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May 29, 2020

MEMORANDUM TO: Raj M. Iyengar, Chief
Component Integrity Branch
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Office of Nuclear Regulatory Research

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SUBJECT: SUMMARY OF THE APRIL 23, 2020, RES CATEGORY 3 PUBLIC MEETING WITH EPRI AND STAKEHOLDERS TO DISCUSS PUBLIC RELEASE OF THE XLPR PROBABILISTIC FRACTURE MECHANICS CODE

The U.S. Nuclear Regulatory Commission (NRC) staff from the Office of Nuclear Regulatory Research (RES) held a meeting on April 23, 2020, with representatives of the Electric Power Research Institute (EPRI) to present the Extremely Low Probability of Rupture (xLPR) Version 2 (V2) code and inform stakeholders of its pending public release.

The agenda and slide presentations for the meeting are available in the NRC's Agencywide Documents Access and Management System (ADAMS) under Accession Numbers ML20097E522 and ML20119A463, respectively. Enclosed are a list of the meeting participants and responses to questions asked by stakeholders at the meeting. Additionally, a video recording of the meeting is available at https://youtu.be/McVVFriy7wQ.

A summary of the meeting's discussions follows by agenda topic.

1. Introduction and Opening Remarks

   The NRC staff welcomed the participants and covered administrative items for the meeting. Senior managers from the NRC and EPRI then delivered opening remarks. They highlighted the significance of xLPR V2 to both organizations as a risk-informed decisionmaking tool. They also reflected on how the NRC and EPRI developed the code cooperatively while leveraging leading experts from industry, government, and the commercial sectors. Additionally, they emphasized xLPR V2's flexibility and transparency and that it was built following modern software design concepts under the framework of a robust quality assurance program. They highlighted the NRC and EPRI

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plans to soon make the code available to regulators, industry, and researchers in the U.S. and internationally, and encouraged stakeholders to become active users of the code.

2. Program History and Perspectives

A representative from EPRI provided an overview of the xLPR code's history. He explained that RES bore the concept of a flexible, probabilistic fracture mechanics platform with a modular structure to accommodate analyses for a range of reactor coolant pressure boundary integrity problems. The initial focus was then directed to piping components and to resolving questions involving primary water stress-corrosion cracking (PWSCC) in dissimilar metal welds and its associated impacts on prior leak-before-break analyses. RES partnered with EPRI to share resources and funding, and a pilot study was initiated to answer key technical and organizational questions. The pilot study resulted in xLPR Version 1. It served as a proof-of-concept and was used to guide the xLPR V2 development.

Building on successful completion of the pilot study and the resulting lessons learned, RES and EPRI then launched into development of xLPR V2. This effort involved approximately 75 subject matter experts from the NRC, EPRI, U.S. national research laboratories, and several commercial companies to ensure a well-vetted product that reflected a diversity of technical knowledge. Like in the pilot study, RES and EPRI jointly managed the project, co-funded it in roughly equal shares without co-mingling funds, and independently contributed appropriate subject matter experts. Code development occurred under a quality assurance program meeting certain criteria from Title 10 of the Code of Federal Regulations, Part 50, Appendix B, to ensure a well-documented, high-quality product and to facilitate future industry use in licensing submittals. Internal and external review groups were involved in the xLPR V2 development effort to build additional confidence.

Following presentation of the code development history, select NRC staff and EPRI personnel provided their perspectives. The NRC staff reflected on the value of the technical collaboration that had occurred among the development team members. The EPRI personnel emphasized the value in the code's transparency. That, with ready understanding of the software tool itself, focus can be better placed on the results from its applications.

3. xLPR Version 2 Code Overview and Features

The NRC staff provided an overview of the xLPR V2 code structure and key features. It first highlighted how probabilistic methods, such as those employed in xLPR V2, differ from traditional deterministic approaches. The NRC staff then described the basic piping component geometries and physical models used in the code. xLPR V2 can model both PWSCC and fatigue degradation mechanisms from crack initiation to crack growth and subsequent rupture in both the axial and circumferential directions. xLPR V2 can also model a variety of ways in which plant operators might mitigate cracking using physical and chemical techniques. Additionally, xLPR V2 can simulate the detection of cracks through inservice inspections and leak rate monitoring.

Next, the NRC staff depicted the modular structure of the code. A central computational framework serves as the user interface, controls the simulation, and calls various deterministic modules that perform the calculations necessary to simulate crack initiation, growth, rupture, and detection. The NRC staff explained that the computational framework is run using GoldSim, which is a commercially available Monte Carlo simulation software. The probabilistic features of xLPR V2 were then covered. The code uses a dual-loop sampling structure to handle both aleatory and epistemic uncertainties. It allows the user to select from numerous probability distributions when defining inputs, and it has advanced sampling algorithms, such as Latin hypercube sampling and importance sampling, to make simulations more efficient. The NRC staff also explained the basic output of the code, which includes time histories (i.e., cumulative probability vs. plant operating time) of metrics such as occurrence of cracks, leaks, and ruptures.

