Probabilistic Risk Assessment of the Spent Fuel Pools of Olkiluoto 1 and 2 NPP Units

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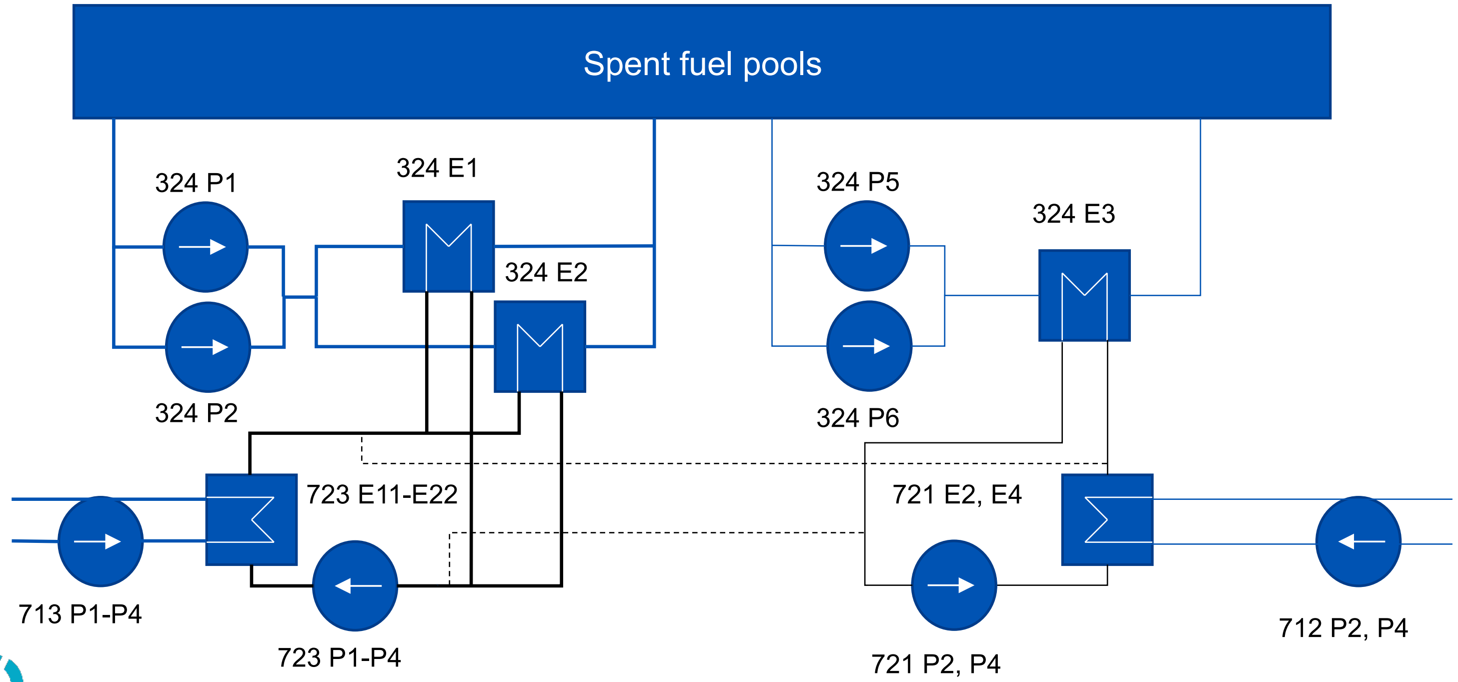
Olkiluoto NPP

- Owned and operated by Teollisuuden Voima Oyj (TVO)
- Operating units: Olkiluoto 1 and Olkiluoto 2 (OL1 and OL2)
  - 910 MWe BWR’s supplied by ASEA-ATOM
  - In commercial operation since 1979 (OL1) and 1982 (OL2)
- Unit under commissioning: Olkiluoto 3
  - 1600 MWe EPR supplied by Framatome ANP

SFP and related systems

- Spent fuel is stored for 5 years in the spent fuel pools (SFP)
- Decay heat vary between 0.9 and 1.3 MW throughout the unit power cycle
- Total water inventory 3500 m^3
- SFP is cooled by a diesel-backed RHR system (2 x 100 %)

RHR systems of the SFP



Plant damage states

- Fuel uncovering
  - The ultimate PDS
  - It is assumed that fuel uncovering will lead to fuel melting and a subsequent radioactive release
- SFP boiling
  - Informational PDS
  - Prevents using SFP RHR system due to water level decrease

Initiating events

Loss of RHR

- Internal events
  - Failure of RHR pump
- Internal hazards
  - Fire events
  - Flooding events
- External hazards
  - Weather phenomena leading to LOOP or LUHS

Unisolated leak of SFP or connecting systems

- Internal events
  - Unisolated pipe breaks
- External hazards
  - *Seismic events*

Initiating event prevention and mitigation

- Startup of backup pump (in case of loss of RHR)
- Realignment of cooling chains
- Repair of failed components or pipes

- Filling of SFP with demi water from demi water tanks
- Filling of SFP with fire water (drinking-grade water)

