Charter of xLPR External Review Board

Background

Since 2008, the NRC and the commercial nuclear power industry (working under the auspices of EPRI) have been engaged in a project whose objective is to develop a probabilistic assessment methodology for use in assessing compliance with 10CFR50 Appendix A, General Design Criteria (GDC)-4. GDC-4 specifies that the *"probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping."* This requirement has traditionally been fulfilled by following the NRC's Standard Review Plan (SRP) 3.6.3. SRP 3.6.3 describes a deterministic procedure for leak-before-break (LBB) assessment. Also, it contains an entry requirement that no active degradation can be present in the systems approved for LBB. The discovery in 2000 that primary water stress corrosion cracking (PWSCC) is active within these piping systems called into question their compliance with GDC-4. Through a quantitative approach which includes the industry's inspection and PWSCC mitigation program the NRC has determined that these susceptible piping systems are presently in compliance with GDC-4. However, in the long term, a quantitative approach is required to demonstrate the continued compliance of these systems with GDC-4. As a consequence, the xLPR project was undertaken. A more detailed description of the xLPR project is provided as an attachment to this Charter.

Objectives

The objectives of the external review Board are to perform periodic oversight reviews of the xLPR project and to provide non-binding recommendations to the NRC concerning the following matters:

1. Assess whether the xLPR approach is adequate to meet the stated objectives of the project and whether the project work reflects a full understanding of the regulatory and industry needs.
2. Assess the organization and management adequacy of the xLPR project. Specifically:
    a. Are the qualifications and capabilities of the xLPR project staff appropriate to address all of the technical challenges identified for the project?
    b. Are the analytical resources, facilities, and laboratory equipment appropriate to address the technical challenges identified for the project?
    c. Are the program management, communications, quality assurance, and other project management practices adequate to ensure the success of the project?
3. Assess the technical adequacy of the xLPR project. Specifically:
    a. Is the engineering/scientific quality of the work comparable to the technical quality that exists in leading federal, university, and/or industrial research and development efforts?
    b. Does the xLPR project demonstrate a broad understanding of, and appropriate accounting for, the underlying scientific principles? Are these principles appropriately applied?
    c. Does the xLPR project demonstrate a broad understanding of, and appropriate accounting for, the realities and constraints imposed by nuclear power plant design and operation?
    d. Does the work performed employ an appropriate mix of theory, computation, and experimentation?
    e. Does the work performed include adequate and appropriate benchmarking of the analytical models to independent and rational metrics of truth?

Review Periodicity

Reviews are requested twice annually, with the first review requested in January 2013.

Review Board Members

The Board will be comprised of five members, as follows:

- EPRI manager or senior technical staff
- NRC manager or senior technical staff
- Risk assessment expert
- Large-scale computational expert
- Materials expert

To ensure the impartiality of the reviews performed by the xLPR External Review Board, the EPRI and NRC manager/staff positions shall not be in a management chain responsible for either (a) the practical motivation for performing the xLPR project, or (b) the staff working on the xLPR project. Additionally, the EPRI and NRC manager/staff positions shall be filled with individuals who possess technical expertise relevant to the xLPR project. The three technical experts shall not be EPRI or NRC staff, nor shall they be current contractors to the NRC or EPRI, or have provided contract support since January 1, 2009. Board members shall serve for two-year terms.

Format for Reviews

Reviews shall consist of one day of briefings provided to the Board by the following individuals:

- The xLPR Technical Leads
- The xLPR Project Manager
- The Computational Group Lead or Co-Lead
- The Models Group Lead or Co-Lead
- The Inputs Group Lead or Co-Lead
- The Acceptance Group Lead or Co-Lead

Read ahead material shall be provided to the xLPR External Review Board members no less than three weeks prior to each meeting. No less than one week prior to each meeting, the xLPR External Review Board members shall send the xLPR Technical Leads a list of any questions they want to have addressed during the meeting. The one day of briefings shall be followed by half-day sessions during which the xLPR External Review Board members may compare notes and begin to prepare their assessments.

The xLPR External Review Board's assessments and recommendations shall be made to the xLPR Project in an advisory sense only; addressing the Board's recommendations by the NRC is not mandatory. The Board's recommendations shall contain the consolidated views of the entire xLPR External Review Board; they may also contain the individual views of each xLPR External Review Board member if the Board views this as beneficial. Each recommendation made by the xLPR External Review Board shall be tied to a one of the Board's objectives, which are defined by this Charter.

