ANALYSIS OF DEC-A SEQUENCES IN A NUSCALE-LIKE SMR CONSIDERING ATF FUEL PERFORMANCE USING THE SYSTEM CODE TRACE

SESSION 8.3: SMRs Safety Demonstration

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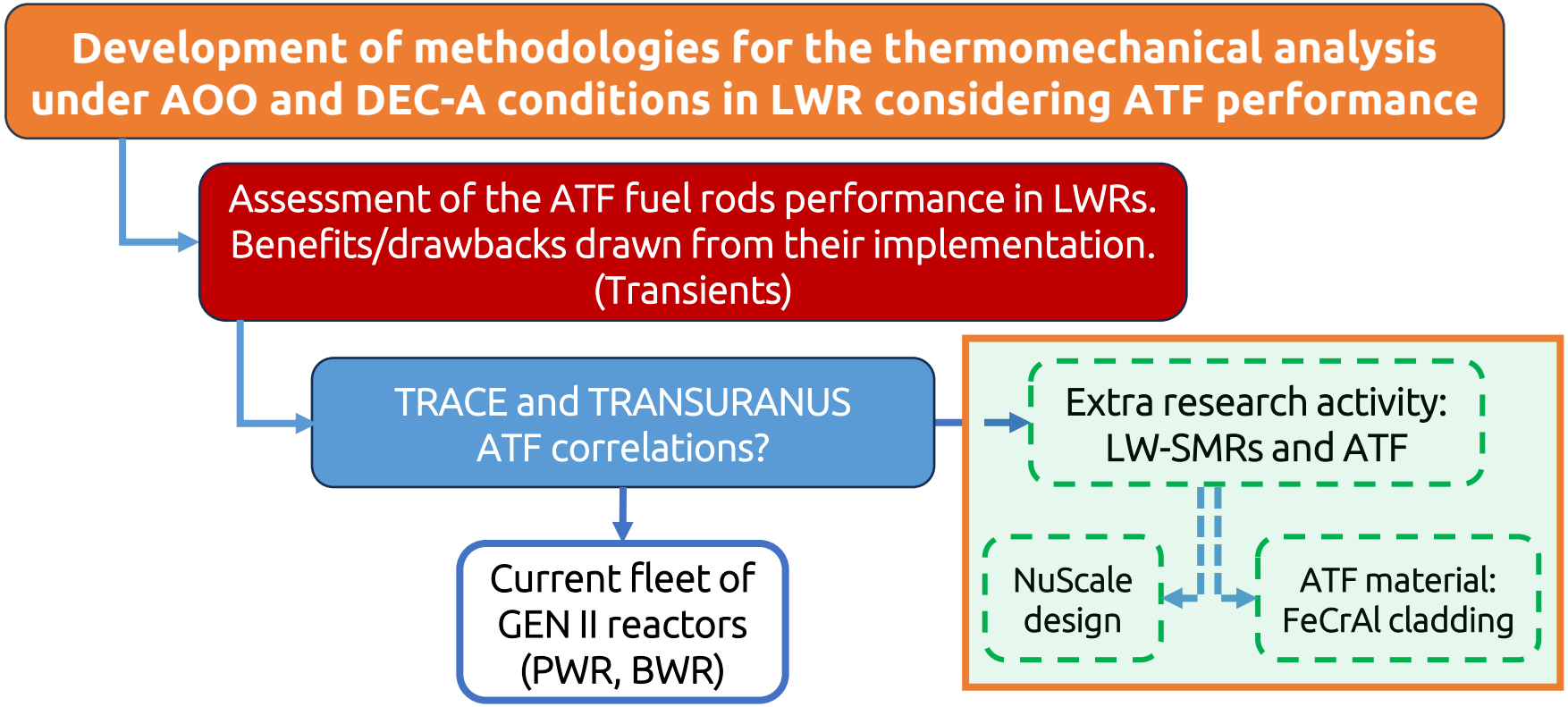
01. Introduction

