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Innovative 1000K sodium loop for qualification of new materials for applications in CSP field

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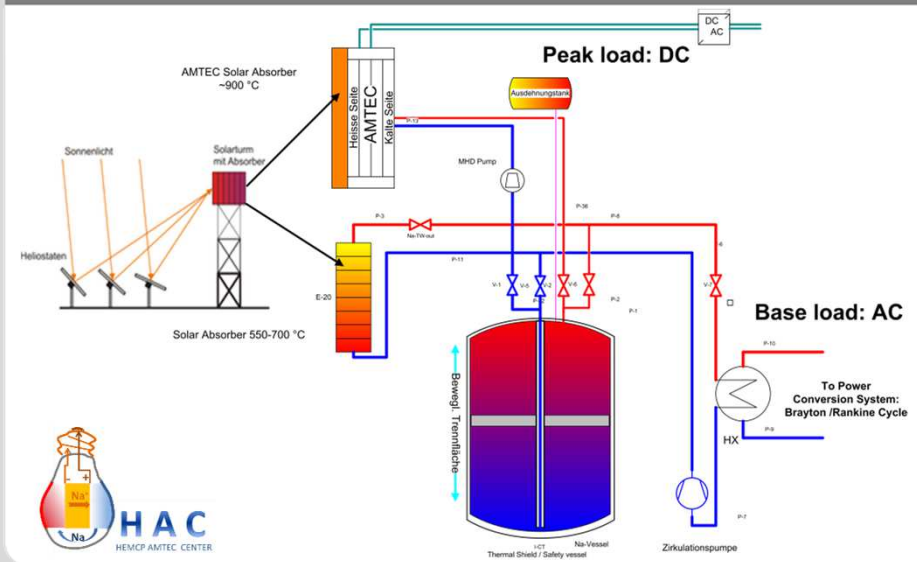
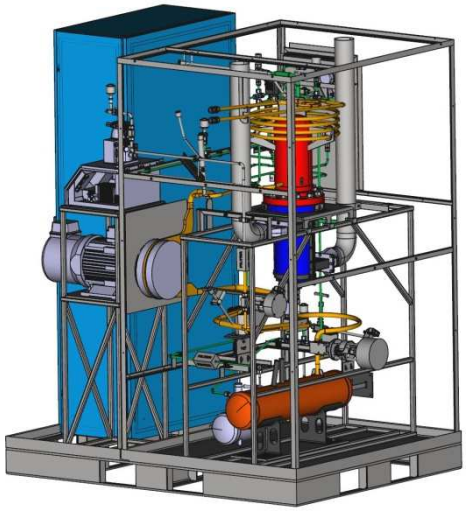
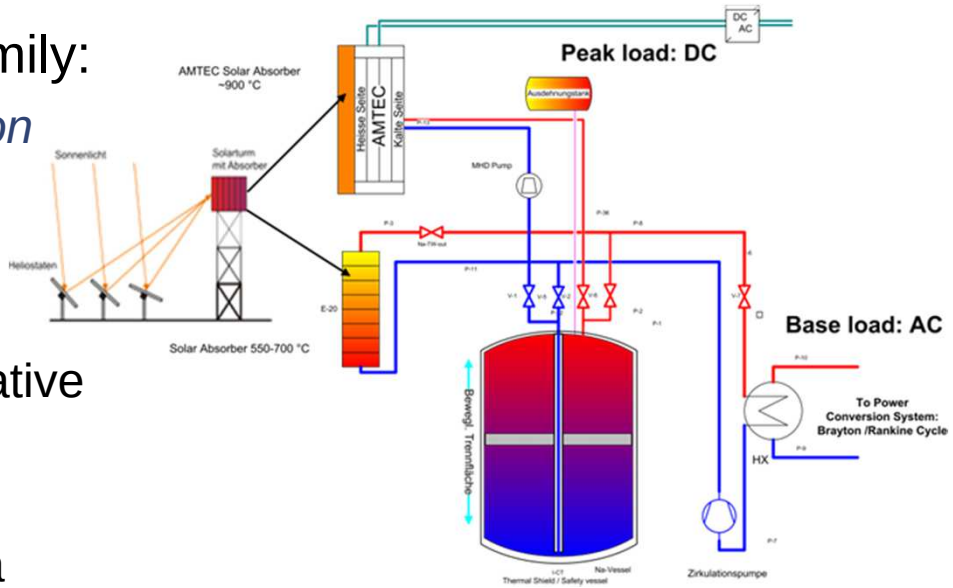




