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Swedish Radiation Safety Authority

On the Use of Probabilistic Methods and PFM for Regulatory Applications in Sweden

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Outline

- Situations when probabilistic methods and PFM are used to support regulatory decisions in Sweden.
  - LBB applications
  - RI-ISI
  - Analyzing service-induced damages for continued operation of mechanical components
  - Periodic Safety Reviews
- How to gain confidence in PFM results.

The new Regulatory Code SSMFS 20XX:YY for Analysis of Radiation Safety of Nuclear Power Plants (under development)

About pipe ruptures

The most challenging pipe ruptures shall be postulated as design basis accidents regarding core cooling and reactor isolation.

However, if the occurrence frequency with high confidence can be shown to be considerably lower than 1E-6 per year, then such pipe ruptures can be postulated as design extension conditions (DEC). An example of such situation is when LBB can be demonstrated.

Probabilistic insights for LBB

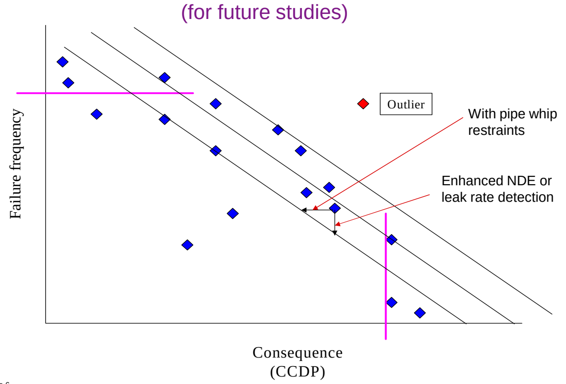
- Probabilistic analyses may strengthen the assessment that there is a sufficiently low probability for a pipe rupture and that there is a sufficient margin between initial detectable leak and break.
- SSM has financed a project in Sweden called ProLBB. In this project the deterministic criteria used in the LBB guidelines (NUREG/CR-6765) are compared with a probabilistic analysis.
- A probabilistic analysis should be able to demonstrate that the frequency of a pipe break is so low that it can be considered as a residual risk.
- The resulting SKI Report 2007:43 can be downloaded from: http://www.stralsakerhetsmyndigheten.se/Global/Publikationer/Rapport/Sakerhet-vid-karnkraftverken/2007/SKI-rapp-2007-43.pdf

Further studies on LBB

- Investigate the possibility to develop a risk-informed LBB-concept. The consequences of a pipe break with and without pipe whip restraints can be estimated with PRA and changes in failure frequencies can be estimated from enhanced NDE and/or enhanced leak rate detection. Possibly, these measures can be shown to be equivalent.

- Investigate the possibility to develop a probabilistic LBB-concept based on acceptance criteria for a low p_{break} and for a sufficiently low p_{break}/p_{leak}. Such a concept may perhaps also be applied for piping with degradation mechanisms together with mitigating actions.

Risk-informed LBB-concept (for future studies)



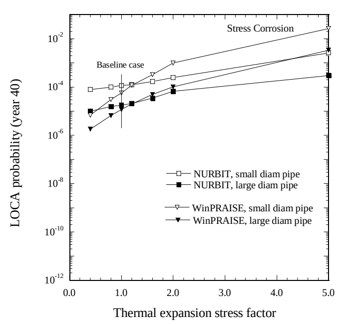
NURBIM = NUclear Risk Based Inspection Methodology for passive components

- EU-funded project, budget 1.2 million Euro
- Duration: November 2001 to July 2004
- 12 participating organisations from 8 European countries: Sweden, Germany, France, UK, Netherlands, Spain, Czech Republic and Finland
- Presented at the ASME PVP in San Diego, 2004 by Brickstad et al

Objectives of NURBIM

- Review PFM models and associated software in terms of main features, capabilities and limitations.
- Benchmark PFM models and associated software for SCC and fatigue by performing a comprehensive sensitivity study and compare results.
- Investigate the reasons for differences in results from the benchmark studies and identify strengths and weaknesses of the PFM codes.
- Issue recommendations for how to verify and validate PFM models and associated software.

Example of NURBIM results



- Are the PFM codes generating a wide range of failure probabilities (1E-10 to 1)?
- Is the result consistent with expectations?
- Expected risk ranking between different pipe sizes and using different PFM codes?
- For differences in behaviour, there should exist a justified PFM theory explanation.

About service-induced damages in Swedish NPPs, Swedish Regulations SSMFS 2008:13, Chapter 2, § 6

"A device where damages have been detected, may be kept for continued operation, without repair or replacement, when it has been demonstrated that sufficient safety margins exist against failure and such leakages and other deficiencies which can influence the safety during the operation period in question."

- Deterministic analyses are usually performed to demonstrate sufficient safety margins. In these analyses, the R6 Failure Assessment Diagram is recommended with safety margins comparable to ASME XI.

- SSM recognizes that probabilistic analyses can be a valuable complement to deterministic evaluations in order to make a better decision regarding the safety of a damaged reactor component.

Regulatory aspects on Periodic Safety Reviews (PSR)

- A PSR shall be done by the licensees every 10 years in Sweden.
- The PSR demonstration shall take into account the latest developments in Science and Technology.
- For demonstration of sufficient structural integrity of the RPV with respect to neutron embrittlement, SSM has recommended that NPPs shall perform both a deterministic and a probabilistic analysis.
- The probabilistic analysis based on PFM should confirm that the failure frequency is small enough not to contribute significantly to the total CDF of the plant.

How to gain confidence in PFM results

- SSM requires that models and computer codes used for PFM shall be sufficiently verified and validated.
- SSM recommends to use the results from NURBIM.

Recommendations from the NURBIM project

1. The PFM theory and technical basis should be published and independently reviewed.

2. A sensitivity study using the PFM and the associated software should be presented where failure probabilities for events varying from small leaks to ruptures, should be evaluated for variations of input parameters and shown to be consistent with expectations and the given PFM theory assumptions.

3. Sample calculations of the PFM code should be presented where the assigned input parameters should be described and sources of the data assignments should be given. The probability distributions and internally assigned (hardwired) parameters (if any) in the PFM code should be documented and the reasons stated.

4. The PFM code should be benchmarked against at least one other publically available PFM code for the relevant damage mechanism under consideration. The report of this benchmark study should be published and independently reviewed.

5. The PFM code should be benchmarked against operating experience using actual plant failure frequencies. For damage mechanisms where no ruptures have occurred, leak frequencies may be used for the comparison.

6. The used software should be clearly identified. It is desired that new information or better modeling assumptions should be continuously incorporated into the PFM code so that the generated results may reflect the best current knowledge.