Evaluation of Operating Experience with Regard to Passive Mechanical Components Approach and New Insights
Introduction

- Intention of this presentation
  - to share knowledge gained from 35 years of experience
  - to provide information on the GRS approach
  - to present examples of recent generic studies

- Focus on passive mechanical components (PMCs)
  - pressurised components
  - RPV internals

- A few questions on OE evaluation
  - Where to get the necessary data from and how to store them?
  - How to evaluate the available data?
  - How to make the gained insights retrievable for future work?
GRS approach

Operating experience with German NPPs
- VERA DB
- KomPass & Internal DBs

Operating experience with foreign NPPs
- IRS DB
- CODAP DB

Detailed evaluation of individual events

Generic evaluations on different levels

Position Papers

Information Notices

Technical Reports

Knowledge base on degradation mechanisms "ALMA MATER"
### Databases used at GRS for evaluation of OE with PMCs

<table>
<thead>
<tr>
<th>Database</th>
<th>No. of records</th>
<th>Acquisition period</th>
<th>Scope</th>
<th>Criteria for data capture</th>
</tr>
</thead>
<tbody>
<tr>
<td>VERA</td>
<td>~ 6,000</td>
<td>since 1965</td>
<td>SCCs</td>
<td>Reportable events</td>
</tr>
<tr>
<td>KomPass</td>
<td>~ 1,000</td>
<td>since 1972</td>
<td>Pressurised components</td>
<td>Reportable events</td>
</tr>
<tr>
<td>Internals</td>
<td>~ 100</td>
<td>since 1973</td>
<td>RPV internals</td>
<td>Reportable events</td>
</tr>
<tr>
<td>IRS</td>
<td>~ 3,800</td>
<td>since 1978</td>
<td>SCCs</td>
<td>Selected safety-related events</td>
</tr>
<tr>
<td>CODAP</td>
<td>~ 4,500</td>
<td>since 1970</td>
<td>Pressurised components + RPV internals</td>
<td>Selected safety-related events</td>
</tr>
</tbody>
</table>
Examples of recent generic studies performed

- **Ageing behaviour** of PMCs
  - topic-specific study on behalf of European CH on OEF
- **Environmentally-assisted cracking** in PMCs
  - mechanism-specific study on behalf of BMU
- **Degradation in essential service water systems**
  - system-specific study on behalf of BMU
- **Changes in leak frequencies of piping** over time
  - topic-specific study on behalf of BMWi
Number of ageing-related individual events in PMCs of German NPPs
Number of ageing-related individual events in PMCs of German NPPs

- Number of events remains largely constant over observation period ➔ effective ageing management
- Increase of events in 2007 / 2009: supplementary inspections + change in data capturing
Proportions of degradation mechanisms in PMCs of German NPPs (1990 – 2009)

- **PWR**
  - Corrosion: 74%
  - Corrosion / Fatigue: 17%
  - Fatigue: 6%
  - Other: 3%

- **BWR**
  - Corrosion: 82%
  - Corrosion / Fatigue: 7%
  - Fatigue: 11%
  - Other: 0%

*Source: [EUROSAFE](https://www.eurosafe.org)*
Proportions of degradation mechanisms in PMCs of German NPPs (1990 – 2009)

Corrosion-related events in PWRs
- 38% Chloride-induced TGSCC
- 20% Shallow pit corrosion
Proportions of degradation mechanisms in PMCs of German NPPs (1990 – 2009)

**Corrosion-related events in PWRs**
- 38% Chloride-induced TGSCC
- 20% Shallow pit corrosion

**Corrosion-related events in BWRs**
- 32% Chloride-induced TGSCC
- 18% SICC and FAC each
- 12% Shallow pit corrosion
- 9% IGSCC
Number of individual events due to chloride-induced TGSCC in German NPPs by calendar year

