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Experimental and analytical tools for safety research of GEN IV reactors

Centrum výzkumu Řež s.r.o
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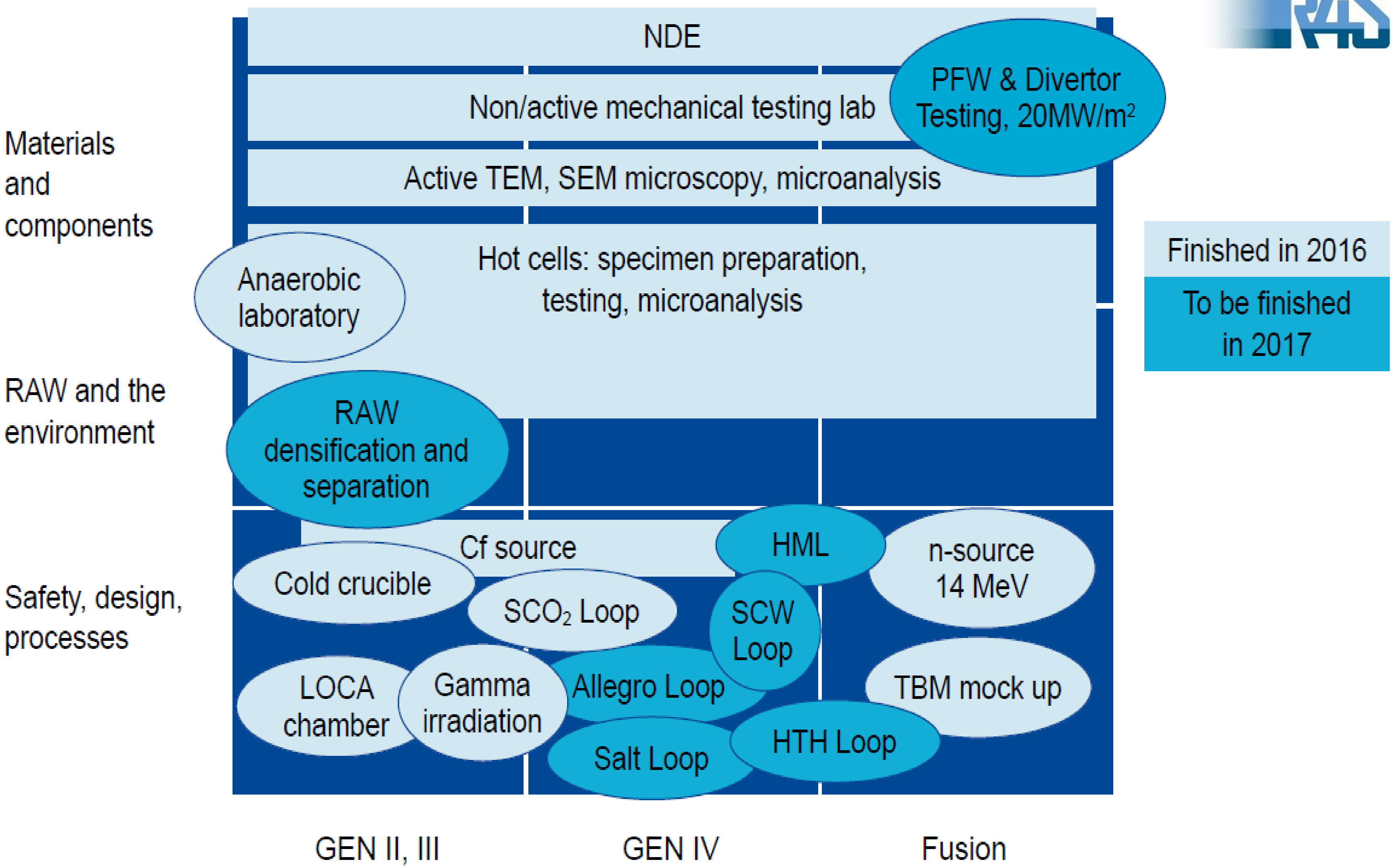
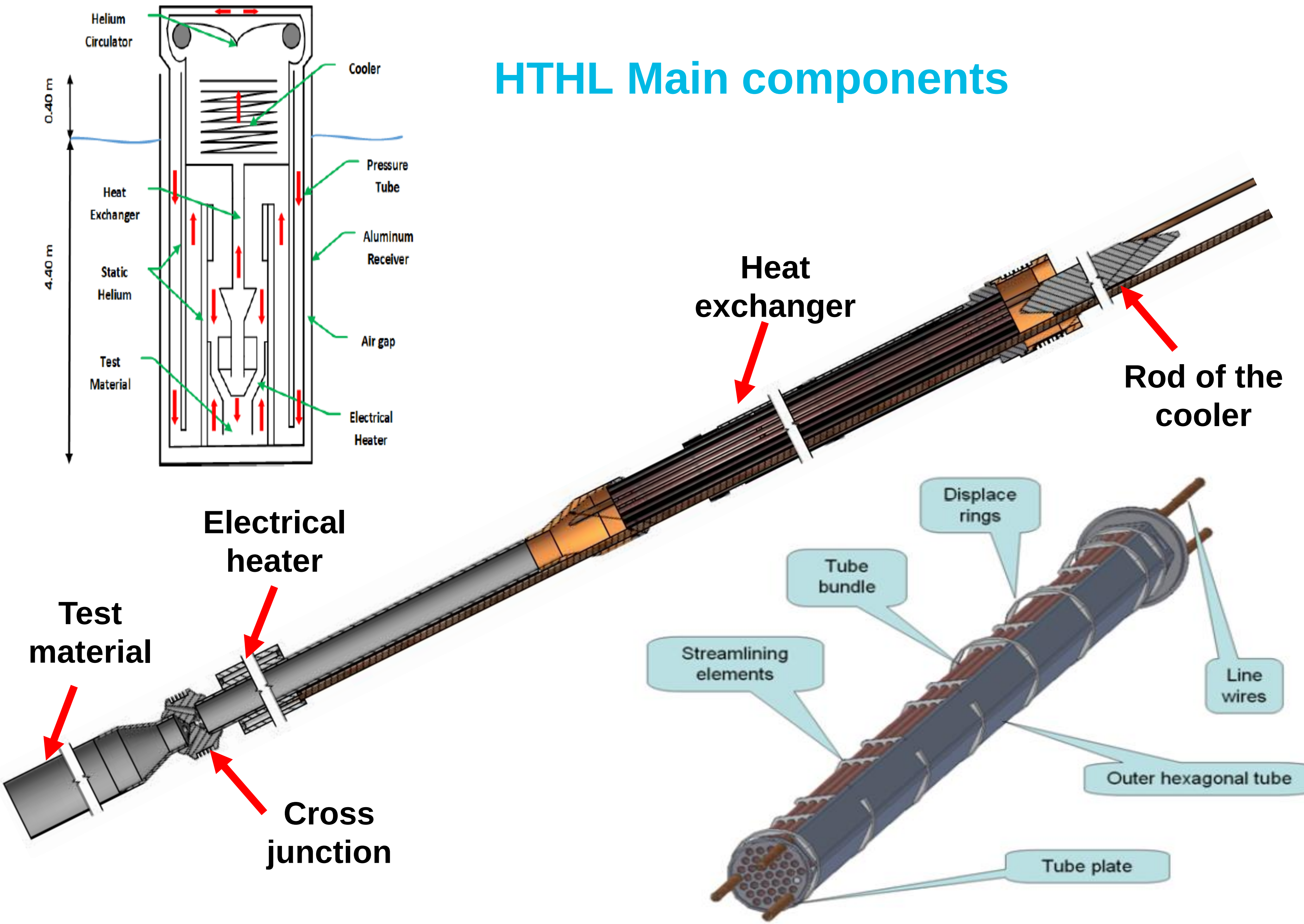
Introduction

