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Development of a Reliability Data Handbook for Piping Components in Nordic Nuclear Power Plants – Part II

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Presentation outline

- Background
- Project status
- Result from Pilot Study – Technical Requirements of the R-Book
- Example of results from Phase II
- Conclusion

Background – History

- **Project history**
  - In 1994 the Swedish Nuclear Inspectorate (SKI) funded a 5 year R&D project with objective to:
    - Investigate possibilities for deriving pipe failure rates and rupture probabilities from service experience as an alternative to probabilistic fracture mechanics
  - Pilot project for LOCA frequencies (SKI Report 98:30)
  - The pipe failure database was transferred to OECD Nuclear Energy Agency
    - **OECD Pipe Failure Data Exchange Project (OPDE)** (www.nea.fr/html/jointproj/opde.html)

Background – OPDE

- **Objectives of OECD Pipe Failure Data Exchange Project (OPDE)**
  - Collect and analyze piping failure event data to facilitate:
    - understanding of **underlying causes**, impact on operations and safety, and prevention
    - establish a mechanism for efficient **feedback**
  - Collect information on piping reliability attributes and influence factors to facilitate estimation of piping failure frequencies
- **Current project participants (12 countries – 19 organizations)**

Belgium	**Canada**	**Czech Republic**	**Finland**
France	**Germany**	**Japan**	**Republic of Korea**
Spain	**Sweden**	**Switzerland**	**United States**

- **OPDE Database (Dec 2007)**
  - 7,385 reactor critical years; 3,755 failure events from 1970 up to date

Project status – Pilot study

- **Presented at PSAM-8 (paper 0063)**
- **Completed during end of 2007 and documented in SKI Report 2008:01**
  - available on the Internet at www.ski.se.
- **Scope included in SKI Report 2008:01:**
  - Review existing pipe failure databases
  - Review of methods for estimation of piping reliability parameters
  - Establishment of user requirements concerning
    - Content
    - Level of detail
    - Updating philosophy
  - For a complete list of requirements refer to SKI Report 2008:01.

Result from Pilot Study – Technical Requirements of the R-Book

- **Applicability and level of detail**
  - Main purpose of the R-Book will be to provide data for PSA
    - Priority is to develop a first issue as soon as possible and therefore the information will be limited to “PSA input data”.
  - The R-Book will provide tabulations of failure rates for an initial defect for different systems organized by pipe size and material
  - Conditional probabilities of different leakage threshold values will be calculated for each initial defect
    - method described in ASME conference paper PVP2007-26281

⇒ frequencies for different leakage threshold values

Result from Pilot Study – Technical Requirements of the R-Book

- **Applicability and level of detail (cont)**
  - In order to have significant statistical material both Nordic and International service data will be used and presented
    - Variability in counts of degradation and failures can normally be explained by differences in:
      - Reporting criteria
      - Design
      - Fabrication
      - Inspection practices
      - Difference in degradation susceptibility (ISI, mitigation, material selections)
    - Completeness
  - The R-Book will contain “recommended” pipe failure rates as well as enough qualitative and quantitative information to allow the user to further data specialization.

Result from Pilot Study – Technical Requirements of the R-Book

- **Traceability**
  - Data will be extracted from the OPDE database using queries in Microsoft® Access, each query will be given a unique ID and referenced in appendix to the R-Book.
    - Together with OPDE database version all failure counts can be reproduced
  - In OPDE the quality assurance of each event is shown with a Completeness Index (CI = 1, 2, 3) where CI=1, 2 means that verification of the specific event is satisfactorily to be included in the R-Book.
    - In case an event with CI=3 have been verified with respect to flaw and degradation mechanism it may be included as well – needs to be documented.

Result from Pilot Study – Technical Requirements of the R-Book

- **Parameters to be presented**

λ_{ik}	Frequency for an initial defect (calculated)
P_{ik}	Conditional probability for a leak consequence given the initial defect (calculated)
n_{ik}	Number of events (result from query)
f_{ik}	Portion of the total piping component population in a system that is susceptible to certain degradation or damage mechanism (based on OPDE and RI-ISI Degradation Mechanism Assessments)
N_i	Number of piping components in population (results from query)
T_i	Exposure time, based on number of reactor years (from plant population database)

Result from Pilot Study – Technical Requirements of the R-Book

- **Impact of power uprate and modernization projects**
  - For each plant system addressed in the R-Book relevant qualitative service experience information will be presented.

