

**DAVIS-BESSE LESSONS LEARNED TASK FORCE  
RECOMMENDATIONS REGARDING ASSESSMENT OF  
BARRIER INTEGRITY REQUIREMENTS  
(FINAL UPDATE)**

Last Update: 06/30/05  
Lead Division: RES/DET  
Supporting Divisions: DRAA, DSARE  
Supporting Offices: NRR, Regions

<u>TAC No.</u>	<u>Description</u>
KC0042	Develop and implement action plans based on recommendations of the Davis-Besse reactor vessel head degradation Lessons-Learned Task Force (LLTF)
MB7287	NRR support for development of action plan
MC0036	NRR Support to RES for action plan activities

Milestone	Date (T=Target) (C=Complete)	Lead	Support
<b>Part I: Leakage</b>			
1. a. Review PWR TS to identify plants that have non-standard RCPB leakage requirements	7/03 (C) ML031980277	NRR/DIPM	
b. Take appropriate action to make TS consistent among all plants. [LLTF 3.3.4(9):High]	9/04 (C) ML042110336		
2. Inspect plant alarm response procedure requirements for leakage monitoring systems to assess whether they provide adequate guidance for the identification of RCPB leakage. [LLTF 3.2.1(3)]			
a. Revise inspection procedures.	05/04 (C)	NRR/DIPM	RES/DET NRR/DE NRR/DSSA
b. Assess adequacy of licensee procedure requirements based on results of inspections.	05/05 (C)	NRR/DIPM	Regions
3. Develop inspection guidance pertaining to RCS unidentified leakage that includes action levels to trigger increasing levels of NRC interaction with licensees in response to increasing levels of unidentified RCS leakage [LLTF 3.2.1(2):High]	1/05 (C) ML050270190	NRR/DIPM	RES/DET NRR/DE NRR/DSSA

Milestone	Date (T=Target) (C=Complete)	Lead	Support
<p>4. Evaluate RCS leakage requirements and leakage detection systems.</p> <p>a. Perform research study to reevaluate basis for RCS leakage requirements and assess the capabilities of currently used and state-of-the-art leakage detection systems.</p> <p>(1) Provide initial draft report for internal staff comment</p> <p>(2) Provide revised report for internal staff comment</p> <p>(3) Issue final report as NUREG/CR</p> <p>b. Form working group to review report and make recommendations.</p> <p>c. Working group to complete a white paper to address:</p> <p>(1) Determine whether PWR plants should install on-line enhanced leakage detection systems on critical plant components, which would be capable of detecting leakage rates of significantly less than 1 gpm. [LLTF 3.1.5(1):High]</p> <p>(2) Recommend improvements in the requirements pertaining to RCS unidentified leakage and RCPB leakage to ensure that they are sufficient to: (1) provide the ability to discriminate between RCS unidentified leakage and RCPB leakage; and (2) provide reasonable assurance that plants are not operated at power with RCPB leakage. [3.2.1(1):High]</p> <p>(3) Evaluate appropriate regulatory tools to implement recommendations, if necessary.</p>	<p>07/04 (C)</p> <p>10/04 (C)</p> <p>12/04 (C)</p> <p>08/04 (C)</p> <p>02/05 (C)</p>	<p>RES</p> <p>RES</p> <p>RES</p> <p>NRR/RES</p> <p>NRR/RES</p>	<p>NRR</p> <p>NRR</p> <p>NRR</p>

Milestone	Date (T=Target) (C=Complete)	Lead	Support
<p>d. Prepare a memorandum from division directors to office management to disposition conclusions in staff white paper.</p> <p>e. Implement approved changes in RCS and RCPB leakage requirements using appropriate regulatory tools. [3.2.1(1):High]</p>	<p>03/05 (C) ML050830139</p> <p>Not Required ML050830139</p>	NRR/RES	
<b>Part II. Performance Indicators (PI)</b>			
<p>1. Continue ongoing efforts to review and improve the usefulness of the barrier integrity PIs. Evaluate the feasibility of establishing a PI which tracks the number, duration, and rate of primary system leaks that have been identified but not corrected. [LLTF 3.3.3.(3):High]</p>	<p>5/05 ( C) ML051440371</p>	NRR/DIPM	<p>RES/DRAA RES/DET NRR/DE NRR/DSSA Regions</p>
<b>Part III. Risk Associated with Passive Component Degradation</b>			
<p>1. Form working group to address recommendation LLTF 3.3.7(3).</p> <p>2. Working group to complete a white paper to address:</p> <ul style="list-style-type: none"> <li>- Evaluate the adequacy of analysis methods involving the assessment of risk associated with passive component degradation, including the integration of the results of such analyses into the regulatory decision-making process. [LLTF 3.3.7(3)]</li> </ul> <p>3. Prepare a memorandum from division directors to office management to disposition conclusions in staff white paper.</p>	<p>08/04 (C)</p> <p>02/05 (C) ML050590324 ML050590328</p> <p>05/05 ( C) ML051380060</p>	<p>RES</p> <p>RES/NRR</p> <p>RES/NRR</p>	<p>NRR</p>