Introduction

- CSP concept[1] of solar tower plant with Na as HTF and AMTEC[2] direct thermoelectric convertes → R&D on materials and components
- Main tasks for the SOLTEC* ** [3] family:
  - *Material development and qualification* for high temperature applications (collaborations with IAM-AWP, IHM)
  - Soltec-1: *Creep fatigue* tests of innovative materials in hot Na
  - Soltec-2: *Corrosion/erosion* tests for conventional and new steels in hot Na
  - Soltec-3: Tests for *new thermoelectrical converters* and new *LM receiver designs* and materials



[1] W. Hering et al. – Europ. Ph. J. 33, 03003 (2012)

[2] AMTEC: Alkali Metal Thermal-to-Electric Converter

[3] SOLTEC: SOdium Loop for TEst Materials and Corrosion

* Developed in the frame of the Helmholtz Energy Material Characterization Platform (HEMCP) and Helmholtz Alliance on Liquid Metal Technology (LIMTECH)

** Funded by HEMCP (Helmholtz Energy Materials Characterization Platform)

SOLTEC-1/2 Technical data

LIMTECH Alliance

HEMCP:Helmholtz Energy Materials Characterization Platform

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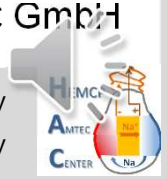
- Compact configuration: 1.2 × 1.6 × 1.9 m^3
- Main components:
  - Na-pump (3kW permanent magnet pump)
  - Na-air HX (7.5 kW) and Na-Na heat recuperator (27 kW)
  - Storage tank (15 L) as expansion tank
  - HT heater (6.7 kW); Heating power: ~40 kW
- Materials: Inconel (HT side), 316Ti (LT side)
- Cover gas: Ar (fill/drain, pressure monitoring)
- PLC: Siemens Simantec S7
- Instrumentation: Na/Ar – pressure, temperature, Na-level meter, Na flowmeter
- Mass flow rate: 300 kg/h
  - S1: ~ 5 m/s (test sample)
  - S2: ~ 1 m/s (test sample Re ~28600, 300°C)
- Temperature: cold loop 450°C; hot loop 720°C
- Max. pressure: 3.5 bar g

Manufacturer: SAAS GmbH, SOWEC GmbH



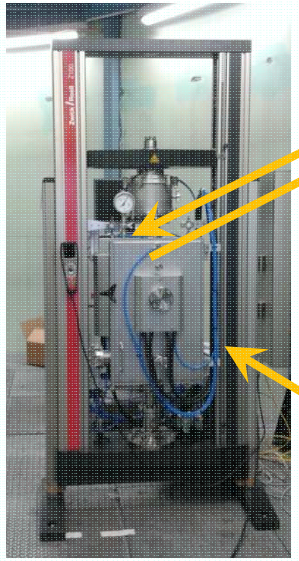
Safety measures

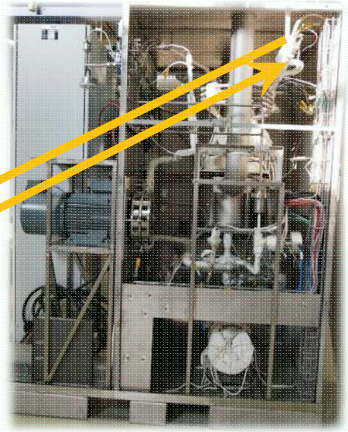
- Dedicated infrastructure for LM facilities (KASOLA facility, LM lab)
- Fail safe design:
  - Fast drainage is to be made at any critical malfunction
  - Sample rupture: vacuum monitored in the test chamber
  - Heater and pump to be stopped either by the programmable logic controller (PLC) or by sensors operating separately from the PLC
- Limited amount of Na (~14 L)
- Ar used as cover gas. All argon/sodium interfaces protected by filters
- All Na valves have a NO configuration
- Low overpressure in any operation state
- Any leackage to be detected by the leackage detection system:
  - Emergency drainage
  - Ar intake
- Any possible fire/smoke limited within the insulated metallic housing
- Na collection tray in the bottom part of the framework