Table 3.2: Scope of R-Book

Plant System – e.g., BWR 313		Event History (Failure Count)			
Degradation Mechanism (DM#)		**1970-1979**	**1980-1989**	**1990-1999**	**2000-2007**
DM1	Worldwide				
	Nordic				
DM2	Worldwide				
	Nordic				
DM3	Worldwide				
	Nordic				
DM4	Worldwide				
	Nordic				

Notes:
a – Mitigation program
b – Water chemistry
c – Material (e.g., typical types, material compositions)
d – Ageing effects (including effects of power uprate projects)
e – Non-destructive examination (NDE)

Result from Pilot Study – Technical Requirements of the R-Book

- **Impact of Human Error**
  - In order for the user to be able to choose between if pipe failure due to humans error should be included or not the R-Book need to reflect the influence of human error for each system.
  - OPDE contains a “damage mechanism” that is attributed D&C – Design & Construction Errors/Defects. In OPDE “human error” is a subset of D&C which only applies to failures of small bore piping being damaged by maintenance personnel.
  - In the R-Book a format is therefore necessary for presenting the role of “human error”, if any.

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Project status – Scope of Phase II

- **For some selected systems qualitative and quantitative data will be developed to demonstrate R-Book:**
  - Content
  - Design
  - Methods
- **A seminar will be held at June 18 with representatives Nordic utilities and SKI.**
  - Demonstrate calculation format (theory, methods & techniques)
  - Comments and recommendations to be accounted for will be gathered
  - Decision point for continued work
- **Continued work (2008 – 2009)**

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Example of results from Phase II

- **Up to date the following system have been summarized with respect to qualitative information.**
  - System 313 – PWR Reactor Coolant System
  - System 313 – BWR Reactor Recirculation System
  - System 321 – Residual Heat Removal System
  - System 414/430 – Condensate System
  - System 713/714 – Service Water System

- **Following slides will present some information about System 321 (PWR).**

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Example of results from Phase II – System 321 (PWR - Worldwide)

