Shutdown PSA for Ringhals NPP Unit 1. Insights, overview and results.

Stefan Eriksson at Ringhals AB

Ringhals Nuclear Power Plant

Agenda

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4. Initiating events
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Introduction - Ringhals PSA studies

- PSA has been performed in different campaigns since the 1980:ies.
- The current PSA studies are plant specific and cover both the risk of core damage, PSA level 1, and the release of source term, PSA level 2.
- Almost all relevant internal events have been considered together with important external events, like extreme weather conditions, and area events like fire and internal flooding.

Introduction - The Shutdown PSA project

- The Shutdown analysis extends the existing PSA for power operation and low power operating modes.

- The project is ongoing and has only been finalized for Level 1 and internal events. Hence this presentation will focus on conclusions and results from the analyse of internal events.

Introduction - Scope of the Shutdown PSA

The considered sources of radioactivity are:

- fuel in the core
- fuel in the spent fuel pit
- transport between the core and the fuel pit

Focus on fuel damage in the reactor pressure vessel within 20h. Other analyzed consequences are:

- Fuel damage in the reactor pressure vessel after 20h
- Fuel damage in spent fuel pit within 20h
- Fuel damage because of exposure of fuel rod during load/unloading because of outage LOCA

All sequences with unstable consequence are analyzed.

Plant Operations States (POS)

Phase	Description	Closed/ Open Primary System	Reactor Vessel Level/C-pool
K1	Cold shutdown – Reactor Vessel Head mounted, water level under streamlines	Closed	Normal
K2	Cold shutdown – Reactor Vessel Head mounted, water level above streamlines	Closed	Top filled above steam lines
K3	Cold shutdown – Open Reactor Vessel	Opened	Empty reactor hall pools
K4	Cold shutdown – Open Reactor Vessel. 40 h -7 days. B-side unavailable	Opened	Reactor hall pools are filled
K5:1	Cold shutdown – Open Reactor Vessel. 7-14 days. B-side unavailable.	Opened	Reactor hall pools are filled
K5:2	Cold shutdown – Open Reactor Vessel. 7-14 days. A-side unavailable.	Opened	Reactor hall pools are filled
K6:1	Cold shutdown – Open Reactor Vessel. 14+ days. B-side unavailable.	Opened	Reactor hall pools are filled
K6:2	Cold shutdown – Open Reactor Vessel. 14+ days. A-side unavailable.	Opened	Reactor hall pools are filled
K7	Cold shutdown – Open Reactor Vessel, 1 bar.	Opened	Empty reactor hall pools
K8	Cold shutdown – Reactor Tank idle on flange	Closed	Normal