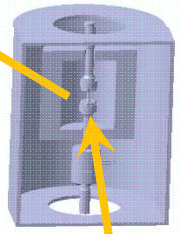
SOLTEC – SOdium Loop for TEst materials and Corrosion

Test sections:

SOLTEC - 1





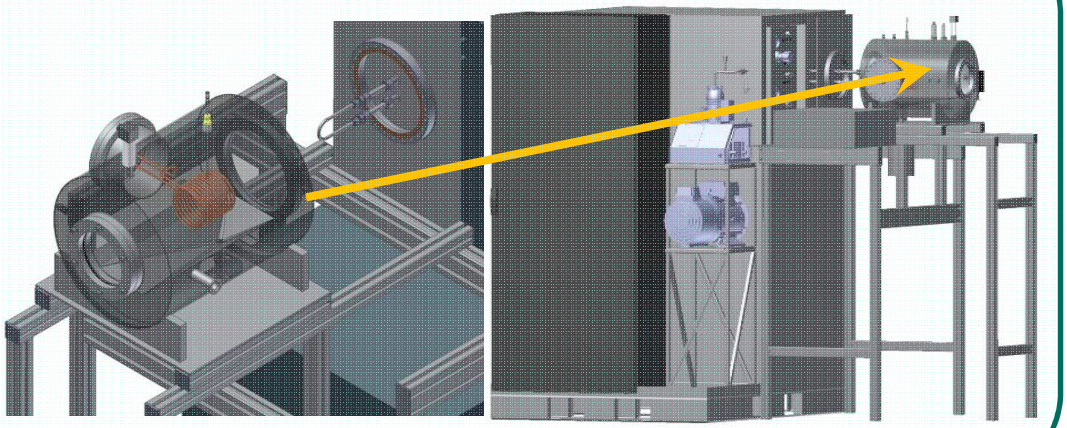


Zwick/Roell Z100 universal traction facility (Low cycle fatigue tests)

Innovative W-Cu compounds*

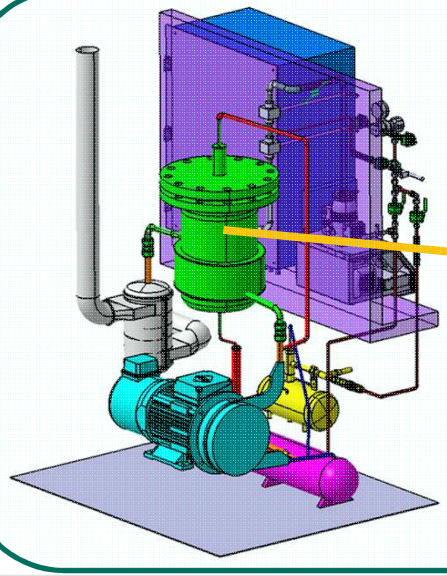
*J. Reiser et al. - Advanced Eng. Mat. 17, 491 (2015)