- The Centrum Výzkumu Řež (CVŘ) and its partners are supporting the development of the Generation IV and Fusion technologies.
- The CVŘ has finalized a large investment program SUStainable Energy (SUSEN) for continuous R&D.
- The HTHL and SCWL loops are to be inserted inside the LVR-15 reactor in the CVŘ.
- The SUSEN project consists of 4 programs:
  1. Technological Experimental Circuits (TEO)
  2. Structural and System Diagnostics (SSD)
  3. Nuclear Fuel Cycle (NFC)
  4. Material Research (MAT)

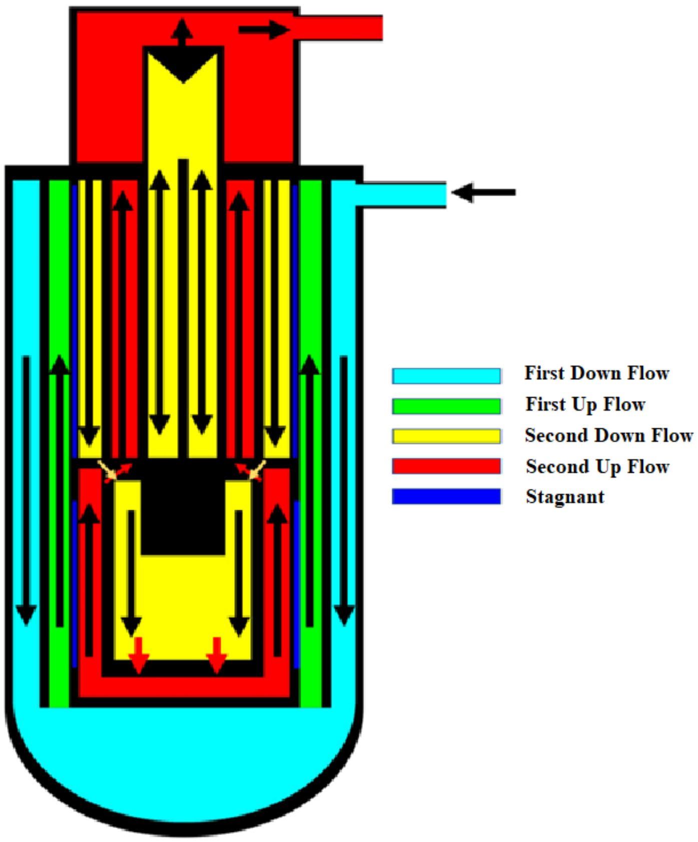
Facilities built under SUSEN Project