Initiating Events

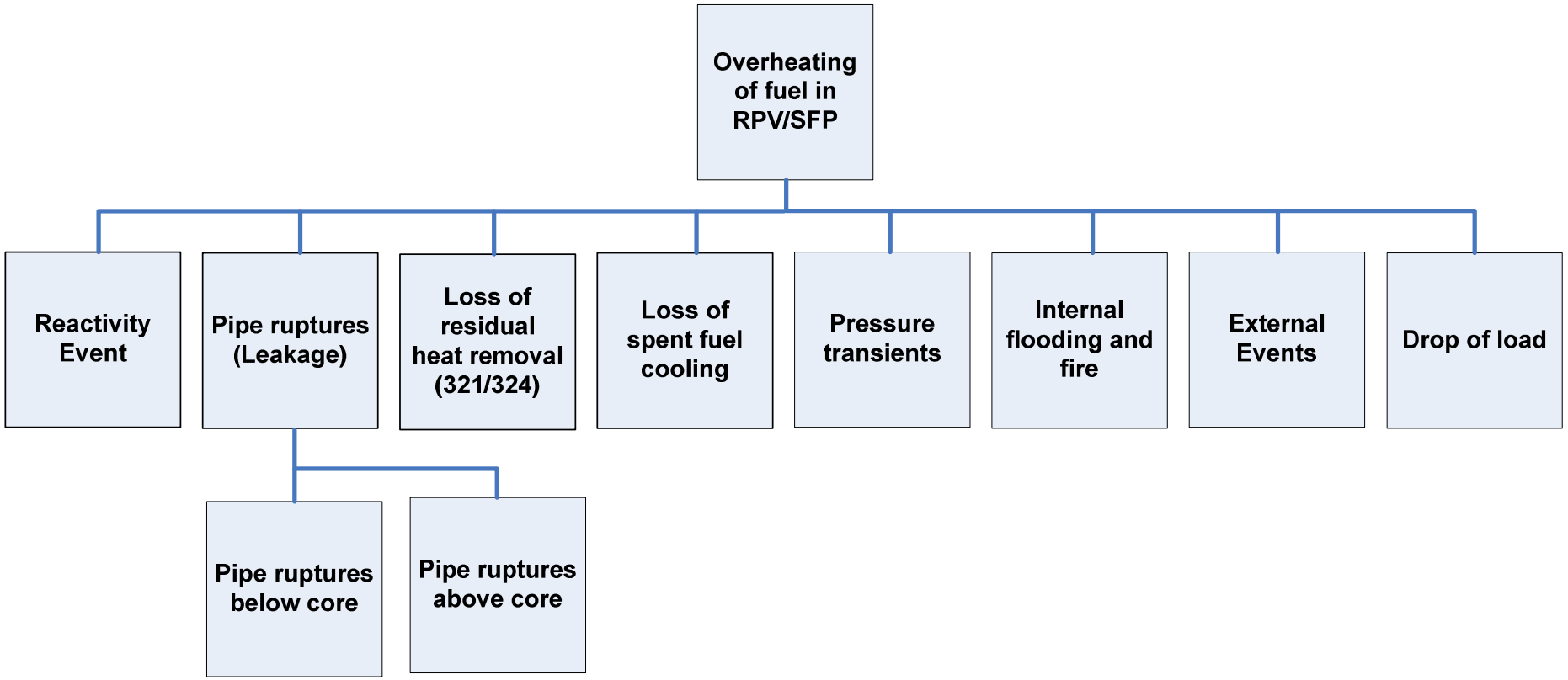
- The considered initiating events are:
  - Internal Events
  - Area Events (fire and flooding events will be analysed)
  - External Events (will be analysed)

- The sources of radioactivity considered in the analysis are:
  - Reactor Pressure Vessel (RPV)
  - The Spent Fuel Pit (SFP)
  - Exposure of fuel rod during load/unloading because of outage LOCA

Initiating Events

- Basis of identification and analyses of initiating events:
  - Ringhals Licensee Event Reports (LERs)
  - R1 Safety Analysis Report (SAR)
  - Nordic Owner Group report regarding safety during shutdown conditions
  - Previous PSA analyses at Ringhals
  - Previous PSA analyses in Sweden (especially earlier shutdown studies at Forsmark NPP)
  - Reference literature
  - Specific work groups at the NPP (experts) identifying events to occur during shutdown

Initiating Events



Sequence and System Analysis

- The sequence analysis follows the same model as for the power operation.
- It is illustrated by success block diagrams starting with an identified initiating event.
- The system functions that may bring the plant to a safe state are taken into account..
- The end states are fuel damage or safe state.

Sequence and System Analysis

- Success block diagrams are divided in following types:
  1. LOCA below the core
  2. LOCA above the core
  3. External LOCA below the core
  4. External LOCA above the core
  5. Loss of residual heat removal due to loss of system 321 and/or 324
  6. Loss of residual heat removal due to CCI
  7. Loss of residual heat removal due to external events (loss of offsite power)
  8. Loss of residual heat removal due LOCA
  9. Loss of residual heat removal for spent fuel pool due to LOCA
  10. Exposure of fuel rod during load/unloading because of outage LOCA

Human Reliability Analysis (HRA)