METATF Project:
Collaboration Research Project launched in 2023
| NFQ-CSN |



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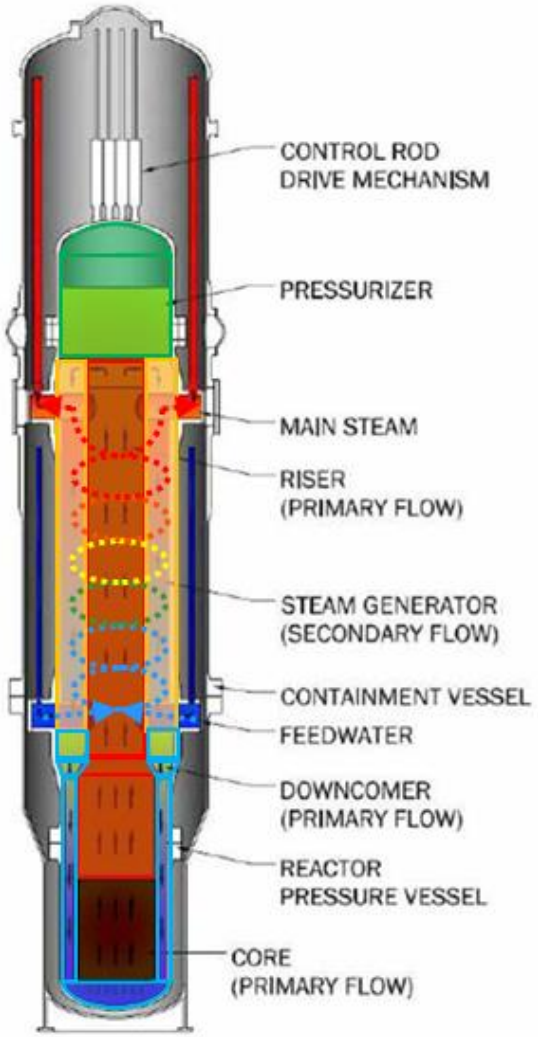
02. NuScale Power Module (NPM). Fundamentals

Main design features:

- Mass-flow rate within the primary side driven by natural circulation.
- iPWR.
  - Primary side within the RPV.
  - PZR located at the RPV top head.
- Small Core (37 fuel assemblies) with a rated power of 160 MWth.
- Two Intertwined Helically Coiled Steam Generators (HCSGs).
- RPV allocated within a CNV submerged in the reactor pool.
- Passive safety systems: ECCS | DHRS.



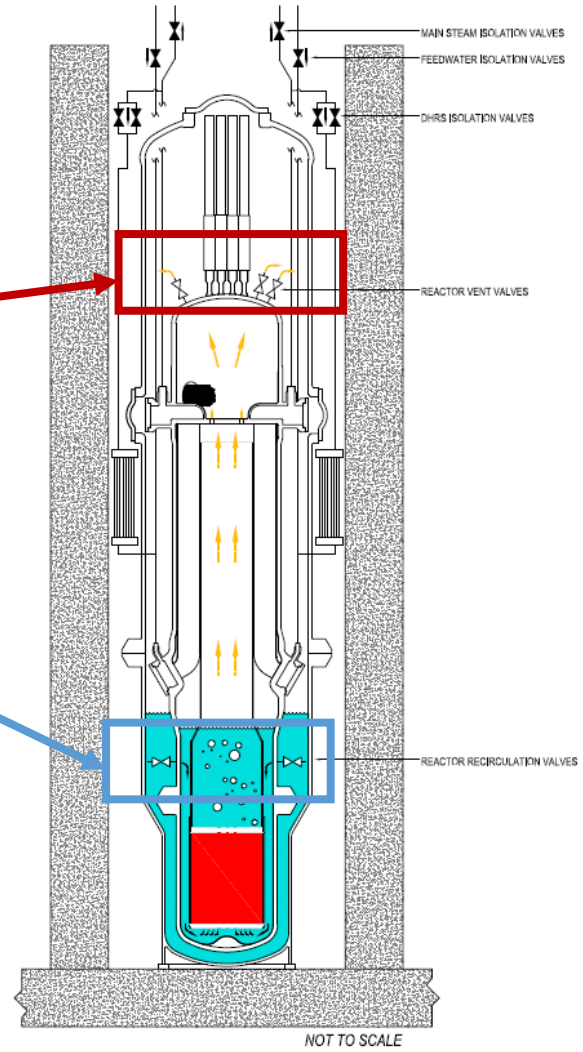
02. NuScale Power Module (NPM). Fundamentals

ECCS performance:

- Natural circulation loop established between RPV and CNV.
- Steam condensation in the CNV wall.
- Three RVVs located at the top head of the RPV.
- Two RRVs located 1.8 m above TAF approximately.

DHRS performance (not credited in LOCA DCA sequences):

- Two independent trains (one per each steam line).
- Natural circulation loop through the DHRS HXs.
- DHRS HXs are fully submerged within the reactor pool.
- The condensed is directly re-injected to the HCSGs.



