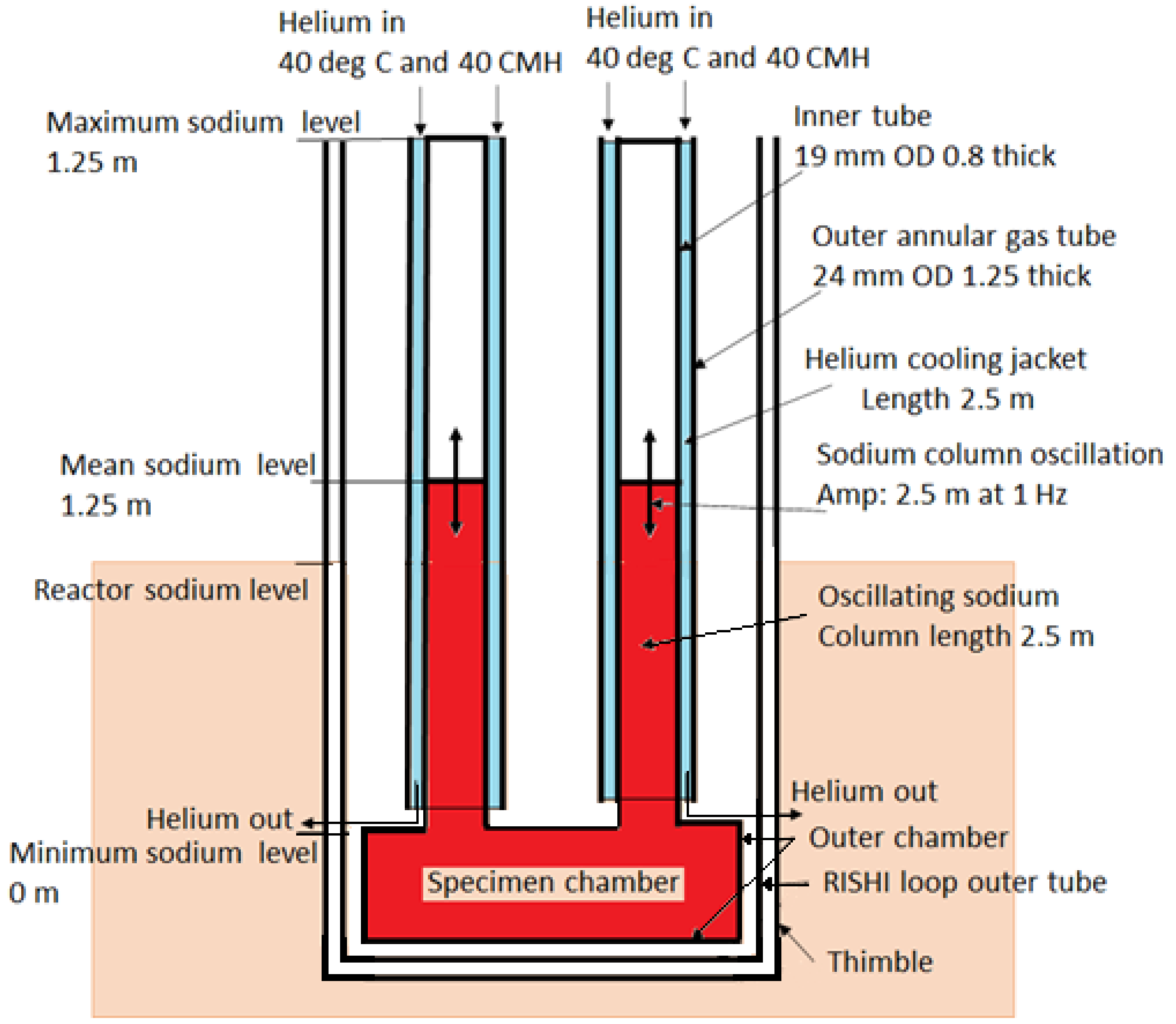
G. Vikram*, K. Natesan, M. Rajendrakumar, S. Raghupathy, IGCAR

Introduction & Background

- Nuclear research reactors are used for **testing materials** in neutron environment.
- It is essential to **cool the specimen chamber** because there is heat generation in the specimen and heat transfer from the surrounding
- Due to **space constraints** in the reactor, a compact **cooling arrangement (**shown in figure) was proposed
- The chamber at bottom is connected to two limbs each half-filled with **liquid sodium**. **Argon cover gas** is present above sodium to prevent its contact with air.
- Sodium level in the limbs is varied using an **oscillator**.
- Outer tubes are provided around the limbs and form the **annular cooling jackets** through which **helium** is passed to remove the heat from sodium in the limbs.
- In the reference design, sodium oscillates with an amplitude of **2.5 m at 1 Hz**, helium inlet pressure = 2 bar, temperature = 313 K, mass flow rate =40 CMH