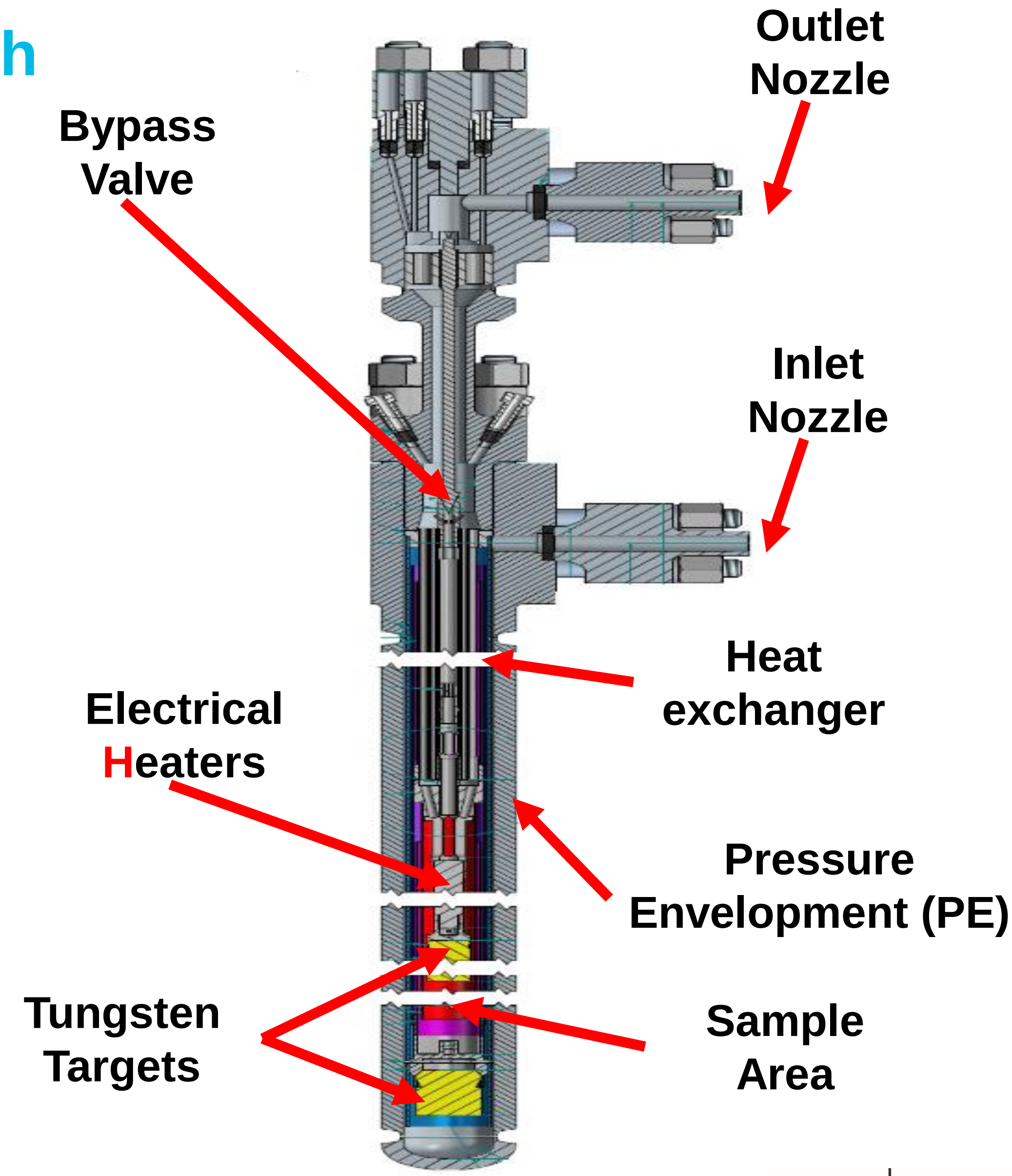


HTHL Main components

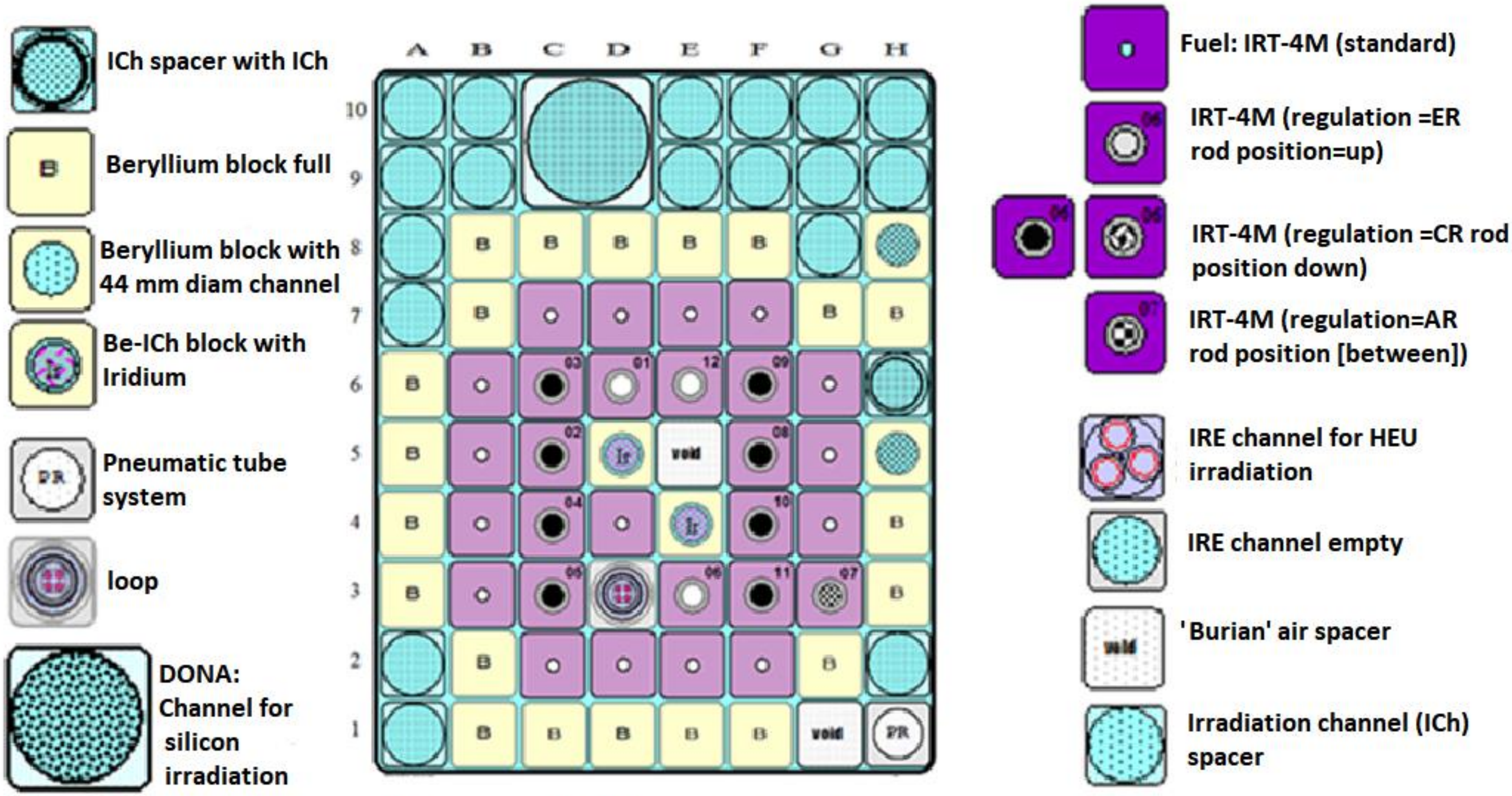


SCWL Flow and Sketch





Core of LVR -15 nuclear research reactor



ER=Emergency Rod CR=Compensation Rod
AR=Automatic Regulator

LVR-15 FSAR Amedment Methodology

- Assessing the codes capability to adequately simulate helium and SCW during steady-state and transients conditions.

- Creating the loop models to be used for the TH analyses.

- Performing analyses of the selected scenarios to verify the system performance in accordance with the safety criteria.

- Providing input data for structural analyses.