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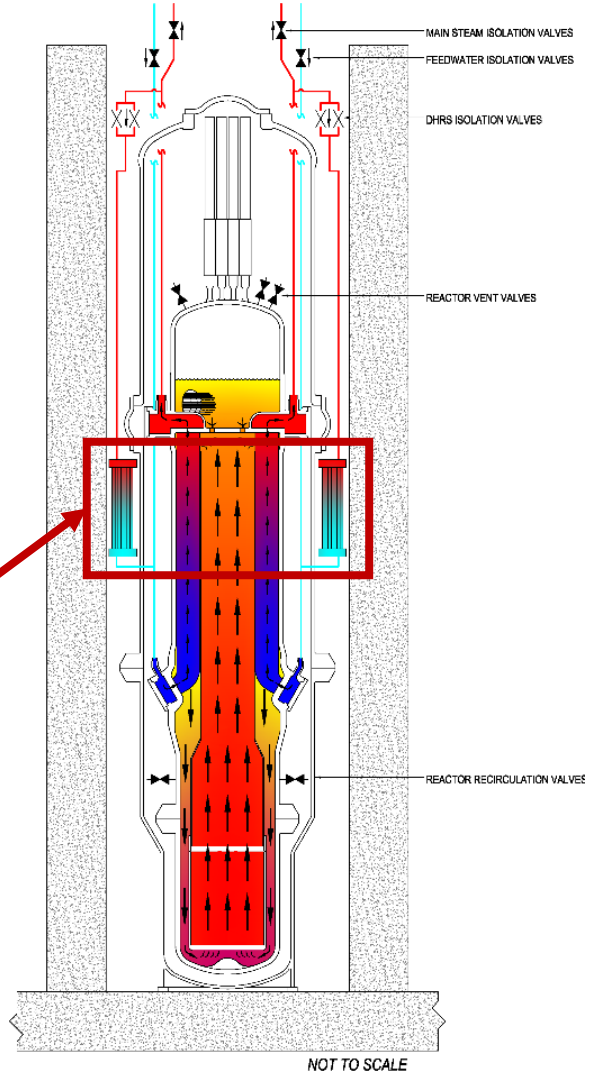

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02. NuScale Power Module (NPM).
LOCA sequence

Sequence	Region (Fluid condition)	Rupture Location (System)	ECCS Actuation
LOCA (Large-Breaks are prevented by design)	Steam space	• High point vent line • PZR spray supply line	Low RCS pressure
	Liquid space	• CVCS makeup line • CVCS letdown line	High-CNV level

02. NuScale Power Module (NPM).
LOCA sequence

Sequence	Region (Fluid condition)	Rupture Location (System)	ECCS Actuation	Sequence of events (DEGB-LOCA CVCS letdown line)
LOCA (Large-Breaks are prevented by design)	Steam space	• High point vent line • PZR spray supply line	Low RCS pressure	• RCS pressure drop. • CNV pressurization. • Reactor SCRAM. • ECCS actuation. • CNV/RCS pressure equalization. • Re-injection of liquid from CNV into the RPV. • Natural circulation loop between CNV and RCS • Long-term core cooling using the reactor pool
	Liquid space	• CVCS makeup line • CVCS letdown line	High-CNV level	

