME Code, Section XI, Task Group on Boric Acid. | 06/06 (C) ML060390427 | DCI | RES/DET |

| Milestone | Date (T=Target) (C=Complete) | Lead | Support |
|---|---|---|---|
| **Part III - Inspection Programs** | | | |
| 1. Develop inspection guidance or revise existing guidance to ensure that VHP nozzles and the RPV head area are periodically reviewed by the NRC during licensee ISI activities. [LLTF 3.3.4(3)-High] | 06/04 (C) ML022940597 ML041340207 | DIPM | DE Regions |
| 2. Develop inspection guidance that provides for timely, periodic inspection of PWR plant BACC programs. [LLTF3.3.2(1)-High] | 06/04 (C) ML022940597 ML041340207 | DIPM | DE Regions |
| 3.a Develop inspection guidance for assessing the adequacy of PWR plant BACC programs (implementation effectiveness, ability to identify leakage, adequacy of evaluation of leaks). [LLTF 3.2.2(1)-High] | 06/04 (C) ML022940597 ML041340207 | DIPM | DE RES/DET Regions |
| 3.b Perform follow-up evaluation of inspection guidance and licensee program acceptability after conducting inspections for approximately one year. | 05/05 (C) ML051360392 | DIPM | DE RES/DET Regions |

Notes: (1) Milestone dates are dependent upon issuance of industry proposals.

(2) The subject of this rulemaking will be requirements for inspection of only the upper head.

Description: The reactor vessel head (RVH) degradation found at Davis-Besse, along with other documented incidences of circumferential cracking of vessel head penetration (VHP) nozzles, have prompted the NRC staff to question the adequacy of current RVH and VHP inspection programs that rely on visual examinations as the primary inspection method. Also, the failure to adequately address indications of boric acid leakage at Davis-Besse raised questions as to the efficacy of industry boric acid corrosion control (BACC) programs. Finally, review of the Davis-Besse event identified deficiencies in the NRC inspection programs.

Historical Background: In March 2002, while conducting inspections in response to Bulletin 2001-01, the Davis-Besse Nuclear Power Station identified three CRDM nozzles with indications of axial cracking, which were through-wall, and resulted in reactor coolant pressure boundary leakage. During the nozzle repair activities, a 7 inch by 4-to-5 inch cavity on the downhill side of nozzle 3, down to the stainless steel cladding was identified. The extent of the damage indicated that it occurred over an extended period and that the licensee's programs to inspect the RPV head and to identify and correct boric acid leakage were ineffective.

One of the NRC follow-up actions to the Davis-Besse event was formation of a Lessons Learned Task Force (LLTF). The LLTF conducted an independent evaluation of the NRC's regulatory processes related to assuring reactor vessel head integrity in order to identify and recommend areas of improvement applicable to the NRC and the industry. A report summarizing their findings and recommendations was published on September 30, 2002. The report contains several consolidated lists of recommendations. The LLTF report was reviewed by a Review Team (RT), consisting of several senior management

personnel appointed by the Executive Director for Operations (EDO). The RT issued a report on November 26, 2002, endorsing all but two of the LLTF recommendations, and placing them into four overarching groups. On January 3, 2003, the EDO issued a memo to the Director, NRR, and the Director, RES, tasking them with developing a plan for accomplishing the recommendations. This action plan addresses the recommendations in the "Assessment of Stress Cracking" grouping of the RT report. The LLTF recommendations are listed in the attached Table 1, and have been identified under the appropriate milestone(s).

Proposed Actions: The NRC staff is interacting with all PWR licensees, the American Society of Mechanical Engineers (ASME), the Electric Power Research Institute (EPRI) Materials Reliability Program (MRP), and other external stakeholders in addressing the issues discussed above. This action plan includes milestones aimed at guiding the NRC and industry to effectively manage RVH degradation and BACC. Throughout the implementation of this action plan, the NRC will establish the necessary communications mechanisms to ensure that the NRC, the industry, and all stakeholders are informed and sharing the same information. This will be accomplished through public meetings, technical working groups, ACRS briefings, and web site postings, as appropriate.