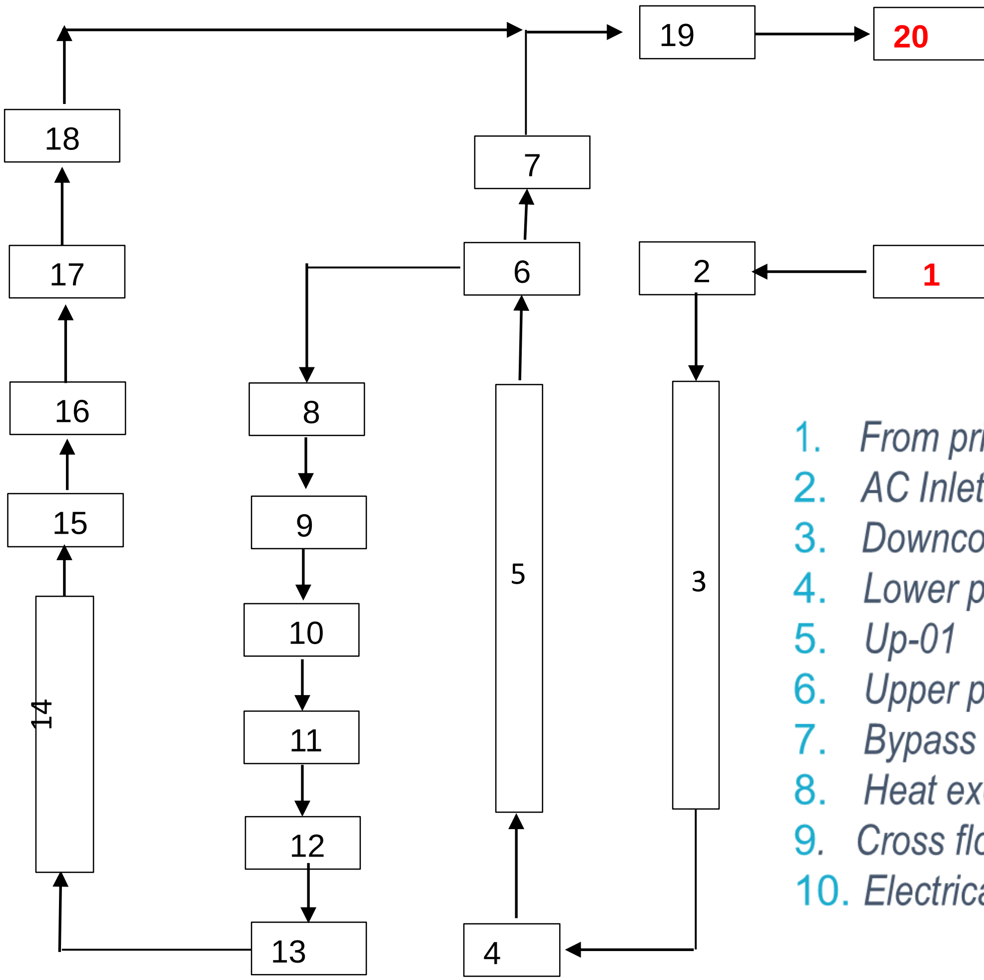
Codes used for simulation of SCW coolant: ATHLET

- Is a thermal hydraulic system code developed by the GRS for simulating time-dependent phenomena in the PWRs and BWRs.
- An additional module cover the pressure range from 22.5 to 100 MPa
- Several Independent correlations are setup for simulating the heat transfer in SCW conditions: Mokry and Gupta
- ATHLET 3.1A uncertainties:
  - HTC: ±25%
  - Wall temperature: ±10-15%.
- Regulatory certification acquired: March 2017

Code used for simulation of helium coolant: TRACE

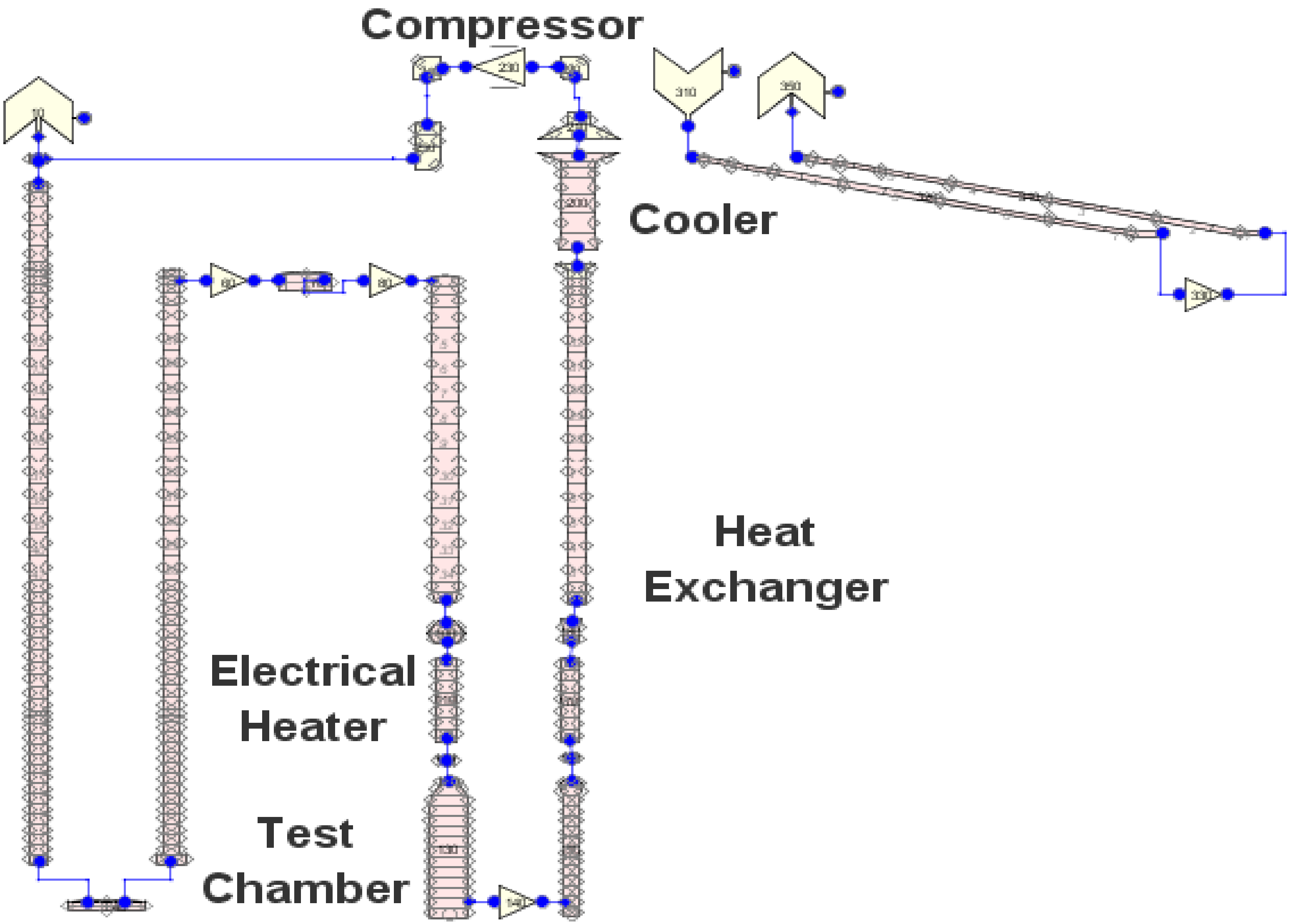
- TRACE has been designed by US NRC to perform best-estimate analyses during accident scenarios in Light Water Reactors (LWRs).
- It has been used as an alternative to the RELAP5/Mod3.3 code.
- The code was selected and used for the simulation for Helium at 7 MPa with a temperature rise from 200 °C up to 900 °C (nominal parameters for HTHL). The correlations adopted for the helium coolant are: Gnielinsky and El Genk.
- The TRACE HE-FUS3 thermal hydraulic model was developed and compared with experimental data from steady state loop operation and selected transients.
- Regulatory certification acquired: December 2016