Description: The Reactor Pressure Vessel Head degradation event at the Davis Besse Nuclear Power Station has many safety implications. One concern is the integrity of the reactor coolant pressure boundary. This action plan was developed to improve some of the requirements intended to ensure an effective barrier to the release of radioactivity. This plan describes the required actions, establishes milestone schedules, identifies responsible parties, and estimates resource requirements.

Historical Background: In March 2002, while conducting inspections in response to Bulletin 2001-01, the Davis-Besse Nuclear Power Station identified three control rod drive mechanism (CRDM) nozzles with indications of axial cracking, which were through-wall, and resulted in reactor coolant pressure boundary leakage. During the nozzle repair activities, the licensee removed boric acid deposits from the RVH, and conducted a visual examination of the area, which identified a 7 inch by 4-to-5 inch cavity on the downhill side of nozzle 3, down to the stainless steel cladding. The extent of the damage indicated that it occurred over an extended period and that the licensee's programs to inspect the reactor pressure vessel (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 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 these recommendations. This action plan addresses the Group 4 recommendations of the Davis-Besse Lessons Learned Task Force Review Team regarding the Assessment of Barrier Integrity Requirements. The 6 high priority recommendations in the "Assessment of Barrier Integrity Requirements" grouping are included in this Action Plan. The LLTF recommendations are listed in the attached Table 1, and have been identified under the appropriate milestone(s).

Proposed Actions: The specific LLTF recommendations within this category are focused on reviewing and improving leakage detection requirements. However, simply improving leakage detection and lowering allowable leakage may not be sufficient to provide increased assurance of reactor coolant pressure boundary (RCPB) integrity. Leakage monitoring assumes that the pressure boundary will fail only under a leak-before-break (LBB) scenario. Small leak rates associated with tight stress corrosion cracks or cracks which may be partially plugged are not necessarily associated with small flaws in the RCPB. Therefore, the scope of this action plan also includes methods which may be capable of detecting crack initiation and monitoring crack growth before a through-wall crack develops and leakage occurs. Other degradation modes, such as boric acid corrosion and erosion-corrosion, which can lead to failure without leakage as a precursor will also be considered.

To support the decision for revising requirements, a comprehensive review and evaluation of plant experiences and current leakage detection systems will be performed. A similar study was performed by Argonne National Laboratory in the late 1980's. This task would essentially be to update that work. The technical bases for the current requirements on leak rates will also be reviewed. If changes should be made to leak rate limits, the impacts of these changes to other

plant systems and analyses need to be identified. An evaluation of state-of-the-art systems capable of detecting leaks and cracks will also be completed. This evaluation will include, but is not limited to, acoustic emission technology. An evaluation will also be done to determine if leak rates can be correlated to unacceptable levels of degradation. It should be noted that this evaluation will be more difficult for tight stress-corrosion cracks which typically have low leak rates. Results of these reviews and analyses will then be used to develop an updated basis for leak rate requirements. Once this basis is complete, recommendations will then be made for improving leak rate limits, plant alarm response procedures, TS, and inspection guidance. Then a determination will be made to select which recommendations should be imposed as new requirements. The appropriate regulatory tools and procedures will be used to develop and implement these new requirements. A regulatory analysis will probably be needed to help establish the appropriate leakage criteria. It may not be possible or practical to implement leakage requirements small enough to preclude failure. Therefore, a regulatory impact analysis will be necessary to establish appropriate risk-informed leakage limits.

In addition to the broad study described above, some other specific activities will be implemented. First, PWR TS will be reviewed to identify plants that have non-standard RCPB leakage requirements (based on current standard TS), and appropriate action will be taken to make TS consistent. Second, inspection guidance for evaluating plant alarm response procedures will be developed and the adequacy of licensee procedure requirements will be evaluated. Finally, inspection guidance will be developed to trigger increasing levels of NRC interaction with licensees in response to increasing levels of unidentified RCS leakage.

The second group of milestones relate to LLTF recommendation 3.3.3(3) regarding the review and improvement of barrier integrity performance indicators (PI). The NRC/Industry ROP Working Group will review the feasibility of establishing a PI that tracks the number, duration and rate of primary system leaks that have been identified but not corrected, as well as other possible PIs that could monitor RCPB leakage.

