OECD/NEA -JRC RISMET project: Benchmarking of RI-ISI methodologies

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NEA/JRC coordinated Benchmark Study on RI-ISI Methodologies (RISMET)

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Background

- To date, no one-to-one comparison of risk-informed in-service inspection (RI-ISI) methodologies by applying them to same set of systems
- RI-ISI applied widely (but mainly to limited scope) in US, application elsewhere still rather limited but increasing
- Several organisations have recommended or expressed support for a Benchmark Study

History

- A project proposal drafted by JRC and the European Network for Inspection and Qualification, Task Group Risk (ENIQ/TGR), presented to OECD/NEA/IAGE in spring 2005
- Preliminary meeting held at JRC in the Netherlands in September 2005
- Kick-off meeting held in Switzerland, on January 30-31 2006
- Last meeting held in February 2008, final report near completion
- More than 20 organizations participating (Europe, US, Canada, Japan, IAEA)

Objectives

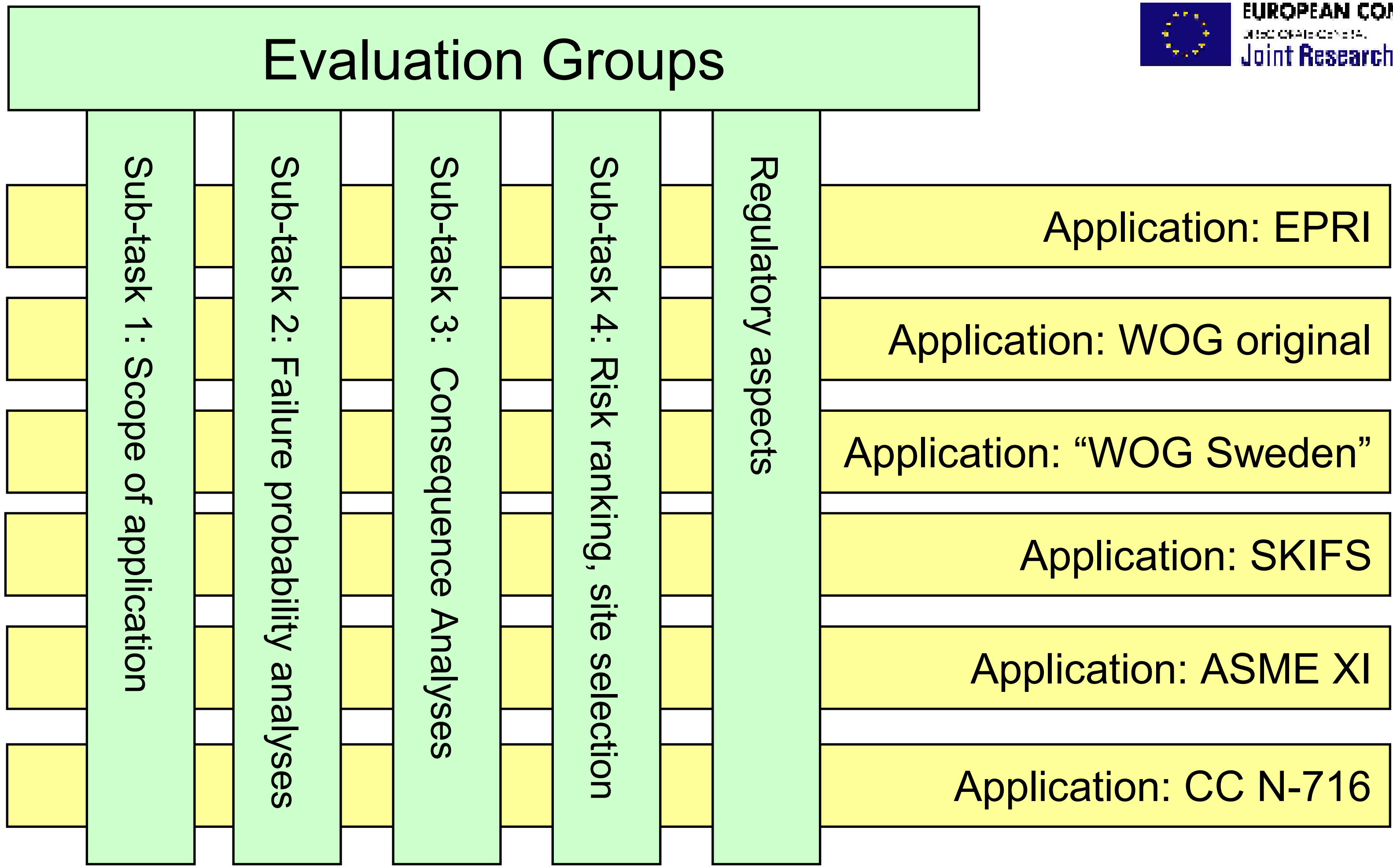
- **To apply various RI-ISI methodologies to the same case**
- **To compare different RI-ISI methodologies and traditional ISI programmes**
- **To study different RI-ISI methodologies:**
  - **Identification of differences in the analysis results in all phases**
  - **Analysis of the importance of differences**
  - **Comparison with "traditional" inspection programs and principles/recommendations by NRWG, ENIQ, NURBIM**
  - **Highlighting good practices in each applied methodology**