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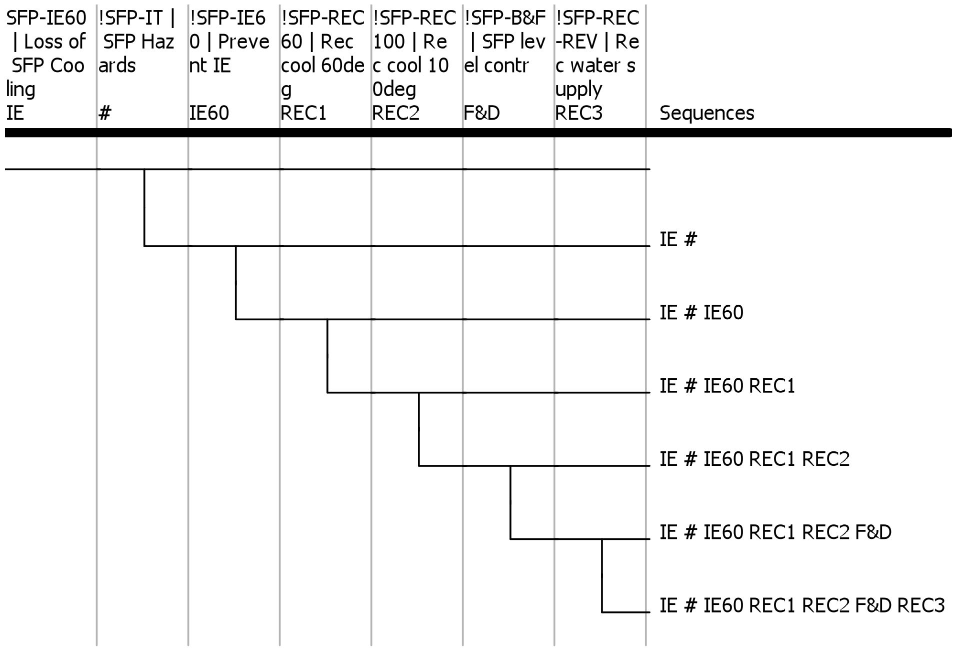
Event tree modelling



Human reliability analysis (HRA)

- No automated functions.
- Grace times are long – at least 13 h before SFP temperature reaches 60 °C (140 °F).
- In events leading to both reactor and SFP initiating event, focus of the operators is primarily on the reactor.

PART I. EVALUATE EACH PSF FOR DIAGNOSIS

A. Evaluate PSFs for the Diagnosis Portion of the Task.

PSFs	PSF Levels	Multiplier for Diagnosis	Please note specific reasons for PSF level selection in this column.
Available Time	Inadequate time	P(failure) = 1.0 ☐	
	Barely adequate time (≈ 2/3 x nominal)	10 ☐	
	Nominal time	1 ☐	
	Extra time (between 1and 2 x nominal and > 30 min)	0.1 ☐	
	Expansive time > 2 x nominal & > 30 min	0.1 to 0.01 ☐	
	Insufficient Information	1 ☐	
Stress/ Stressors	Extreme	5 ☐	
	High	2 ☐	
	Nominal	1 ☐	
	Insufficient Information	1 ☐	
Complexity	Highly complex	5 ☐	
	Moderately complex	2 ☐	
	Nominal	1 ☐	
	Obvious diagnosis	0.1 ☐	
	Insufficient Information	1 ☐	
Experience/	Low	10 ☐	

Modelling of repairs

- Modelled only after temperature has reached 60 °C
- Assumption that finishing a repair is a Poisson process with parameter MTTR

$$P_{\text{repair fails}} = e^{-\frac{T_{\text{available}}}{\text{MTTR}}}$$

Repair event	**Available time to repair (h)**	**MTTR (h)**	**Failure probability**
Repair of large pipe failure	10	20	0.6
Repair of DG after severe lightning event	10	6	0.2
Cleanup of air intake after severe snow storm	10	2	0.007

Results

Relative proportion of hazard frequency of modelled hazards

Hazard	Proportion
Failure of RHR system pump	90 %
Fire - loss of house supply transformer	3.3 %
Fire - loss of one division	1.8 %
Leak in RHR system filters	1.3 %
Leak in intermediate RHR cooling circuit	0.70 %
Fire - loss of both RHR cooling system divisions	0.59 %
Failure in diesel-backed 660 V switchgear	0.32 %
Fire - loss of running RHR pump	0.31 %
Leak in SFP RHR system	0.28 %
Mussels clog seawater channel - LUHS	0.28 %

Relative proportion of initiating event frequency of modelled hazards

Hazard	Proportion
Leak in SFP RHR system	98 %
Frazil ice clogs seawater channels - LUHS	0.63 %
Fire in cable room, loss of two divisions	0.51 %

Relative proportion of SFP boiling frequency of modelled hazards

Hazard	Proportion
Leak in SFP RHR system	0.997
Fire in cable room, loss of two divisions	2.1E-03
Frazil ice clogs seawater channels - LUHS	3.7E-04

Conditional SFP boiling probability due to modelled hazards

Hazard	Probability
Leak in SFP RHR system	0.091
High wind and mussels - LOOP and LUHS	2.5E-03
Algae clog seawater channels - LUHS	2.5E-03

Conclusion

- SFP events progress slowly
- Ample time available for taking measures to recover from the hazard

- Future work on HRA methodologies would be beneficial
- Refined modeling of repair times – now source of uncertainty

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Thank you!