Schematic of the cooling scheme for the specimen chamber

G. Vikram*, K. Natesan, M. Rajendrakumar, S. Raghupathy, IGCAR

Methodology

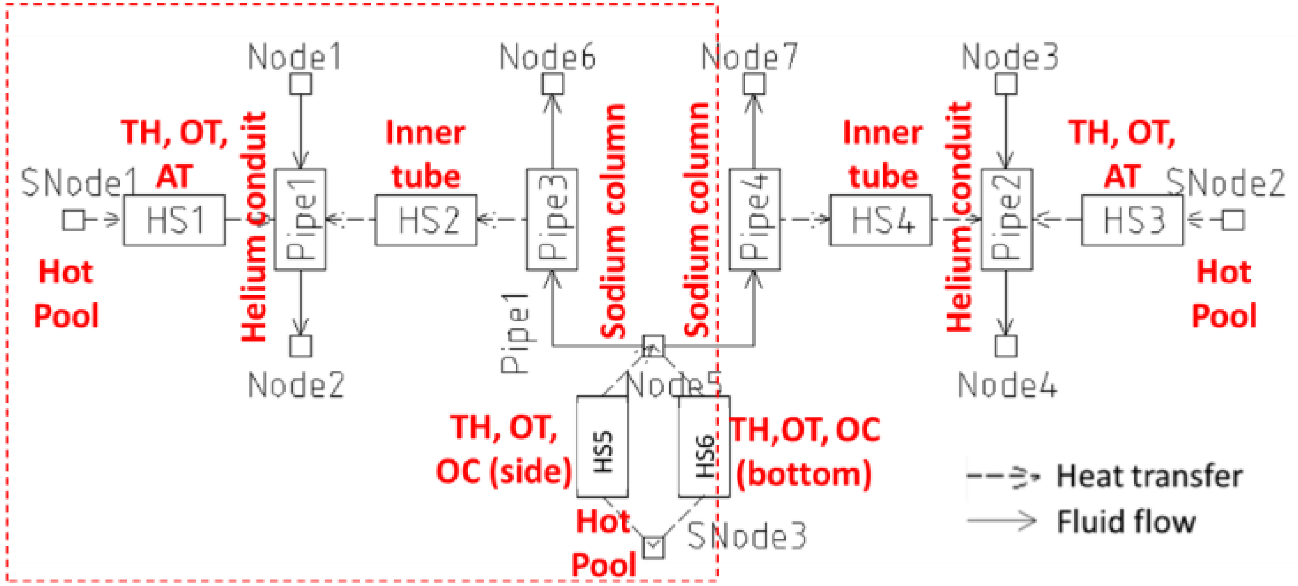
- The general-purpose in-house system dynamics code **PINET** has been used for the study.
- **Assumptions**:
  - Thermal capacities of the specimen chamber and argon were not considered
  - Walls in contact with gas were treated adiabatic
  - **Variable time steps** were used
- Dittus-Boelter correlation on helium side & Seban-Shimazaki correlation on sodium side were used to determine heat transfer rates.
- Heat addition to the domain is due to contact with **hot pool sodium at 515 °C**.

$$\frac{\partial(\rho A)}{\partial t} + \frac{\partial(\rho V A)}{\partial x} = d'''$$

$$\frac{\partial(\rho V)}{\partial t} + \frac{\partial(\rho V^2 A)}{A\partial x} + \frac{\partial p}{\partial x} + \rho g\cos\theta + f\frac{\rho V|V|}{2D} = S_x$$

$$\frac{\partial\big(C(\rho h_0 - p)\big)}{\partial t} + \frac{\partial(C\rho V A h_0)}{A\partial x} = q'''$$

$$C_p\frac{\partial(\rho T)}{\partial t} = \frac{1}{A}\frac{\partial}{\partial x}\left(kA\frac{\partial T}{\partial x}\right) + \frac{1}{A}\frac{\partial}{\partial y}\left(kA\frac{\partial T}{\partial y}\right) + q'''$$