The xLPR External Review Board's recommendations will be provided to each of the following individuals no less than two weeks following the conclusion of each review:

- xLPR Technical Leads
    - Dave Rudland, NRC
    - Craig Harrington, EPRI
- The Chairman of the Materials Subcommittee of the Advisory Committee on Reactor Safeguards (ACRS[1]).
- Chairman of the Materials Reliability Program Integration Committee (currently Mr. Tim Wells, Southern Company)

Responsibilities of xLPR External Review Board Members

The xLPR External Review Board Members shall:

1. Prepare for all meetings by reading the material provided in advance, and providing questions on critical issues in advance of the review.
2. Attending and participating in all reviews.
3. Providing output and assessment to the xLPR Technical Leads within two weeks of the conclusion of all meetings.

[1] The xLPR External Review Board's reviews will supplement the reviews performed by the ACRS, since other duties prevent the ACRS from following the xLPR project in a close and detailed manner.

Attachment – xLPR Project Overview

xLPR (Extremely Low Probability of Rupture) Project Background

Within the U.S. nuclear regulatory framework, the general design criteria (GDC) contained in Title 10 of the *Code of Federal Regulations* Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix A, "General Design Criteria for Nuclear Power Plants," are the cornerstones establishing basic design requirements that nuclear power facilities in the United States must meet. GDC 4, "Environmental and Dynamic Effects Design Bases," presents specific compliance challenges to the pressurized-water reactor (PWR) fleet with the requirement to protect against the local dynamic effects of pipe ruptures. These issues were generally resolved through a deterministic, analytical approach that has come to be known simply as leak-before-break (LBB). GDC 4 allows LBB through an addition to the text stating "dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping." NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition" (also known as the SRP), Section 3.6.3, "Leak-Before-Break Evaluation Procedures," describes deterministic LBB assessment methodologies that are acceptable to the staff of the U.S. Nuclear Regulatory Commission (NRC). SRP Section 3.6.3 also includes a key condition that the piping system not be subject to any known active degradation mechanisms. Exclusion of active degradation mechanisms is both a conservative simplifying assumption and an artifact of prevailing analytical capability limitations in the 1980s when these regulations were put in place.

LBB has generally been applied to select portions of the reactor coolant system piping in domestic PWRs. However, when the revision to GDC 4 was promulgated, intergranular stress corrosion cracking had already been identified as an active degradation mechanism of concern to boiling-water reactors (BWRs), and thus LBB has not been implemented within the BWR fleet. The more recent identification of primary water stress corrosion cracking (PWSCC) in PWR locations previously approved for LBB raises questions that now must be resolved. While industry and the NRC have taken appropriate actions to adequately ensure fleet safety relative to PWSCC for the intermediate term, a long term technical resolution is needed.

The prescribed LBB analytical methodologies are deterministic approaches to address a fundamentally probabilistic design requirement. Although the LBB technical basis is sound, the linkage between the deterministic analytical methodology and the probabilistic design criteria is not sufficiently robust to allow direct incorporation of rigorous analytical treatment of active degradation mechanism effects. The Electric Power Research Institute (EPRI) Materials Reliability Program (MRP) and the NRC Office of Nuclear Regulatory Research (RES) have therefore initiated a cooperative effort to take advantage of advances in analytical methods and computational capabilities to develop a new, more robust technical basis and analytical methodology to demonstrate and assess compliance with the "extremely low probability of rupture" standard. A project-specific addendum to the general memorandum of understanding for such cooperative research activities between the NRC and EPRI formally established this cooperative effort. Although initially focused on resolving the PWSCC challenge for PWRs, the intent of the Extremely Low Probability of Rupture (xLPR) project is to develop a fully probabilistic approach applicable to a range of active degradation mechanisms associated with both BWRs and PWRs. The resulting computer code will be comprehensive with respect to known materials degradation

challenges, vetted with respect to the scientific adequacy of models and inputs, flexible enough to permit analysis of a variety of in-service situations, and sufficiently adaptable to accommodate evolving and improving knowledge.

xLPR Project Objective

The overall objective of the xLPR project is to develop a probabilistic assessment tool that can be used to *quantitatively* assess compliance of nuclear power plant primary water piping systems with 10CFR50 App-A GDC-4 requirements relating to piping failure probabilities in a manner that is consistent with NRC Commission policy guidance on risk-informed decision making and regulation.

xLPR Project Scope

A joint EPRI - NRC program has been developed to address the issue of assessing pipe rupture probability accounting for active degradation mechanisms and mitigation/inspection activities. The long-term goal of this project is to develop a probabilistic assessment tool that can be used to *directly* assess compliance with 10CFR50 Appendix-A, GDC-4 by properly modeling the effects of both active degradation mechanisms and of the mitigation/inspection activities. This tool will be comprehensive with respect to known challenges, vetted with respect to scientific adequacy of models and inputs, flexible enough to permit analysis of a variety of in-service situations, and adaptable so as to accommodate evolving and improving knowledge. This large-scale probabilistic tool will provide a much more effective way of assessing pipe safety given the uncertainty involved with PWSCC crack initiation and growth mechanisms than does the deterministic assessment method currently in use. The challenge in developing such a tool is to ensure that it incorporates the best available models required to address the expected degradation and mitigation mechanisms, and links these models together appropriately to provide accurate information flow and account for model and input value uncertainty propagation throughout the code. A further program goal is to develop a code that will be flexible enough to incorporate model updates and improvements, as well as assessment of a range of materials, degradation mechanisms and pipe geometries.