Scope

- **4 systems from Ringhals 4 PWR selected, representing a good coverage of safety classes, degradation mechanisms and risk categories**

Criteria	Reactor Coolant System	Main Steam System	Condensate System	Residual Heat Removal system
Safety Class	**Class 1**	**Class 2 and 4**	**Class 4**	**Class 1 and 2**
Medium consequences / high failure probability	**-**	**X**	**-**	**X**
High consequences/low failure probability	**X**	**-**	**-**	**-**
Low consequences/high failure probability	**-**	**-**	**X**	**-**
Systems with a significant increase or decrease in the new inspection programme (before/after applying RI-ISI)	**X** **Factor of 13**	**-** **Factor of 1,7**	**X** **Factor of 29**	**X** **Factor of 29**
Systems with more than one (possibly interacting) degradation mechanisms	**LCF, thermal stratification**	**LCF, SH**	**Erosion corrosion, LCF, thermal stratification, WH**	**Vibration fatigue, thermal mixing point, cavitation**
Initiating event (power operation)	**X**	**X**	**X**	**-** **(important in shut-down!)**
Mitigating systems	**-**	**X**	**X**	

Organisation of the technical work



Applied RI-ISI methodologies

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SKIFS methodology

	Consequence index		
Damage index	1	2	3
I	A	A	B
II	A	B	C
III	B	C	C

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PWROG Sweden = combination of PWROG & SKIFS

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	LOW SAFETY SIGNIFICANT	HIGH SAFETY SIGNIFICANT
HIGH FAILURE IMPORTANCE	3 OWNER DEFINED PROGRAMME	1 (A) SUSCEPTIBLE LOCATION(S) (100%) -- 1 (B) INSPECTION LOCATION SELECTION PROCESS
LOW FAILURE IMPORTANCE	4 ONLY SYSTEM PRESSURE TEST & VISUAL EXAMINATION	2 INSPECTION LOCATION SELECTION PROCESS

PWROG methodology

POTENTIAL FOR PIPE RUPTURE PER DEGRADATION MECHANISM SCREENING CRITERIA	CONSEQUENCES OF PIPE RUPTURE IMPACTS ON CONDITIONAL CORE DAMAGE PROBABILITY AND LARGE EARLY RELEASE PROBABILITY			
	NONE	LOW	MEDIUM	HIGH
HIGH FLOW ACCELERATED CORROSION	LOW Category 7	MEDIUM Category 5	HIGH Category 3	HIGH Category 1
MEDIUM OTHER DEGRADATION MECHANISMS	LOW Category 7	LOW Category 6	MEDIUM Category 5	HIGH Category 2
LOW NO DEGRADATION MECHANISMS	LOW Category 7	LOW Category 7	LOW Category 6	MEDIUM Category 4

EPRI methodology

CC N-716 = ”Streamlined EPRI methodology”
- No consequence assessment
  (pre-determined set of HSS locations)
- Full scope analysis required

Limitations of the study

Some limitations due to:

- Limited number of systems
  - Still rather good “sample” to cover e.g. degradation mechanisms & risks
- Limitations in applications
  - Full SKIFS and PWROG analyses available
  - For EPRI, CC N-716 and ASME XI some limitations and own assumptions
- Same PSA results
  - No possibility to analyse the impact of PSA coverage / quality
- Not analysed up to selection of inspection sites, techniques, intervals
  - Identification of inspection sites at segment level
  - Final selection process and determination of the ISI program excluded

Evaluation of the scope

Identification and analysis of differences in the process of selecting systems in a full scope or partial scope analysis

- **The PWROG, PWROG Swedish and EPRI methodologies allow 2 types of scopes – partial and full scope**
- **The SKIFS, ASME Section XI and CC N-716 methodologies have basically one scope**
- **In PWROG methodology, changing the scope influences the ranking of segments in other systems**

Identification and analysis of differences in the process of defining segment boundaries

- **PWROG methodology: segmentation based on the consequences**
- **EPRI methodology: based on both consequences and degradation mechanisms**
- **ASME XI, SKIFS: no segmentation**