Schematic of the model

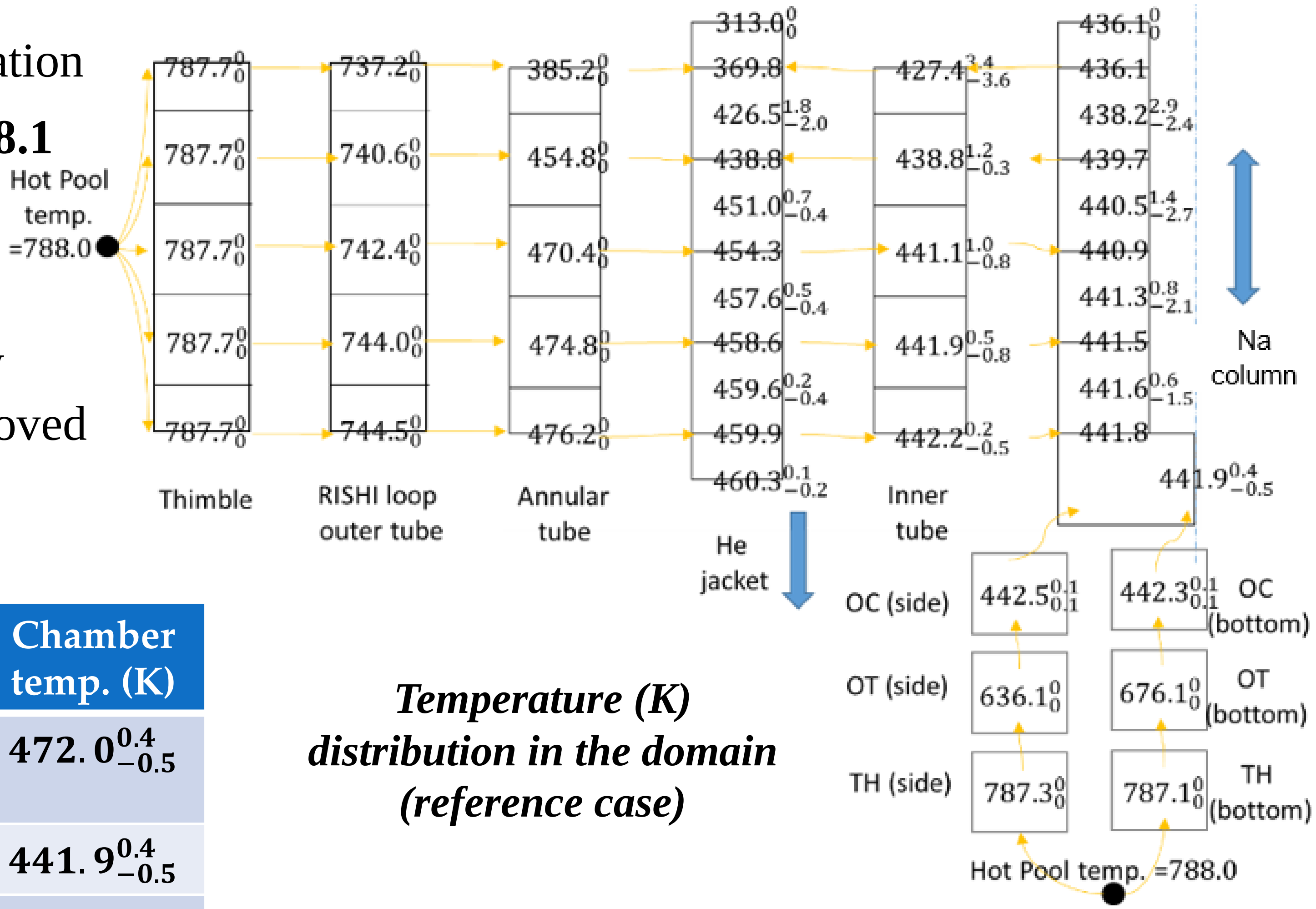
G. Vikram*, K. Natesan, M. Rajendrakumar, S. Raghupathy, IGCAR

Results and Discussion

- All temperatures **oscillate** due to sodium oscillation
- Average specimen temperature = **~441.9 K (168.1 °C)** - peak-to-peak amplitude of chamber temperature oscillation = **~0.9 K**
- Average net heat added = **~1.56 kW per limb** (~1.26 kW from the helium jacket and ~0.3 kW from the chamber region) - equals the heat removed by helium (thereby ensuring **heat balance**)
- **Parametric Studies:**

He inlet temp.	Chamber temp. (K)
Ref. Value – 10 K	$433.9^{0.4}_{-0.5}$
Ref. Value	$441.9^{0.4}_{-0.5}$
Ref. Value + 10 K	$449.9^{0.4}_{-0.5}$

He flow	Chamber temp. (K)
80 % nominal	$472.0^{0.4}_{-0.5}$
Nominal	$441.9^{0.4}_{-0.5}$
120 % nominal	$423.5^{0.4}_{-0.5}$



Temperature (K) distribution in the domain (reference case)