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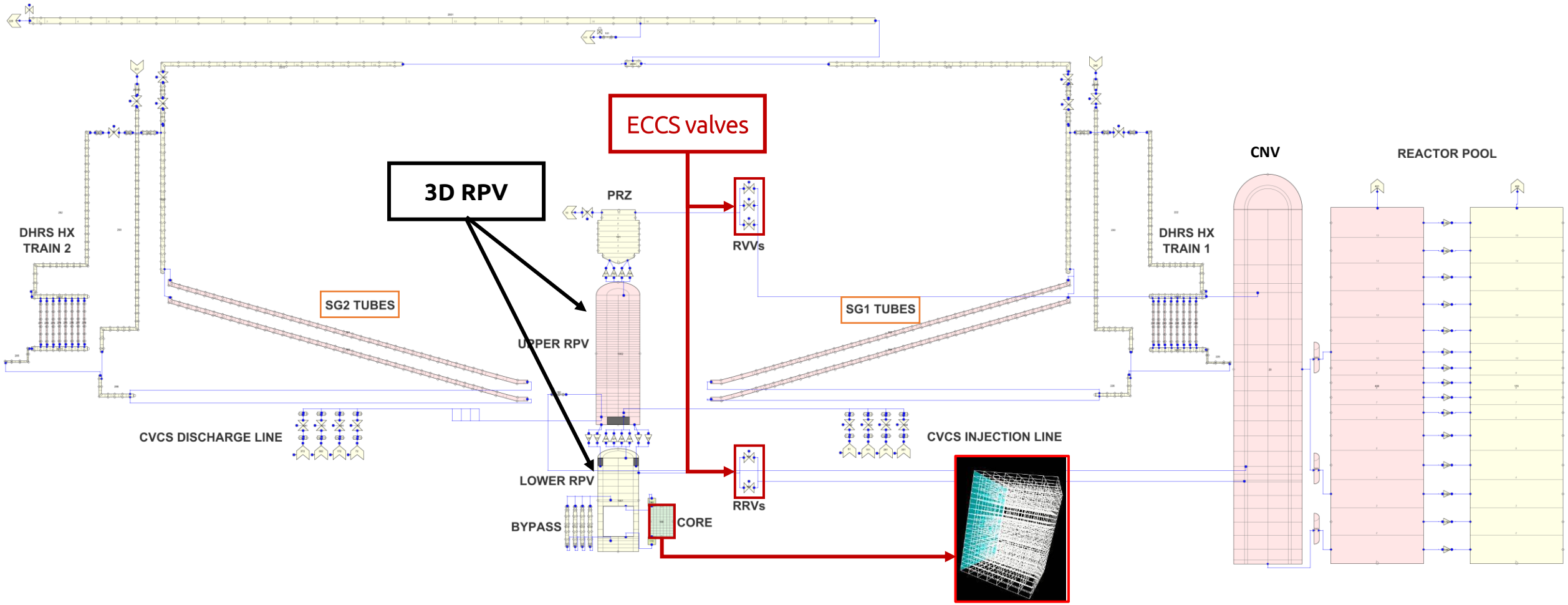
03. Modelling of a NPM using TRACE.

TRACE full-plant model of a NuScale-like SMR:



03. Modelling of a NPM using TRACE.

Steady-State calculation:

- Initial status of the reactor: Hot Full Power at BOC condition;
- RCS mass flow rate is restrained to its minimum value (535.24 kg/s);
- CVCS letdown mass flow rate is assumed to be equal to the CVCS makeup mass flow rate and restrained to its maximum value (3.15 kg/s);
- CNV pressure under normal operation condition remains at 0.21 bar.

After 6000s of Null-Transient calculation:

Parameter (SI units)	DCA	TRACE (Error %)
RCS pressure (MPa)	12.755	12.732 (-0.18)
RCS mass-flow rate (kg/s)	535.24	536.98 (0.32)
Core mass-flow rate (kg/s)	496.17	501.52 (1.08)
Core inlet temperature	531.48	531.59 (0.02)
Steam temperature (K)	580.04	585.45 (0.93)
SG pressure (MPa)	3.447	3.443 (-0.11)