SCWL ATHLET Model



1. *From primary circuit*
2. *AC Inlet*
3. *Downcomer*
4. *Lower plenum-1*
5. *Up-01*
6. *Upper plenum*
7. *Bypass flow*
8. *Heat exchanger*
9. *Cross flow*
10. *Electrical heater*
11. *Tungsten*
12. *Sample area*
13. *Lower plenum*
14. *Up-02*
15. *Cross flow*
16. *Heat exchanger*
17. *Upper plenum*
18. *Bypass Valve*
19. *AC Outlet*
20. *To the primary circuit*

HTHL TRACE Model



Scenarios Selections

Normal operating conditions	Pressure tests	Abnormal conditions	Accident conditions
Steady State LVR-15 Start up LVR-15 Shutdown Loops Start up Loops Shutdown	(not simulated)	Switch off electrical heater for 1 min. LVR-15 SCRAM and switch off of electrical heater at t = 0 s + pump trip after 1 min. Switch off electrical heater at t = 0 s + LVR15 SCRAM and Pump Trip after 3 min.	Loss of Flow Accident (LOFA) Loss of Coolant Accident (LOCA)

Safety Criteria for AC insertion in LVR-15

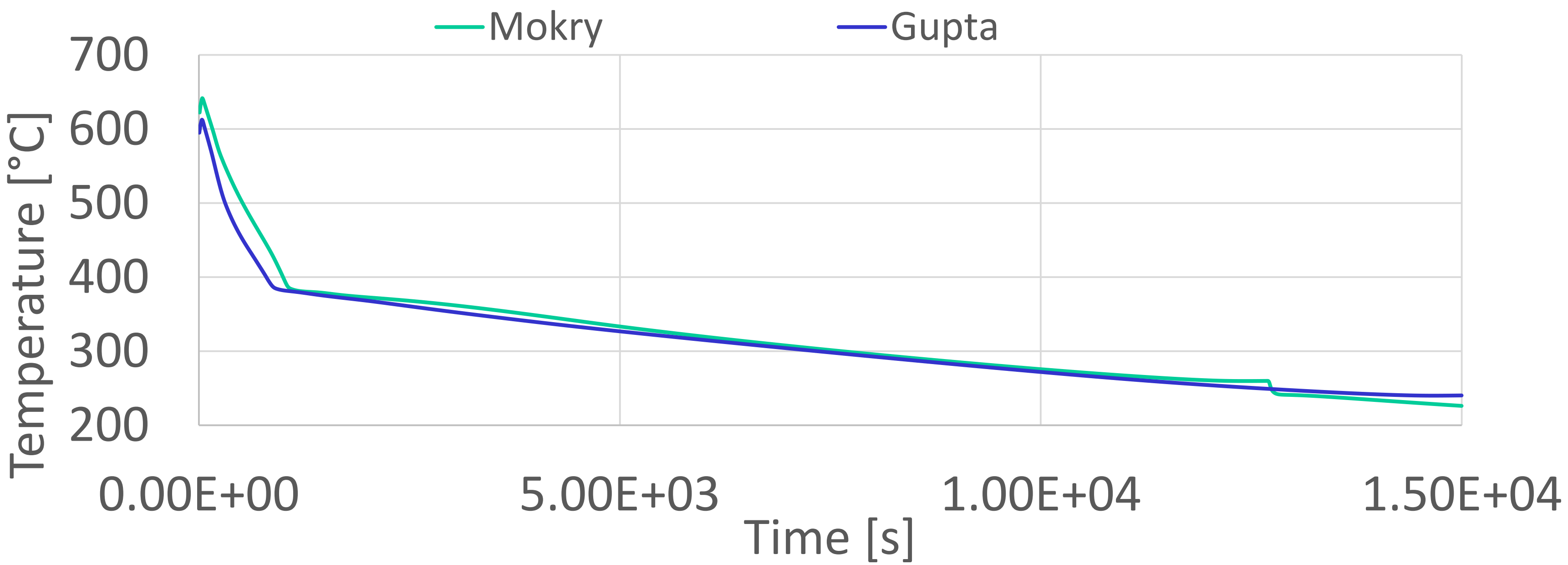
1. PE maximum temperature during normal/abnormal transients is less than 450°C
2. PE maximum temperature during accident conditions is less than 600°C
3. Aluminium surface of the Receiver maximum temperature in contact with LVR-15 coolant less than 45 °C during normal/abnormal conditions.
4. Aluminium surface of the Receiver maximum temperature in contact with LVR-15 coolant less than 60 °C during accident conditions.