The Part I milestones deal with development of improved inspection requirements for the RPV head and VHP nozzles. Interim inspection guidelines for the RPV upper head have been issued via Order EA-03-009 and associated temporary inspection guidelines (TI-150) have been issued for use by NRC inspectors. These will be updated as needed based on inspection results. The ASME Boiler and Pressure Vessel Code (ASME Code) published ASME Code Case N-729-1 in May 2005. ASME Code Case N-729-1 provides alternative inspection requirements for reactor pressure vessel closure heads. NRC staff has performed a technical evaluation of N-729-1 and finds the code case, with certain conditions, is acceptable for implementation in lieu of the requirements of Order EA-03-009. Therefore, the NRC staff has initiated an action to incorporate ASME Code Case N-729-1, with conditions, in a revision to 10 CFR 50.55a. This action is included in the 10 CFR 50.55a update rulemaking package to incorporate the 2004 Edition of the ASME Code. For those licensees which choose to implement ASME Code Case N-729-1, with conditions, in lieu of current Order EA-03-009 requirements prior to the completion of the rulemaking, they may do so through a relaxation request from the requirements of the Order EA-03-009 as explained in a letter dated August 9, 2006, from J. Grobe, NRC, to J. Riley, NEI (ADAMS Accession No. ML062220594).

The Part II milestones evaluate whether industry BACC programs are meeting NRC expectations and whether additional inspection guidance should be issued. First, the NRC staff will establish a technical basis for BACC program requirements through ongoing and planned research programs. This will include evaluation of boric acid events in past reports and in responses to Bulletin 2002-01, and studies of rates of reactor pressure boundary materials in boric acid solutions. The NRC staff is also monitoring development of revised ASME Code requirements by the Section XI Task Group on Boric Acid. If the NRC staff determines that additional interim guidelines are needed prior to issuance of the revised Code requirements, they will be issued by an appropriate regulatory tool. When the ASME Code requirements are revised, the NRC will initiate action to endorse them, if acceptable. If the revised ASME Code requirements cannot be made acceptable to the NRC, then alternate requirements would have to be developed and implemented by an appropriate regulatory tool. Based on the leaks discovered in lower vessel head penetrations at South Texas Project, the NRC staff issued Bulletin 2003-02 regarding RPV lower head inspections. Associated temporary inspection guidelines (TI-152) were issued for use by NRC inspectors. The NRC staff will complete and evaluate the results of ongoing research on materials degradation, engage external stakeholders and develop a plan to implement a proactive approach to manage degradation of the RCPB.

In engaging external stakeholders to develop a plan to implement a proactive approach to manage degradation of the RCPB, the industry has developed a staggered approach to addressing all areas susceptible to PWSCC and boric acid corrosion in pressurized water reactors. This industry approach is partially complete with activities concerning susceptible butt welds as identified in MRP-139. NRC staff review of this action is underway and has provided industry with questions and comments concerning MRP-139. Further industry actions for the lower reactor pressure vessel head and other components are

expected by the March 2007. However, this estimate is tied to industry activities which have experienced some delay.

The ASME published Code Case N-722, "Additional Examinations for PWR Pressure Retaining Welds in Class 1 Components Fabricated with Alloy 600/82/182 Materials," in Supplement 6 to the 2004 Code Cases. ASME Code Case N-722 provides recommended additions to the requirements of Table IWB-2500-1 for inspection of partial and full penetration welds in Class 1 components fabricated with Alloy 600/82/182 material. This material is susceptible to cracking, which can lead to leakage that could cause boric acid corrosion. NRC staff performed a technical evaluation of Code Case N-722 and found the code case, with certain conditions, provides an acceptable approach for addressing safety issues associated with boric acid corrosion due to cracking in Alloy 600/82/182 material. Therefore, the NRC staff has initiated an action to incorporate ASME Code Case N-722, with conditions, in a revision to 10 CFR 50.55a. This revision is reflected in milestone II.7.

The Part III milestones address the LLTF findings that the NRC inspection guidelines did not provide effective oversight of licensee RPV head inspection and BACC programs. Revised guidelines for these activities will be developed. Throughout the process of establishing new requirements, existing NRC inspection procedures would be evaluated to verify whether they adequately address the revised requirements, and would be updated as needed.