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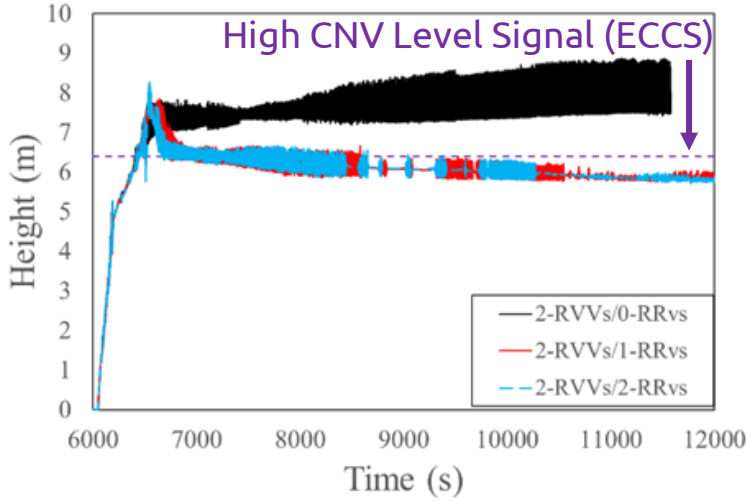
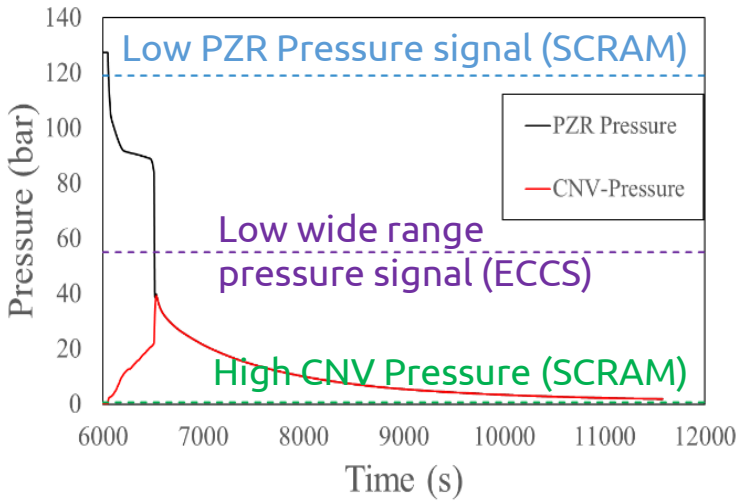
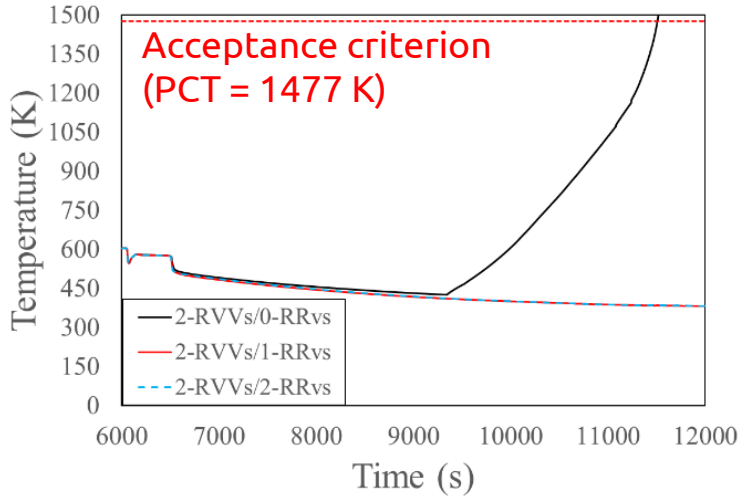
04. Simulation of the LOCA sequence.

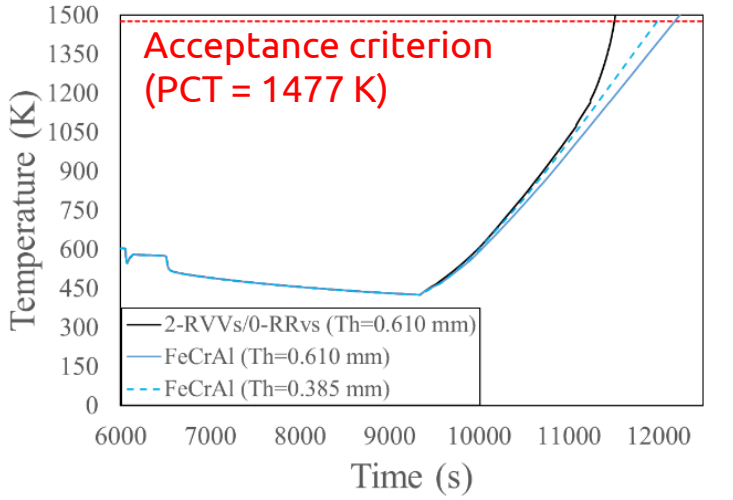
Transient calculation:

- The rupture of the CVCS letdown line (SBLOCA) is simulated.
- Two cladding materials: Zr-4 | FeCrAl.
- Two cases for FeCrAl:
  1. Same geometry of the reference case.
  2. Reduced cladding thickness (0.385 mm).
- In terms of coping time:
  - UO_2/Zr-4 with 0/2 RRVs: 5450 s
  - UO_2/Zr-4 with 1/2 RRVs: NO CORE DAMAGE
  - UO_2/Zr-4 with 2/2 RRVs: NO CORE DAMAGE
  - FeCrAl 0/2 RRVs (1): UO_2/Zr-4 + 11 min
  - FeCrAl 0/2 RRVs (2): UO_2/Zr-4 + 8 min









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05. Conclusions and final remarks

- A TRACE model of a NuScale-like SMR is built to simulate a LOCA due to the rupture of the CVCS discharge line.
- In accordance with the results, the core damage condition is reached after 5500 s of transient, if none of the RRVs are able to open, for the case with fuel rods made with UO2/Zry.
- A slight improvement in the coping time (several minutes) is accomplished when the FeCrAl material is considered for the cladding.
- Two additional cases have been simulated considering the opening of 1/2 and 2/2 RRVs respectively, and the results show that the NuScale-like SMR would be able to deal with the postulated scenario conditions with only 1 RRV available.

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The end


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