Initial Development of the Extremely Low Probability of Rupture (xLPR) Version 2.0 Code

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Introductory Note



- This work is a continuation of the results presented at last year's PVP conference (PVP2012-57531)
- Final Pilot Study NRC/EPRI document has been published
 - xLPR Pilot Study Report. U.S. NRC-RES, Washington, DC, and EPRI, Palo Alto, CA: NUREG-2110 and EPRI 1022860. 2012.

GDC-4 and LBB



- 10CFR50 Appendix A GDC-4 allows local dynamic effects of pipe ruptures to be excluded from design basis if pipe ruptures have extremely low probability of occurrence
- Local dynamic effects include pipe whipping and discharging fluids
- Commission-approved conservative flaw tolerance analyses developed and incorporated in SRP3.6.3 to demonstrate leak-before-break (LBB) and satisfy GDC-4
- One screening criterion in SRP3.6.3 requires no active degradation mechanism

xLPR Problem / Motivation



- LBB approved for piping systems prior to PWSCC operational experience
- LBB systems still in compliance with regulations
- Qualitative: mitigations and inspections
- Quantitative: probabilistic evaluation to assess compliance



xLPR Development



- NRC goal to develop "modular" code for evaluating the risk of pressure boundary integrity failure
- Currently focusing on piping issues
 - LBB
 - May be applicable to other needs
- Working cooperatively with EPRI through Memorandum of Understanding addendum
- Initial pilot study to assess effectiveness of approach



Code Development Team Members

U.S.NRC United States Nuclear Regulatory Commission

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Code Development Leads

David Rudland - USNRC Craig Harrington - EPRI

Computational Group

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Inputs Group

Guy DeBoo – Exelon Gary Stevens – U.S. NRC Craig Harrington – EPRI Ashok Nana – AREVA NP Inc. Nathan Palm - Westinghouse

Program Integration Board

Denny Weakland - Ironwood Consulting Bruce Bishop – Westinghouse Rob Tregoning – U.S. NRC Bob Hardies - U.S. NRC Ted Sullivan – PNNL

Models Group Marjorie Erickson – PEAI Raj lyengar- U.S. NRC David Rudland - U.S. NRC Howard Rathbun – U.S. NRC Gary Stevens - U.S. NRC Carol Nove - U.S. NRC Mark Kirk – U.S. NRC John Broussard - Dominion Engineering Glenn White – Dominion Engineering Chuck Marks – Dominion Engineering Do-Jun Shim – Emc2 Flizabeth Kurth – Fmc2 Bud Brust – Emc2 Sean Yin - Oak Ridge National Laboratory Richard Bass - Oak Ridge National Laboratory Cliff Lange - Structural Integrity Associates Dave Harris - Structural Integrity Associates Steven Xu – Kinetrics Doug Scarth – Kinetrics Russ Cipolla – Aptech Mike Hill - UC Davis Steve Fyfitch - AREVA NP Inc. Ashok Nana – AREVA NP Inc. Rick Olson – Battelle Andrew Cox – Battelle Lee Fredette – Battelle Bruce Young - Battelle Craig Harrington – EPRI Patrick Heasler – PNNL Bruce Bishop – Westinghouse Mark Dennis - EPRI George Connolly - EPRI



through Memorandum of Understanding



Models described in detail in PVP2010-25681

xLPR Framework





Fully Open SourceGoldSim Commercial Code

Two framework structures considered in pilot study Framework code discussed in PVP2010-25963

Pilot Study Results





Lessons:

- Management structure needs some work
- CM only a small portion of
- **Best-estimate models are** required

2.6E-06

3.2E-06

 Classification of uncertainty very important

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Pilot Study Results



- The project team demonstrated that <u>it is feasible</u> to develop a modular-based probabilistic fracture mechanics code within a cooperative agreement while properly accounting for the problem uncertainties.
- The project team demonstrated that the cooperative management structure was promising, but recommends slight restructuring.
- The GoldSim commercial software will be used for future xLPR versions.