Completion of this action plan may require participation in public meetings and establishing communications with stakeholders. These items will be scheduled as needed.

A working group consisting of RES and NRR staff will evaluate the adequacy of risk analysis methods for passive component degradation, including how such analysis results could be incorporated into the regulatory decision making process.

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." [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." [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." [ML022740211]

Regulatory Assessment: The reactor coolant pressure boundary forms one of the 3 defense-in-depth barriers to the release of radioactive products. General Design Criteria 14, 30, and 32 of

Appendix A to 10 CFR Part 50 specify requirements for the reactor coolant pressure boundary.

- GDC 14 states in part that “[t]he reactor coolant pressure boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage.”
- GDC 30 states in part that “[m]eans shall be provided for detecting and, to the extent practical, identifying the location of the source of reactor coolant leakage.”
- GDC 32 states in part that “[c]omponents which are part of the reactor coolant pressure boundary shall be designed to permit periodic inspection and testing of important areas and features to assess their structural and leaktight integrity.”

In addition, the NRC has developed Regulatory Guide 1.45 “Reactor Coolant Pressure Boundary Leakage Detection Systems.”

From a practical standpoint, it was recognized that the RCPB cannot be made completely leaktight since some leakage is to be expected from equipment such as pump and valve seals. Therefore, it becomes important to identify the source of any leaks. Identified leaks, such as from valves or pump seals, should be measured, collected, and isolated so as not to interfere with detection of leakage from an unknown source which could indicate a breach of the RCPB. Specific limitations on leakage are stated in the Technical Specifications (TS) for each plant. In general, the TS place a limit on unidentified leakage (usually to 1 gpm) and state that continued operation with RCPB leakage is not allowed. In addition Title 10, Section 50.55a of the *Code of Federal Regulations* requires plants to meet the requirements of the ASME Boiler and Pressure Vessel Code. Section XI (Inservice Inspection of Nuclear Power Plant Components) of this code provides acceptance criteria for flaws found during inspection and evaluation procedures for determining the acceptability of flaws exceeding these standards.

Since the vessel head penetration (VHP) nozzles are considered part of the RCPB and significant degradation of the RPV head occurred at Davis-Besse, the issues raised by this event extend beyond problems of stress corrosion cracking in CRDM nozzles to issues of RCPB integrity in general. Primary water stress corrosion cracking of the VHP nozzles and their associated welds has been experienced by both U.S. and foreign plants. In addition, the degradation mechanism that occurred at Davis-Besse was also known. Therefore, one of the conclusions from the LLTF report was that this incident was preventable, but occurred because of a failure to follow-up and integrate relevant operating experience and other available information.

The TS for Davis Besse set a 1 gpm limit for unidentified leakage. In general, unidentified leakage was kept below 0.2 gpm. Despite this conservatism, the leakage eventually caused the degradation found in the vessel head. Therefore, the requirements associated with RCS leakage need to be reviewed and improved as warranted.

Current Status: To address the first milestone in Part I, NRR completed a review of PWR plant TS in July 2003 and identified plants with nonstandard RCS leakage requirements. The comparison of the PWRs to the STS identified two distinct levels of non-standard reactor coolant pressure boundary TS requirements: 1) units with no TS leakage limit requirement and, 2) units with a TS leakage limit but the TS Action requirements were non-standard.

Only one PWR plant did not have TS for reactor coolant pressure boundary leakage. This

licensee submitted a license amendment request to make its TS consistent with the improved STS, and the staff issued the amendment in May 2004. For the other PWR units, the action requirements and completion times when the TS limit is not met are not identical to the STS. However, these plants have a reactor coolant pressure boundary TS leakage limit that is equivalent to the STS, in that the plants will take appropriate conservative actions in the time frame specified in the STS. In addition, the TS for these plants are consistent with the requirements of 10 CFR 50.36(C)(2) in that the reactor must be shut down and plant cool down must be initiated. Therefore, the staff concluded that the TS are consistent among all plants and no additional actions are required.