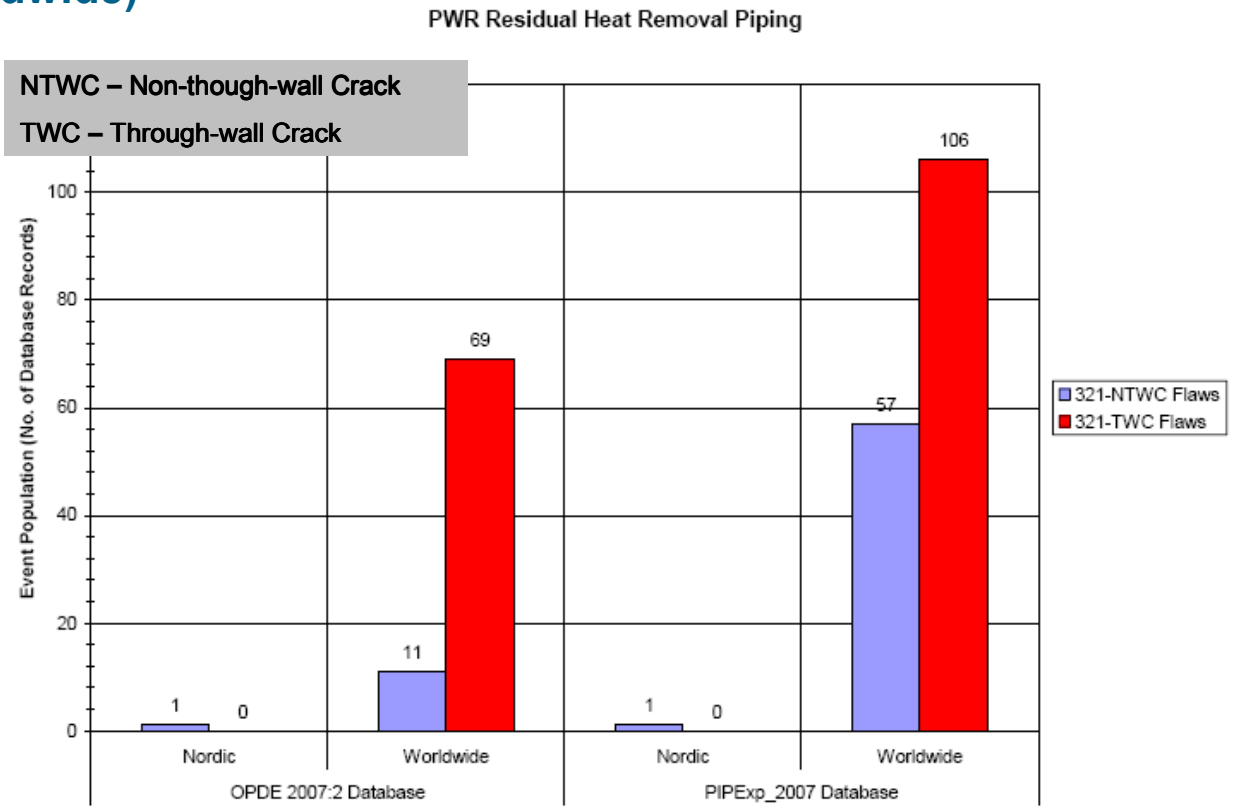

Figure 2
Summary of 321 Event Population (ii)

Example of results from Phase II – System 321 (PWR - Worldwilde)

NTWC – Non-though-wall Crack

TWC – Through-wall Crack

Table 4: Worldwide PWR-Specific Pipe Failure Data for System 321 (Residual Heat Removal System)

Attribute / Degradation Mechanism			Event Population										
			1970-79		1980-89		1990-99		2000-07		1970-2007		
			NTWC	TWC	NTWC	TWC	NTWC	TWC	NTWC	TWC	NTWC	TWC	All
Worldwide Data	∅ > 250	B/A Wastage	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		D&C	0	0	1	1	2	0	1	0	4	1	5
		E-C	0	0	2	1	1	0	0	0	3	1	4
		E/C	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		FAC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		SCC	0	0	4	5	5	1	2	0	11	7	18
		TF	0	0	0	0	0	0	0	0	0	0	0
		VF	0	0	0	2	0	0	0	0	0	2	2
		WH / OVL	0	0	6	0	12	0	5	0	23	0	23
	50 < ∅ ≤ 250	B/A Wastage	0	0	0	0	0	0	0	0	0	0	0
		D&C	0	1	1	0	1	2	2	0	4	3	7
		E-C	0	1	4	0	0	0	0	0	4	1	5
		E/C	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		FAC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		SCC	0	2	1	0	0	2	0	0	3	4	7
		TF	0	0	1	2	2	0	0	0	3	3	6
		VF	0	2	0	1	0	0	1	1	1	4	5
		WH / OVL	0	0	0	0	0	0	0	0	0	0	0
	∅ ≤ 50	B/A Wastage	0	0	0	0	0	0	1	0	1	0	1
		D&C	0	5	0	5	0	3	0	1	0	14	14
		E-C	0	0	0	4	0	0	0	0	0	4	4
		E/C	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		FAC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		SCC	0	0	0	0	0	3	0	5	0	8	8
		TF	0	0	0	0	0	1	0	0	0	1	1
		VF	0	12	0	10	0	18	0	11	0	51	51
		WH / OVL	0	0	0	0	0	1	0	1	0	2	2
	All sizes	All Mechanisms	0	23	20	30	23	33	14	20	57	106	163
	Reactor-years		398		1319		2030		1666		5413		

Mechanism

Diameter

Ø>250: SCC dominate TWC

50<Ø≤250: E-C, SCC, TF, VF

Ø≤50: VF and D&C dominate TWC

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The exposure term for each damage mechanism must be relevant!

Conclusion

- The usefulness of any component failure data collection depends on the way by which a stated purpose is translated into database design and QA.
- Developing the R-Book is an important step to verify the content and quality of the OPDE database.
- Also it is important that interested parties strive against harmonized ways of creating reliability data to be used in safety analyses.
- R-Book will be one of many important information resources for risk-informed structural integrity management

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