4. Code Demonstration

The NRC staff delivered a live demonstration of some of the key xLPR V2 features and capabilities. The demonstration showed:

- the basic organization and range of available input variables and settings recorded in a spreadsheet format
- the graphical user interfaces (i.e., spreadsheet and Sim Editor software) and how they can be used to change inputs and access the input databases
- how to run a simulation and monitor its progress using the free GoldSim Player
- how to check for potential errors in the simulation
- how to view example simulation results, including general statistics, specific realizations, and properties for specific cracks (e.g., crack depth vs. plant operating time time).
- how to view results in tabular format and extract for further analysis in a spreadsheet tool or other application
- how to use GoldSim to graphically show and quickly navigate through the details of the computational model

5. Code Applications

The NRC staff and EPRI personnel described areas of current and potential future code applications.

The NRC and EPRI are currently using the code to analyze the effects of PWSCC in leak-before-break analyses. The NRC staff compared deterministic and probabilistic approaches to conducting such analyses and showed how results from xLPR V2 can be used to quantify how conservatisms affect the outcome of the analysis. The EPRI personnel described how it harnessed the inherent flexibility in xLPR V2 to generate several additional results not directly calculated by the code for studying leak-before-break probabilistically. Rather than modifying the source code, it explained how it developed third-party software to automate the extraction of data and expand on the

code's post-processing capabilities. It noted that such an approach can also be used to facilitate increased realization counts for evaluation of lower probability events.

EPRI personnel then highlighted several areas it is currently investigating for potential future xLPR V2 applications. Examples include:

- optimization of inspection and repair/replacement strategies
- re-definition of the design-basis break size
- licensing of high-burnup and high-enrichment core designs
- high-energy line break postulation
- changes to how balance-of-plant systems are maintained or inspected due to better understanding of loss-of-coolant accident frequencies

Thus, it was emphasized that xLPR V2 has many applications beyond performing probabilistic leak-before-break analyses.

6. Process for Requesting a Copy of the Code

An EPRI representative stated that xLPR Version 2.1 will be available for request from the NRC and EPRI public Web sites beginning on May 28, 2020. He provided an overview of the request process, summarized eligibility requirements, and stated that prospective users will be required to sign an End User License Agreement. Supporting software requirements were also highlighted. To run the code, users will need a Microsoft Windows 10 operating system, Microsoft Excel 365 32-bit, and either GoldSim Player or GoldSim Pro, Version 11.1.7. The GoldSim Player is free to download, whereas GoldSim Pro requires the purchase of a license but offers more features. Both are available at www.goldsim.com.

The initial public release will include the xLPR Version 2.1 executable software, user manual, input databases, and training materials. In the longer-term, the NRC staff and EPRI plan to organize an xLPR user group. Membership in the user group will be fee-based and include access to additional materials, including the source code, full maintenance and software quality assurance documentation, and other benefits.

7. Future Training Series

The NRC staff stated that a series of additional webinars will be held to supplement the training materials that will be included with xLPR V2:

- June 3, 2020 – Technical seminar to provide more in-depth information about the code and its various physical models.
- Week of June 15th – User training on setting up inputs for the code.
- Week of June 29th – User training on running simulations with the code.
- Week of July 13th – User training on accessing and understanding results output by the code.

The user training sessions are planned to include demonstrations on key features of the code, useful hints and tips, and time for news users to interact directly with and have questions answered by experienced users and code developers.

The NRC staff encouraged stakeholders to participate in these events as they will provide additional opportunities to learn about the code and its proper use. Formal announcements for these events will be sent in the future.

8. Questions and Answers

As an NRC Category 3 public meeting, stakeholders had the opportunity to participate by providing comments and asking questions throughout the meeting. This participation was facilitated through the electronic submission of questions and comments using the chat feature of the virtual platform used to host the meeting. All questions and comments and the associated responses are available in the enclosure.

9. Closing Remarks

The NRC staff concluded the meeting by providing a recap of the presentations. Participants were thanked for their time and encouraged to submit any future questions or comments concerning xLPR V2 to the NRC staff at xlpr@nrc.gov and to the EPRI staff at xlpr@epri.com.

The NRC staff provided EPRI with an opportunity to review a draft of this meeting summary. EPRI comments were incorporated as appropriate.

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Enclosure:
As stated

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