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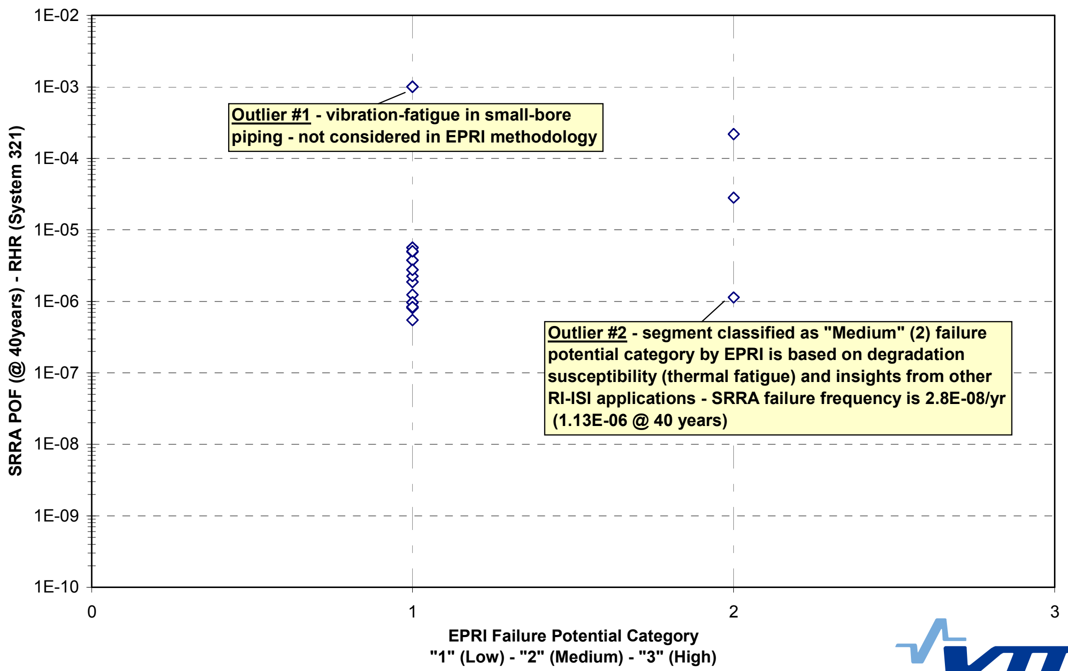
Evaluation of the degradation potential

Differences in applied methodologies

- PWROG: Quantification with structural reliability software SRRA
- EPRI: Qualitative ranking based on failure potential, bounding values used for delta risk evaluation
- SKIFS: Qualitative ranking in 3 damage index classes
- Assumptions on inspection reliability

Effect on results

- Example: comparison of PWROG vs. EPRI ranking for RHR system



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Evaluation of the consequences

Differences in applied methodologies

- ASME XI and SKIFS do not use PSA results => non safety classified systems excluded
- Same PSA results used in RI-applications, but still differences in interpretation
- In PWROG methodology, results are calculated *with* operator actions and *without* operator actions. Initial risk ranking based on the most conservative results, but expert panel may change this
- No corresponding sensitivity analysis in EPRI methodology
- EPRI application split into two:
  - EPRI R4 using directly R4 PSA values
  - EPRI Base making own judgements (no trust in "too high" CCDPs some segments in Main Steam System and RHR System)

Impact on results

- Consequence analyses of RI-methodologies can be strongly affected by
  - Probability to perform manual actions such as closing valves to isolate break
  - Lowest leak rate that initiates SCRAM and RPS-logic from leak detection measurements
  - Realism in thermo-hydraulic analyses evaluating system demands to avoid core damage

Evaluation of the risk ranking and inspection site selection

Differences in applied methodologies

- **Ranking principles / risk measures used:**
  EPRI: CCDPxFF PWROG: RRW (&FF) SKIFS: (Cons Index) x (Dam Index) ASME: SC

- **Comparison of number of inspection sites in applications**

	RCS (313)	RHR (321)	MS (411)	CS (414)	Total
ASME XI	113	30	28	0	171
SKIFS 1994:1	40	1	29	0	70
PWROG orig 4 systems	28 (+4 VT2)	21	10 + FAC	24+FAC	83 (+4 VT2 +FAC)
PWROG-Sweden full	28	35	3 + FAC	0+FAC	66 (+FAC)
PWROG-Sweden 4 syst	30	35	3 + FAC	0+FAC	68 (+FAC)
EPRI base	49	26	2 + FAC	3+FAC	80 (+FAC)
EPRI R4	49	39	15 + FAC	3+FAC	106 (+FAC)
CC N-716	49	4	7 + FAC	0+FAC	60 (+FAC)

- **Comparisons done at detailed level, identification of reasons for main differences**
- **Specific issues: treatment of augmented programs, delta risk evaluations**

Concluding remarks

- RISMET RI-ISI benchmark analysed 4 systems in Ringhals 4 PWR
- Applied risk-informed approaches: SKIFS, PWROG (original & adaptation to Swedish regulatory environment), EPRI, Code Case N-716
- Deterministic ASME XI selection also included in the study
- Main differences in results analysed

- Recommendations in various areas:
  - Evaluation of failure probability
  - Use of PSA in consequence analyses

- Final report near completion
- A joint RISMET-OPDE workshop will be held in Madrid 2-4 June 2008