The second milestone in Part I calls for an inspection of plant alarm response procedure requirements for leakage monitoring systems to assess whether they provide adequate guidance for identifying RCPB leakage. To address this recommendation, inspection guidance has been revised to verify that licensees have programs and processes in place to (1) monitor plant-specific instrumentation that could indicate potential RCS leakage, (2) meet existing requirements related to degraded or inoperable leakage detection instruments, (3) use an inventory balance check when there is unidentified leakage (4) takes appropriate corrective action for adverse trends in unidentified leak rates, and (5) pays particular attention to changes in unidentified leakage. The revised procedures include Inspection Manual Chapter 2515 Appendix D (Plant Status Review), Inspection Procedure 71111.22, and Inspection Procedure 71111.08. These revisions were issued in May 2004. The assessment of the adequacy of licensee procedure requirements was completed as part of the 2005 annual ROP self assessment process. The staff's review of inspection results and feedback from each Region regarding the implementation of these changes indicates that the licensees' alarm response procedures and operating procedures provide adequate guidance for the identification and corrective actions for reactor coolant system boundary leakage. No implementation issues or findings were identified in this area.

The third milestone is also addressed in the revision to IMC 2515, Appendix D. Inspectors are to monitor leakage for adverse trends and notify plant management and regional management if any are noted. Additional technical guidance, including a tool to determine statistically if a trend exists, was issued in January 2005.

The fourth milestone is being addressed by the Barrier Integrity Research Program that is being performed at the Argonne National Laboratory. The objective of this program is to reevaluate the technical basis for RCS leakage requirements. There are 3 main tasks associated with this effort. The first task is an assessment of the leakage associated with the degradation of various RCPB components. This includes a review of leak rate experiments and models to identify correlations between crack size and leak rate. A set of leak rate calculations are also being performed using an updated version of the Seepage Quantification of Upsets in Reactor Tubes (SQUIRT) code developed by the NRC. The second task is a review of leakage operating experience by developing a database of leakage events. The information in this database includes (1) leak location, (2) leak rate, (3) cause of leakage, (4) operation of reactor when leak was detected, and (5) action taken. The third task is an evaluation of the capabilities of various leakage detection systems. To date the systems that have been evaluated included acoustic emission, humidity detection, and localized airborne radioactivity monitoring. In addition, this task is evaluating the capabilities of acoustic emission systems to monitor and detect cracking in RCS components before leakage occurs. On March 24, 2004, a program review meeting was held at headquarters in which Argonne and its subcontractors presented interim results of this program to the staff.

At the end of May 2004, ANL provided a draft NUREG report on barrier integrity research. This draft report contains an updated review of RCS leak rate experiments and leak rate models and identifies correlations between crack size, crack opening displacement (COD), and leak rate. Although the focus of this work is on components susceptible to stress corrosion cracking (SCC), other types of materials and cracking mechanisms are considered.

A database was developed which identifies the number, source, rate, and resulting actions from RCS leaks discovered in U.S. LWRs. It describes for each incident what equipment detected the leakage, how it was determined that the leakage was through the pressure boundary, the cause of leakage, and comparisons with applicable leakage requirements. If the leakage was from a crack in the pressure boundary, the crack size, crack type, and measured leak rates are also described. For each incident the database notes what, if any, indications in identified or unidentified leakage were present (i.e., change in some measurement when the pressure boundary was breached).

The capabilities of each type of leakage detection system were evaluated to determine their sensitivity, reliability, response time, and accuracy. The scope of technology considered includes the state-of-the-art in this area, but was limited to technology that can be applied to the monitoring of RCPB conditions in U.S. LWRs. The evaluations also included crack monitoring systems capable of detecting crack initiation and growth. In addition, technology that can monitor or detect other (non-cracking) degradation modes such as boric acid corrosion or erosion/corrosion was studied. The sensitivity, reliability, response time, and accuracy of these systems, as well as the feasibility of using this technology in nuclear power plant applications have been considered. The systems, procedures, and equipment used in nuclear power plants of other countries to detect leakage were also evaluated.

The RES and NRR staff reviewed this draft report and provided comments for inclusion in the final report. The revised draft report was available for staff use in October 2004 and the final report was issued as NUREG/CR-6861, "Barrier Integrity Research Program: Final Report" (ML043580207) in December 2004.

A working group consisting of members from the Materials Engineering Branch in RES and the Plant Systems Branch and the Materials and Chemical Engineering Branch in NRR was formed to further evaluate the DBLLTF recommendations and NUREG/CR-6861. In evaluating the need for additional requirements pertaining to leakage detection, the staff considered past operating experience related to reactor coolant system integrity and the performance deficiencies that led to the degradation that occurred at Davis-Besse. The staff identified techniques that could improve localized leak detection and on-line monitoring and several areas of possible improvements to leakage detection requirements that could provide increased confidence that plants are not operated at power with reactor coolant pressure boundary leakage. However, implementing these increased capabilities would be expected to produce a very modest reduction in loss of coolant accident frequencies. As a result, it was the staff's judgment that the associated risk reduction that could be realized would not justify the costs to install and maintain such equipment (i.e., the cost-benefit criteria associated with implementation of the backfit rule (10 CFR 50.109) could not be satisfied). Item I.4.e is not required since no changes were recommended for currently operating facilities.