There are many challenges in the conduct of such an encompassing project. Therefore, to manage the associated risk, a pilot study was conducted to assess the feasibility of the approach. Conducting this smaller, focused study using models and component/material information that were readily available enabled the proposed code development and project management process to be exercised and evaluated. Analysis of the pressurizer surge nozzle dissimilar metal weld, focusing on PWSCC degradation mechanisms, was chosen because work had recently been completed on assessment of PWSCC sensitivity of this weld in nine plants and this work was publicly available. The Pilot Study had three goals:

- Assess the proposed management structure's ability to support cooperative and efficient code development and implementation;
- Assess the feasibility of developing a modular-based probabilistic fracture mechanics computer code that can calculate the probability of rupture for a reactor coolant nozzle weld while properly accounting for the problem uncertainties; and

- Determine the appropriate probabilistic framework for constructing the modular-based probabilistic fracture mechanics code.

The results of the pilot study demonstrated that the cooperative management structure was sufficient for the development of a complex probabilistic computer code; however, some slight changes to the structure were recommended to help improve efficiency and communication. Also, the complete xLPR Pilot Study effort, which included not only the code development efforts, but the management structure, the pilot study problem statement, and the detailed analysis of the results, demonstrated that it is feasible to develop a modular-based computer code for the determination of probability of rupture for LBB approved piping systems. Finally, based on an independent comparison between GoldSim and SIAM, a cost analysis, and the long-term prospects of the software, the xLPR project team recommended that the future versions of xLPR be developed using the GoldSim commercial software as the computational framework.

Building on the successes of the pilot study, xLPR Version 2 develop has begun that will take lessons learned from the pilot study, and expand the xLPR code to be applicable to all piping systems currently approved for LBB. xLPR Version 2.0 will be developed under the same management structure as Version 1, but with slight updates to aid in the efficiency and communication of the group. This version of xLPR is being developed under a QA Program that is based on 10 CFR Part 50 Appendix B, *Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants.* In addition, NRC Regulatory Guide 1.28, Revision 4, *Quality Assurance Program Criteria (Design and Construction)* is referenced as a basis and it in turn endorses the use of ASME NQA-1-2008 with the ASME NQA-1a-2009 Addenda, *Quality Assurance Requirements for Nuclear Facility Applications,* as an adequate basis for complying with the requirements of 10 CFR Part 50 Appendix B.

xLPR Project Structure

Successful conduct of a program involving a complex and diverse array of technical specialties requires a well organized and structured team of technical experts. A large team of industry and NRC technical experts, with knowledge in the areas of plant design, component geometry, environment and loading, flaw inspection and assessment, degradation modeling, critical flaw stability and detectible leak modeling, code development, acceptance criteria development, and program management, has been assembled under the structure of an EPRI – NRC Memorandum of Understanding (MoU). The technical experts assembled to work on this project are divided into several task groups, organized around four strategic technical areas:

- **The Computational Group**, responsible for developing the framework of the large, probabilistic code,
- **The Models Group**, responsible for identifying or developing all of the models that must be incorporated into the framework to predict probability of pipe degradation/rupture/leakage accounting for all expected degradation mechanisms
- **The Inputs Group**, responsible for obtaining all plant input information to the models
- **The Acceptance Criteria Group**, responsible for identifying the acceptance goal for pipe rupture probability.
- **The Quality Assurance Administration Group,** responsible for preparing and maintaining the QA planning documents and all supporting implementing documents, for coordinating, defining and

controlling the program and module development revision levels and for managing the xLPR Subversion repository as the project's configuration management system.

Additionally, the Project Integration Board (PIB.), comprised of five senior technical members, fulfills the role of an internal review board providing broad, routine oversight and consultation to the Project Management team.

xLPR Project Timeframe

The xLPR project was initiated as a cooperative effort involving both the NRC and the commercial nuclear power industry, working under the auspices of EPRI and under the umbrella of a MOU, in early 2008. The first comprehensive milestone of the project was achieved in 2011 with the completion of the Pilot Study. It is currently planned to release Version 2 of xLPR at the end of 2013.