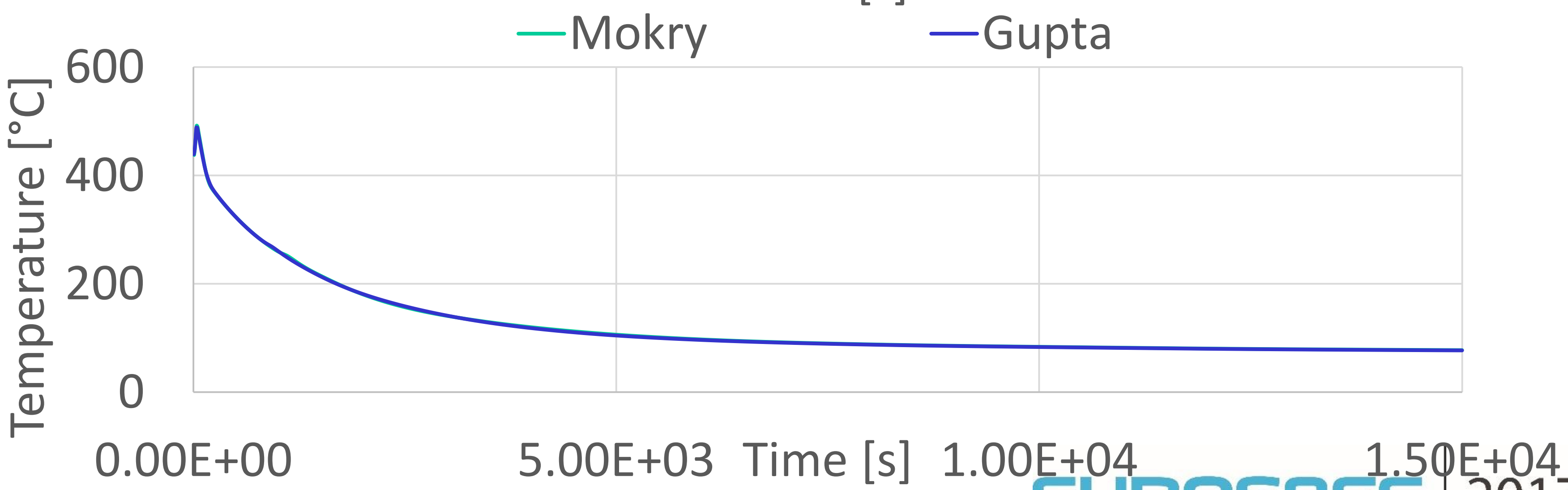
SCWL Steady State Parameters and LOFA Description

Parameter	Value	Unit
Pressure	25	MPa
Inlet Flow Temperature	385	ºC
Outlet Flow Temperature	406	ºC
Max Flow Temperature	600	ºC
Sample Area Mass flow	35	%
By pass flow	65	%
Mass flow	200	kg/h

1. Pump stops in 1 s after the initialization event (25001 s).
2. Active channel internal electrical heaters shut down to 0% on the nominal power in 7s (25007 s).
3. The LVR-15 SCRAM starts at 40 s when the maximum temperature in the PE rises above the 500 °C (25040 s).
4. The whole transient is completed in15000 s (40000 s), when the SCWL and LVR-15 are in the controlled cold state.