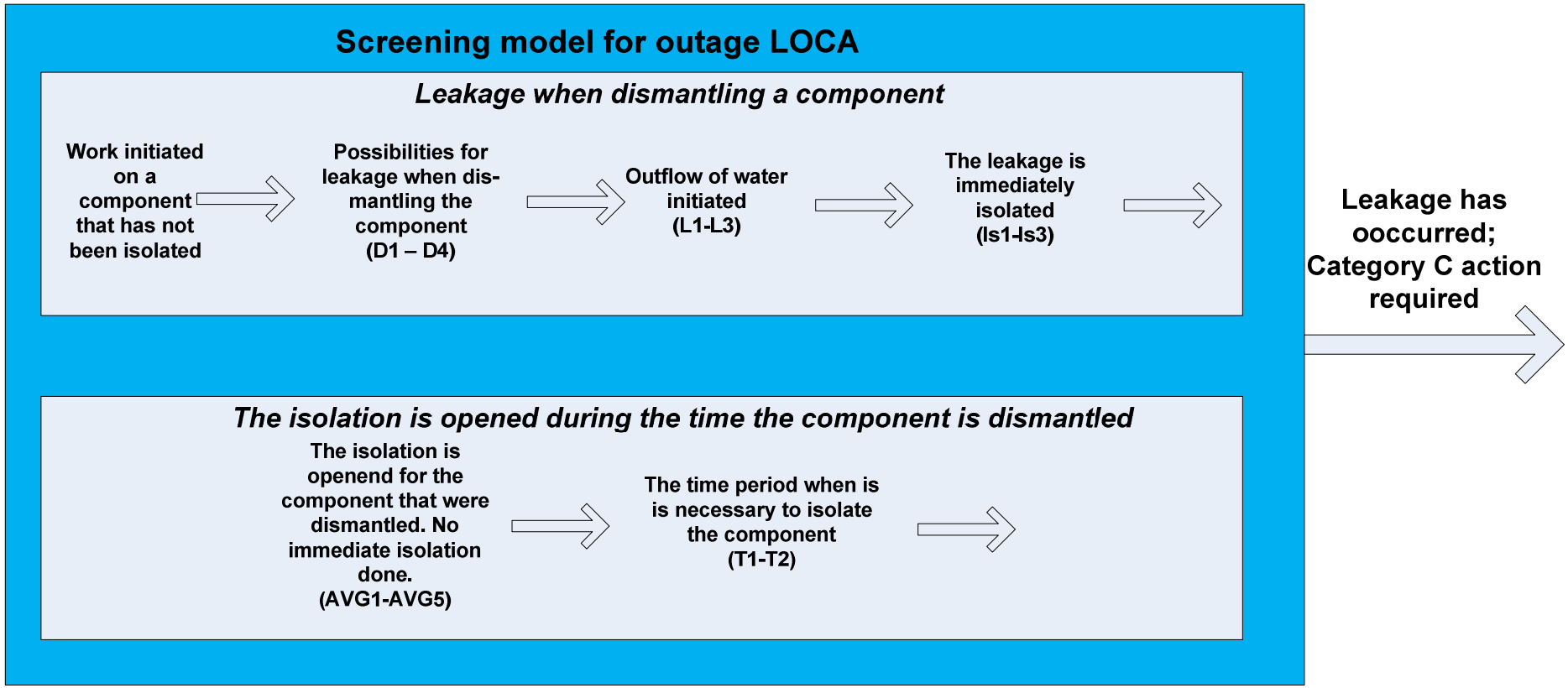
- The analysis covers:
  - Human errors leading to initiating events
  - Human errors making equipment unavailable
  - Human errors when performing recovery actions in accident sequencies

- An expert panel has been used to select critical work tasks that might cause an initiating event.

- For recovery actions the analysis is based on the time available and the degree of difficulty of the task.

Human Reliability Analysis (HRA)

- Screening model for outage LOCA



Results for Ringhals 1

- The core damage frequency for the shutdown period is higher than for the full power operation mode (observe preliminary/not fully reviewed results yet).

- The Plant Operating States 1 (cold shutdown. Reactor Vessel Head mounted, water level under steam lines) gives the largest contribution to the core damage frequency.

- The preliminary results also show that there are no dominating sequences. The contribution from the sequence of highest order is just below, 5%.

Results for Ringhals 1

- Dominating initiating events:
  - Loss of residual heat removal during phase 1 and 2, 45%.
  - Internal LOCA (below core), 45%.
  - LOCA above core (internal and external), just 0,1%

- In all sequences manual action are part of the results, mechanical failures are not a big contributor

- An important sequence in combination with loss of the RH cooling in phase 1 due to loss of 754 (Nitrogen System) or 715 (Salt Water System) and failure of recovery of core cooling.

Conclusion

- As for the preliminary results, the Level 1 SPSA indicates that manual action contribute a lot to the results.
- An extensive amount of work is focused on a complete mapping of initiating events, even more compared to most other shutdown studies in Sweden.
- The biggest advantage of the new updated shutdown PSA for Ringhals NPP Unit 1 is that the model will support the possibility to analyze and plan future outages in a thoroughly and complete risk perspective.