Originating Documents:

Memorandum from Travers, W.D. to Collins, S. and Thadani, A. C., dated January 3, 2003, "Actions Resulting From The Davis-Besse Lessons Learned Task Force Report Recommendations." (ADAMS Accession No. ML023640431)

Memorandum from Paperiello, C.J. to Travers, W.D., dated November 26, 2002, "Senior Management Review of the Lessons-Learned Report of the Davis-Besse Nuclear Power Station Reactor Pressure Vessel Head." (ADAMS Accession No. ML023260433)

Memorandum from Howell, A.T. to Kane, W.F., dated September 30, 2002, "Degradation of the Davis-Besse Nuclear Power Station Reactor Pressure Vessel Head Lessons-Learned Report." (ADAMS Accession No. ML022740211)

Regulatory Assessment: The current method for managing PWSCC in the VHP nozzles of U.S. PWRs is dependent on the implementation of inspection methods intended to provide early detection of degradation of the reactor coolant pressure boundary. Title 10, Section 50.55a(g)(4) of the *Code of Federal Regulations* requires, in part, that ASME Code Class 1, 2, and 3 components must meet the inservice inspection requirements of Section XI of the ASME *Boiler and Pressure Vessel Code* throughout the service life of a boiling or pressurized water reactor. Pursuant to Inspection Category B-P of Table IWB-2500-1 to Section XI of the ASME *Boiler and Pressure Vessel Code*, licensees are required to perform VT-2 visual examinations of their vessel head penetration nozzles and reactor vessel heads once every refueling outage for the system leak tests, and once an inspection interval for the hydrostatic pressure test.

Based on the experience with the VHP nozzle cracking phenomenon, the VT-2 visual examination methods required by the ASME Code for inspections of VHP nozzles do not provide reasonable assurance that leakage from a through-wall flaw in a nozzle will be detected. The VT-2 visual examination methods specified by the ASME Code are not directed at detecting the very small amounts of boric acid deposits, e.g., on the order of a few grams, that have been associated with VHP nozzle leaks in operating plants. In addition, the location of thermal insulating materials and physical obstructions may prevent the VT-2 visual examination methods from identifying minute amounts of boric acid deposits on the outer surface of the vessel head. Specifically, Paragraph IWA-5242 of Section XI of the ASME Boiler and Pressure Vessel Code does not require licensees to remove thermal insulation materials when performing ASME VT-2 visual examinations of reactor vessel heads. Cleanliness of reactor vessel heads during the examinations, which is critical for visual examination methods to be capable of distinguishing between

boric acid residues that result from VHP nozzle leaks and those residues that result from leaks in other reactor coolant system components, is not addressed by the ASME Code.

Based on knowledge obtained from evaluation of the Davis-Besse event, and information provided from PWR licensees in response to Bulletins 2001-01, 2002-01, and 2002-02, the NRC issued an Order to all PWR plants establishing enhanced inspection requirements on an interim basis, which will provide adequate assurance of safe plant operation until permanent requirements are established and promulgated.

Current Status:

*Part I Status* - Part I activities included continued monitoring of outage inspection results, follow-up with plants discovering defects, and evaluation of requests for relaxation from First Revised Order EA-03-009.

The NRC staff evaluated the existing SCC models and determined that they are acceptable for use in prioritizing RPV head inspections. The report is publicly available in ADAMS (ML032461221).

The NRC staff collected information on Alloy 600, Alloy 690 and other nickel-based alloy nozzle cracking and issued a summary report for internal use. The report is publicly available in ADAMS (ML040910354).

The NRC staff developed a rulemaking plan to incorporate the inspection requirements for the RPV upper head into 10 CFR 50.55a. This was submitted for Commission approval in July 2004. The Commission decided not to proceed with this rulemaking and directed the NRC staff to continue to work with the industry to incorporate revised inspection requirements into the ASME code (SRM-SECY-04-0115, August 6, 2004). The NRC staff participated in ASME Code Committee development of revised inspection requirements. In June 2005, the ASME Board on Nuclear Codes and Standards approved Code Case N-729, which provides additional inspection requirements for RPV upper heads. Therefore, Part I, item 5 is considered complete. However, NRC staff review of the code case identified significant publishing errors which necessitated a reissuance of the code case as N-729-1. The revision was published in May 2006. The NRC staff has evaluated the revised code case and found it, with certain conditions, to be an acceptable long term reactor vessel closure head inspection plan. NRC staff has documented its review and acceptance in a memorandum from the Division of Component Integrity to the Division of Policy and Rulemaking (Accession No. ML061800439) to initiate rulemaking to endorse Code Case N-729-1, with conditions, in a revision to 10 CFR 50.55a. Therefore, Part I, item 7 is considered complete.

Once the final rule to incorporate ASME Code Case N-729-1 with conditions into 10 CFR 50.55a is approved, permanent guidelines will have been established for reactor vessel closure head inspections, and all items under Part I will be closed. This rulemaking is scheduled to be completed by June 2008.