SCWL LOFA Results



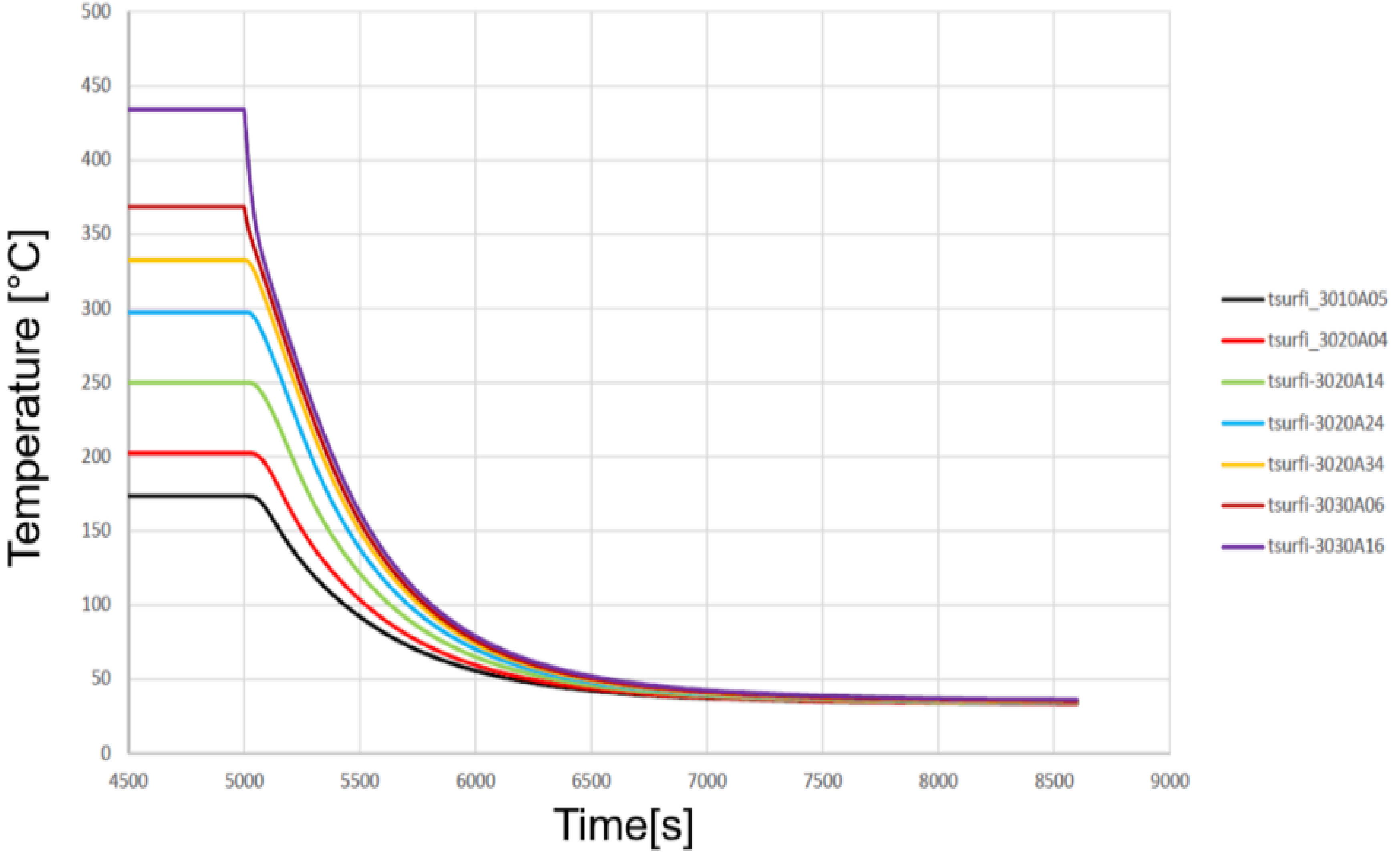


HTHL Steady State Parameters and LOFA Description

Parameter	Value	Unit
Pressure	7	MPa
Inlet Flow Temperature	210	ºC
Max Flow Temperature	900	ºC
Maximum AC Pressure Envelop (PE) Temperature	450	ºC
Mass flow	40	kg/h

1. The steady state simulation is 5000 s (the stabilized conditions were reached after 3500 s).
2. The LOFA transient~~s~~ was characterized by an immediate safety shutdown of the reactor due to the loss of power.
3. The temperature went immediately down following the heat generated by decay gamma flux.

HTHL LOFA Results Activities



Conclusions

- The SUSEN project significantly enlarged the experimental infrastructure of CVŘ.
- A significant part of the research programme is devoted to HTHL and SCWL to be placed into the active core of the LVR-15.
- A special methodology was used for:
  - Assessing the abilities of the codes to simulate these advanced coolants
  - Obtaining regulatory certificate/permit for using these codes for accidental analyses
  - preparing the amendment for LVR-15 FSAR
  - The codes assessment will be improved with data provided by the SCWL and HTHL loops in their experimental campaigns

Future Activities

- The codes assessment will be improved with data provided by the SCWL and HTHL loops in their experimental campaigns.
  - Out-of-Pile campaigns under preparation

- The new reviewed versions of the LVR-15 FSAR amendment will be harmonized between the two loops.

Thank you for your attention

http://susen2020.cz/
http://cvrez.cz/en/