![Graph showing the number of individual events due to chloride-induced TGSCC in German NPPs by calendar year.](image)
Number of individual events due to chloride-induced TGSCC in German NPPs by calendar year

- Several components made of SS affected
- Cracks initiated from inner and outer surface
- Direct safety impact low
  - majority of cracks were found in small pipes
  - in most cases non-through-wall cracks / minor leakage
- Potential safety impact
  - pipe rupture with unisolable leakage
  - degradation of redundant trains of safety systems
Safety-related events due to chloride-induced TGSCC in German NPPs and events which induced INs
Safety-related events due to chloride-induced TGSCC in German NPPs and events which induced INs

- Avoid any contact of chlorides with components made of SS
  - identify any chloride sources
  - identify areas where accumulation of chlorides may occur

- Measures taken in German plants
  - specification of adhesives, gaskets, lubricants, etc.
  - supplementary inspections + enhancement of ISI programmes
  - repair or replacement of components with cracks

- Is chloride-induced TGSCC from inner surface a specific issue in German NPPs only and, if so, why?
Events due to degradation of piping in essential service water systems of German NPPs (1974-2009)
Events due to degradation of piping in essential service water systems of German NPPs (1974-2009)

- 44 events identified
- 3 of them affecting buried piping only
Events in piping of essential service water systems of German NPPs (1997-2009)

by nominal size ranges

by degradation mechanisms

- Corrosion 43 %
- Manufacturing/corrosion 20 %
- Manufacturing 5 %
- Overload 5 %
- Mechanical impact/corrosion 25 %
- Fatigue 2 %

Total: 44
Events in piping of essential service water systems of German NPPs (1997-2009) by nominal size ranges

- Piping of all ranges affected
- Events in piping of NB ≥ 400 mm only reported from older plants
- Majority identified by walk-downs, in large piping within ISI
Events in piping of essential service water systems of German NPPs (1997-2009)

- Through-wall shallow pits in piping made of LAS
- Coating failure due to
  - manufacturing defects
  - mechanical impact
- Areas with stagnant / turbulent flow conditions
- New insights from OEF have been considered in KTA 3211.4 (ISI schedule)

by degradation mechanisms

- Corrosion 43%
- Mechanical impact/corrosion 25%
- Manufacturing/Corrosion 20%
- Overload 5%
- Manufacturing 5%
- Fatigue 2%
Leak frequencies of safety-related piping in German BWRs depending on the root cause by calendar year
Leak frequencies of safety-related piping in German BWRs depending on the root cause by calendar year

- Leak events initiated by various root causes / degradation mechanisms
- No mechanism dominated over the total period of observation
- Significant decreasing trend only recognisable for mechanical fatigue
Leak frequencies of safety-related piping in German plants with PWR depending on location of damage
Leak frequencies of safety-related piping in German plants with PWR depending on location of damage

- Leaks occurring in base material gained in importance
- Reconsideration of criteria for leak-relevant positions
Conclusions

- GRS is evaluating OE in order to early identify changes in the reliability of PMCs and corresponding safety issues
- GRS has established appropriate data and knowledge bases as well as tools and methods for this
- For German NPPs, results confirm robustness of component design and effectiveness of measures taken, such as
  - extended plant monitoring
  - optimisation of operating conditions
  - enhancement of ISI programmes and NDE techniques
  - replacement of components sensitive to degradation
  - enforcing technical requirements in codes and standards
  - implementation of target-oriented R&D programmes
Outlook

- Future GRS work on OE evaluation with PMCs will comprise in particular
  - maintaining, updating and extending of available data and knowledge bases
  - further evaluation of available data in a specific way
  - co-operation in international WGs in order to ensure that sufficient information for safety assessment is available

- Generic studies under way / in the pipeline at GRS
  - long-term behaviour of RPV internals (on behalf of BMU)
  - cracks and leaks of the RCPB (CH on OEF)
  - FAC in water-steam cycles (OECD CODAP)