The Part II milestones regarding Performance Indicators have been revised to indicate more clearly that the response to LLTF 3.3.3(3) is continuation of the ongoing process of working with the industry to improve the Barrier Integrity PIs and to evaluate the feasibility of a PI that tracks the number, duration and rate of primary leaks that have been identified but not corrected.

The PI program is a voluntary program for the industry in that there are no regulatory requirements associated with the program. Changes to the program generally require consensus between the NRC staff and industry. To assess the feasibility of DBLLTF recommendation 3.3.3.3, the industry and NRC staff established a subgroup composed of three NRC staff and three industry representatives. In its discussions, the subgroup concluded that at present it is not feasible to track the number, duration, and rate of primary system leaks that have been identified but not corrected. This is due, in part, to the difficulty licensees have in determining small leak rates accurately, and, in part, to the quarterly data reporting, which makes it difficult for the staff to determine the number of leaks, the rate, and the duration. However, the staff will continue to follow progress in leak detection capability and industry efforts in this area.

The existing RCS Leakage PI already monitors identified leakage. The intent of the PI is to call attention to those plants that have identified primary system leaks but have not corrected them in a timely manner. As part of the effort to continue to improve usefulness of the barrier integrity PIs and the Reactor Oversight Process, the staff/industry working group agreed to have the subgroup explore possible improvements to the RCS leakage PI. The subgroup has met on a number of occasions and is currently interacting with the Westinghouse Owners Group to understand the efforts being undertaken by that group.

In summary, the staff assessed the feasibility of establishing the PI which tracks the number, duration, and rate of primary system leaks that have been identified but not corrected and determined that it is not feasible at this time. As part of the ongoing efforts to improve the Reactor Oversight Process and PI Program, the staff is working with its external stakeholders and has established a NRC staff/industry subgroup to explore and possibly improve the RCS Leakage PI.

Part III milestones were added to track completion of LLTF 3.3.7(3). A working group consisting of RES and NRR staff was formed to study the risk assessment methods related to passive component degradation, evaluate their adequacy, and write a white paper on this issue. The white paper was completed in March 2005. Recommendations were forwarded to management by May 2005. The WG report found that the available risk assessment models alone are usually inadequate to provide strong support for many types of decisions. The portions of the risk models that predict degradation rates and structural integrity effects, and the limited information about plant-specific conditions often make it difficult to make reliable predictions very far beyond the latest available measurements. However, the WG concluded that decisions made on the basis of a proper combination of inspection results and predictive modeling can be successfully used to adequately control the risk to the public. The steam generator tube integrity program that has recently been developed in cooperation with industry, is suggested as a model for success in other portions of the pressure boundary components that are important to safety.

The Division Directors agreed that the methods used to assess risk are adequate and data limitations need to be well understood. An understanding of the limitations and uncertainties is necessary to make the appropriate decision. Degradation issues are not unique with respect to the need for decision-makers to carefully consider the degree of uncertainty of and the level of confidence in the available information and analytical results. But, it is more difficult than usual to do so for degradation issues, because of the greater reliance on predictive models in place of empirical reliability data. Therefore, based on the WG findings, the evaluation required by DBLLTF 3.3.7(3) is complete.

Contacts:

RES Lead Contact: Andrea Lee, DET, 415-6696  
RES Lead PM: Maketuswara Srinivasan, DET, 415-6356  
RES Technical Contact: Donald Dube, OERAB, 415-5472  
NRR/DIPM Lead Contact: Roy Mathew, IIPB, 415-2965  
NRR/DLPM Lead Contact: Brendan Moroney, DLPM, 415-3974  
NRR/DE Lead Contact: William Bateman, DE, 415-2795

References:

NRC Bulletin 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles," August 3, 2001

Memorandum from Ledyard Marsh, Deputy Director Division of Licensing and Project Management, to John Grobe, Chair, Davis-Besse Reactor Oversight Panel, dated December 6, 2002, "Response to Request for Technical Assistance - Risk Assessment of Davis-Besse Reactor Head Degradation (TIA-2002-01)" [ML023330284]

10 CFR Part 50 Appendix A

NRC Regulatory Guide 1.45 "Reactor Coolant Pressure Boundary Leakage Detection Systems" NUREG/CR 4813, "Assessment of Leak Detection Systems for LWR's," May 1988, Argonne National Laboratory.