xLPR Version 2.0 Scope



- xLPR Version 1.0 was developed as part of a feasibility study and focuses on PWSCC in a Westinghouse-style pressurizer surge nozzle DM weld
- Version 2.0 is being expanded to handle welds within piping systems approved for LBB
- Capabilities of Version 2.0 will meet requirements for LBB lines, but <u>must stay</u> within available cost and schedule limitations
- Model inclusion in xLPR Version 2.0 does not guarantee regulatory approval. Process for obtaining approval of xLPR models is under discussion

Version 2.0 Scope "Modifications"



- Framework
 - Investigate advanced methodologies to improve sampling efficiency and solution accuracy
 - Adaptive Sampling
 - Revisit uncertainty propagation methodology
 - Modify GoldSim for additional user capability
- Models
 - Revisit PWSCC initiation Expert panel
 - Update WRS model more generic, better uncertainty
 - Piece-wise linear representation
 - Update K-solution to be consistent with updated WRS model
 - Universal weight function method

Red font represents high priority items

Version 2.0 Scope "Modifications"



- Models
 - Update mitigation to include FSWOL,OWOL, Inlay, surface treatment, and other chemistry
 - Update ISI model sizing, POD, simplified model
 - Update crack stability Surface crack EPFM
 - Update leak rate model Look-up table, SQuIRT,
 - Update COD tension and bending blended solution.
- Inputs
 - Update load definition to include transients
 - Retrieve all relevant data for
 - One reactor coolant loop Westinghouse PWR
 - One reactor coolant loop Babcock & Wilcox (B&W) PWR
 - Others may be considered

Version 2.0 Scope "Additions"



- Framework
 - Microsoft Access dB for inputs
 - Pre-processor to condition inputs
- Models
 - Environmental fatigue
 - Axial cracks
 - IGSCC
 - Surface crack-to-through wall crack transition
 - Manufacturing defects

xLPR QA



- Version 1.0 development was controlled by a Configuration Management plan but not associated with a detailed QA structure
- Conducted QA workshop with diverse group of Regulatory/Industry QA experts
- Consensus agreement that the top level requirements in ASME NQA-1 are sufficient to meet xLPR program, NRC, Industry, and DOE requirements for software development and regulatory use
- QA audits will occur and be aligned with key milestones



Version 2.0 Schedule



ID Task Name 2011 2012 2013 2014 Qtr 1 Qtr 2 Qtr 3 Qtr 4 Qtr 1 Qtr 2 Qtr 3 Qtr 4 Qtr 1 Qtr 2 Qtr 3 Qtr 4 Qtr 1 1 2 **QA** Documentation Development 3 Software Project Management Plan Models /Inputs 4 Software Quality Assurance Plan 5 Software Configuration Management Plan Implement CM system 6 development 7 QA Work plan 8 Completion of QA documentation 0 9 Structure and scope discussion 10 Selection of new models complete early 2013 11 Selection of models to revise 12 Discussion of major framework issues 13 Version 2 model selection finalized 14 Models Group Effort 15 Models Group Work plan 16 Models Selection and update 17 Model technical development 18 Model implementation into DLL 19 Model implementation complete 0 20 Inputs Group Effort Code release 21 Inputs Group Work plan 22 **Revisit Version 1 inputs** 23 Determination of Inputs end 2013 24 Development of input data 25 Development of input database 26 Input determination complete 27 **Computational Group Effort** 28 Computational Group work plan 29 **Revisit Version 1.0 Issues** 30 Framework Development 31 **DLL** implementation 32 Version 2 beta complete 33 Code V&V 34 Code release 35 **PIB Review Meeting** 0 0 41 **ACRS** Meeting 45 0 External review 0 Task Rolled Up Task External Tasks Progress Rolled Up Milestone 🔷 Project Summary Project: xLPR Version 2 Date: Tue 8/16/11 Milestone 0 Rolled Up Progress Group By Summary \bigtriangledown Summary Split Deadline J Page 1

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