



# Numerical investigations of a prototype monolithic channel receiver in the SOLTEC-1 high temperature sodium loop

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# **Background, motivation and tasks**

- 1000 K SOLTEC-1 (SOdium Loop to TEst Corrosion and materials) facility
- Developed in the frame of the Helmholtz Energy Material Characterization Platform (HEMCP) and Helmholtz Alliance on Liquid Metal Technology (LIMTECH) at KIT-INR.
- SOLTEC-2: Similar construction; Facility is presently used for corrosion investigations of high temperature steels.
- Monolithic channel receiver (Inconel 718) to be integrated in SOLTEC-1 facility and qualified at sodium temperatures > 700°C.
- · Task 1: Numerical investigations of the thermo-dynamic behavior of the test monolithic channel.
- Task 2: Assessment of the required heat energy throughput for the preparation of the experimental campaign in SOLTEC-1.

### **Technical specifications SOLTEC-1**

- Mass flow rate: 300 kg/h (3kW permanent magnet pump)
- Velocities: up to ~ 4.8 m/s in test sample (Re: 114 824)
- Pressure loss: S-1: ~ 1.6 bar; S-2: ~ 0.45 bar
- Temperature: cold loop 700 K; hot loop 1000 K
- · Max. pressure: 3.5 bar g
- Compact configuration: 1.2 × 1.6 × 1.9 m<sup>3</sup>
- Na inventory: ~ 14 L
- Main components: Na-pump, Na-air HX coupled to a Na-Na heat recuperator (with integrated flow distributor), storage tank (expansion vessel)
- Ar is used as cover gas to fill/drain the facility and pressure monitoring

# Additive manufactured receiver prototype

- 3D printed monolithic channel receiver manufactured using the Selective Laser Melting method and the Cold Spray metal powder deposition.
- · Prototype manufactured at KIT from Inconel 718 powder.
- · Inner and outer spiral rectangular channels and feed hoppers at the ends.
- Internal flow channels are integrated for improved mixing and heat transfer

### SOLTEC-1: CFD model and numerical results

- ANSYS CFX 2023: Conjugate heat transfer model (Na, air, stainless steel, Inconel).
- Numerical grid: 41.2 mio. cells (49% hexagonal, 45% tetrahedral, 3% pyramids, 3% prisms); y+ < 1 (regions of interest).</li>
- Heat transfer model: thermal energy.
- Turbulence modelling: ω-RS (Na) and SST (air).
- · Air, Na and material properties implemented as temperature dependent.
- Turbulent Prandtl number: Pr<sub>turb</sub> (air) = 0.85;
- Pr<sup>1</sup><sub>th</sub>(Na)=0.014 Re <sup>0.045</sup> Pr <sup>0.2</sup> {1-exp[-1/(0.014 Re <sup>0.045</sup> Pr <sup>0.2</sup>)]} [Aoki, 1963]
- Thermal losses based on experimental data from SOLTEC-2.
- Thermal effectiveness of the Na-Na heat recuperator:

 $\in$  =  $c_h (t_{h1} - t_{h2}) / c_{min} (t_{h1} - t_{c1})$ 

ı	Sodium flow rate [kg/h]	rate		test receiver	e inlet	outlet		Mean velocity inlet receiver [m/s]	
	300	67.4	2.97	1.0	730.6	788.9	58.3	0.49	78.0
	300	67.4	2.97	1.5	795.7	881.3	85.6	0.51	79.4
	300	67.4	0	2	749.7	863.9	114.2	0.50	77.9

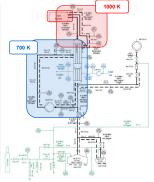
# References:

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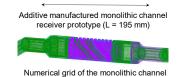


SOLTEC -1: Piping and instrumentation diagram

SOLTEC -1 facility (CAD model)

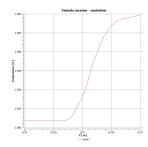
Air outlet

High temperature heater
Na-Na heat recuperator
Na-la heat recuperator



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Temperature distribution @  $q_{receiver} = 1 \text{MW/m}^2$ ,  $m_{Na} = 300 \text{ kg/h}$ 



Temperature distribution in test receiver (centerline) @  $q_{receiver}$  = 1MW/m²,  $m_{Na}$  = 300 kg/h

# **Conclusions**

- Developed numerical model of the SOLTEC-1 facility integrating a monolithic channel design, proposed as material for a CSP receiver.
- Optimized heat transfer in the heat recuperator (flow distributor): uniform temperature distribution and increased efficiency of the heat recuperator.
- Operating range of the facility investigated for preparation of the experimental campaign.
- Numerical investigation of the monolithic channel design performed up to 2 MW/m<sup>2</sup>.