*Part II Status* - For Part II activities, the review and evaluation of licensee responses to Bulletin 2002-01 regarding BACC have been completed. A summary of the evaluation was published in RIS 2003-13 (Accession No. ML032100653). The evaluation of responses to Bulletin 2002-01, which included audits of BACC programs at five plants, determined that the plants complied with requirements at the programmatic level. In general, the results indicated weaknesses in the licensees' BACC and ASME Section XI programs. The weaknesses identified in the RIS included identifying pressure boundary leakage and potential leakage paths, looking for boric acid crystals, walking down systems when the plant is entering or leaving the hot shutdown mode, and detecting small leaks during normal power operation. Based on this review and the discovery of leakage on vessel bottom penetrations at South Texas Project, Bulletin 2003-02 was issued.

The NRC staff collected information on available worldwide operating experience on boric acid corrosion of pressure boundary materials. The NRC staff also contracted Argonne National Lab to conduct a test program on boric acid corrosion of light-water reactor pressure vessel materials. The results were published in NUREG/CR-6875. This information and the information previously collected on nozzle cracking along with the NRC staff evaluation of the SCC models have been incorporated into

NUREG-1823, “U.S. Plant Experience with Alloy 600 Cracking and Boric Acid Corrosion of Light-Water Reactor Pressure Vessel Materials” (ML050690012).

The NRC staff used the information collected regarding boric acid corrosion and the information previously collected regarding Alloy 600, Alloy 690 and other nickel-based alloy nozzle cracking to develop a course of action and an implementation schedule to address LLTF 3.1.1(1). The NRC staff met with industry representatives on March 24, 2005, to discuss their activities for addressing PWSCC in nickel based alloy butt welds and in other locations in the reactor coolant system. Industry presentations were high level and lacked the technical details and scheduler commitments the NRC staff was expecting. On September 29, 2005, the NRC staff again met with the industry, during which representatives of the Materials Reliability Program (MRP) indicated that their inspection guidelines for this issue would not be available until the end of 2006. At a meeting with NRC senior management on February 22, 2006, MRP representatives indicated that these inspection guidelines will not be available until 2007. Based on the result of these meetings, the NRC staff has concluded that an effective course of action for completing milestone II.7 is to incorporate ASME Code Case N-722 into 10 CFR 50.55a. It contains inspection rules for boric acid corrosion and cracking of nickel-based alloy nozzles and addresses the course of actions associated with the closure of LLTF 3.1.1(1). The NRC staff has completed its evaluation of ASME Code Case N-722 and has provided proposed rule language and input to the regulatory analysis in a memorandum from the Division of Component Integrity to the Division of Policy and Rulemaking (Accession No. ML060390427) to initiate rulemaking to endorse Code Case N-722, with conditions, in a revision to 10 CFR 50.55a. Therefore, Part II, item 8 is considered complete. The rulemaking to incorporate ASME Code Case N-722 into 10 CFR 50.55a is scheduled to be completed by June 2008, which will complete all items under Part II.

*Part III Status* - For Part III activities, inspection procedure revisions addressing RPV head inspection and boric acid corrosion control programs were issued. Temporary Instruction (TI) 2515/150, issued on October 18, 2002, provides guidance for assessing the licensees’ RPV head inspections pursuant to Order EA-03-009. The TI also includes instructions for follow-up on findings of boric acid accumulation. Inspection Procedure (IP) 71111.08, “Inservice Inspection Activities,” dated May 11, 2004, provides periodic inspection requirements and guidance for boric acid corrosion control. The Regions provided feedback regarding the implementation of TI 2515/150 and IP 71111.08 since October 2002. In addition, the Inspection Program Branch (IIPB) reviewed inspection results from TI 2515/150 and IP 71111.08. As a result of the licensees’ visual and non-visual inspections and NRC direct observations and oversight of licensees’ activities, a number of facilities have made repairs to their vessel heads and some have replaced the vessel heads. In some cases, repairs were required; in others the licensee took actions voluntarily. Feedback from each Region and IIPB staff review indicates that the licensees’ programs are generally adequate for locating and evaluating and/or correcting boric acid leaks. Although several inspection findings were identified, none were of greater than very low significance. The NRC staff will continue to evaluate the effectiveness of this IP as part of annual ROP self-assessment and make appropriate improvements as needed.

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