SOLTEC - 2

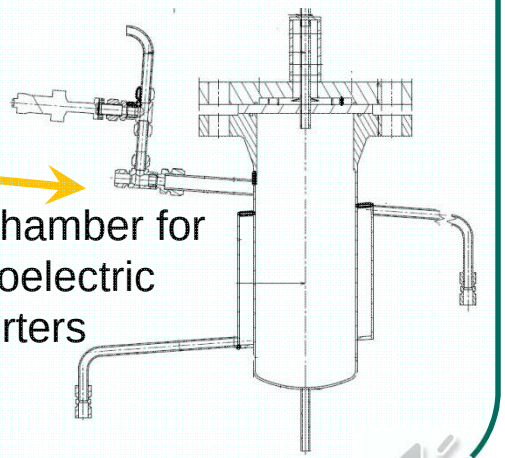


Material test chamber

SOLTEC - 3



Test chamber for thermoelectric converters



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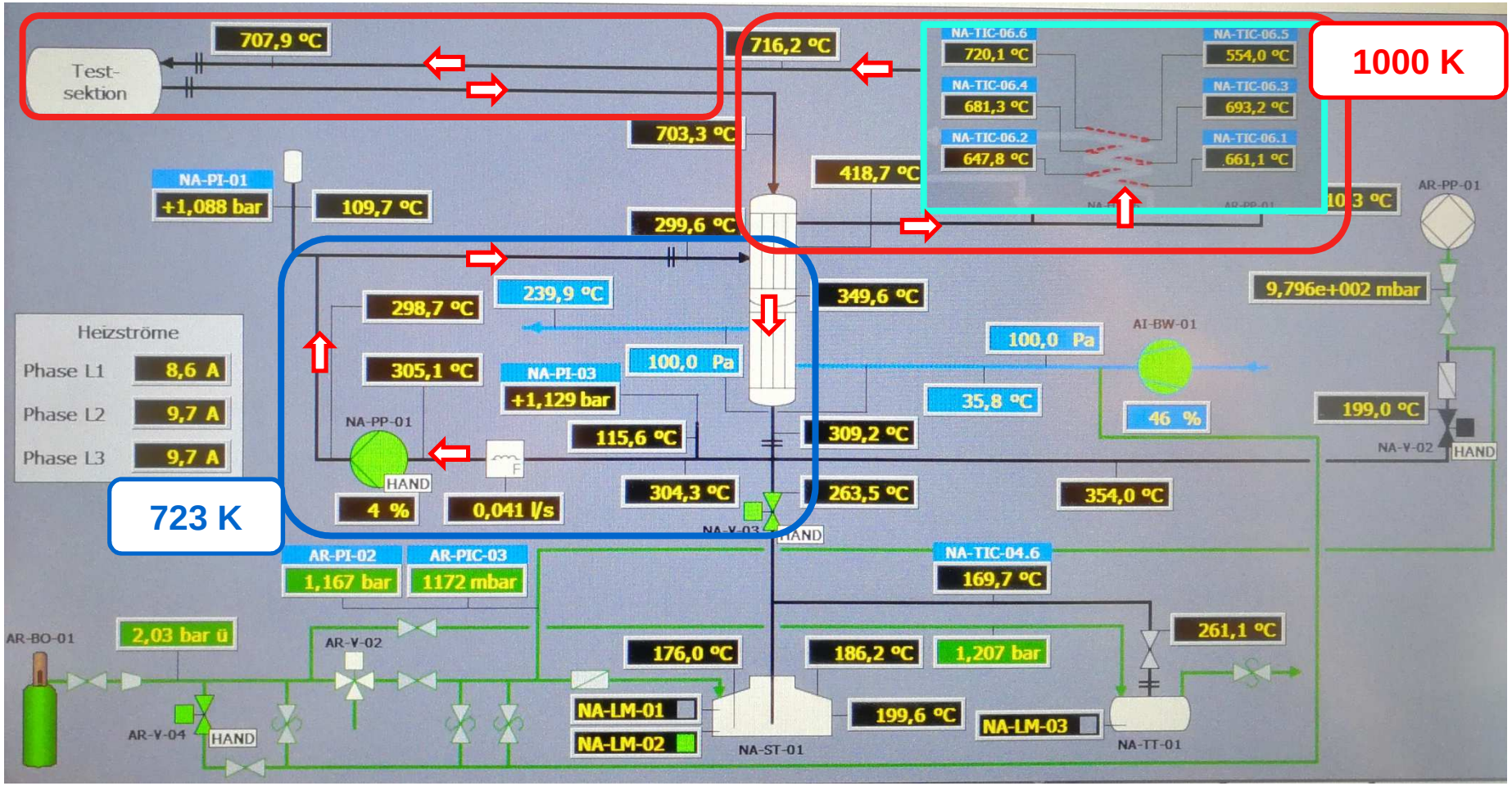
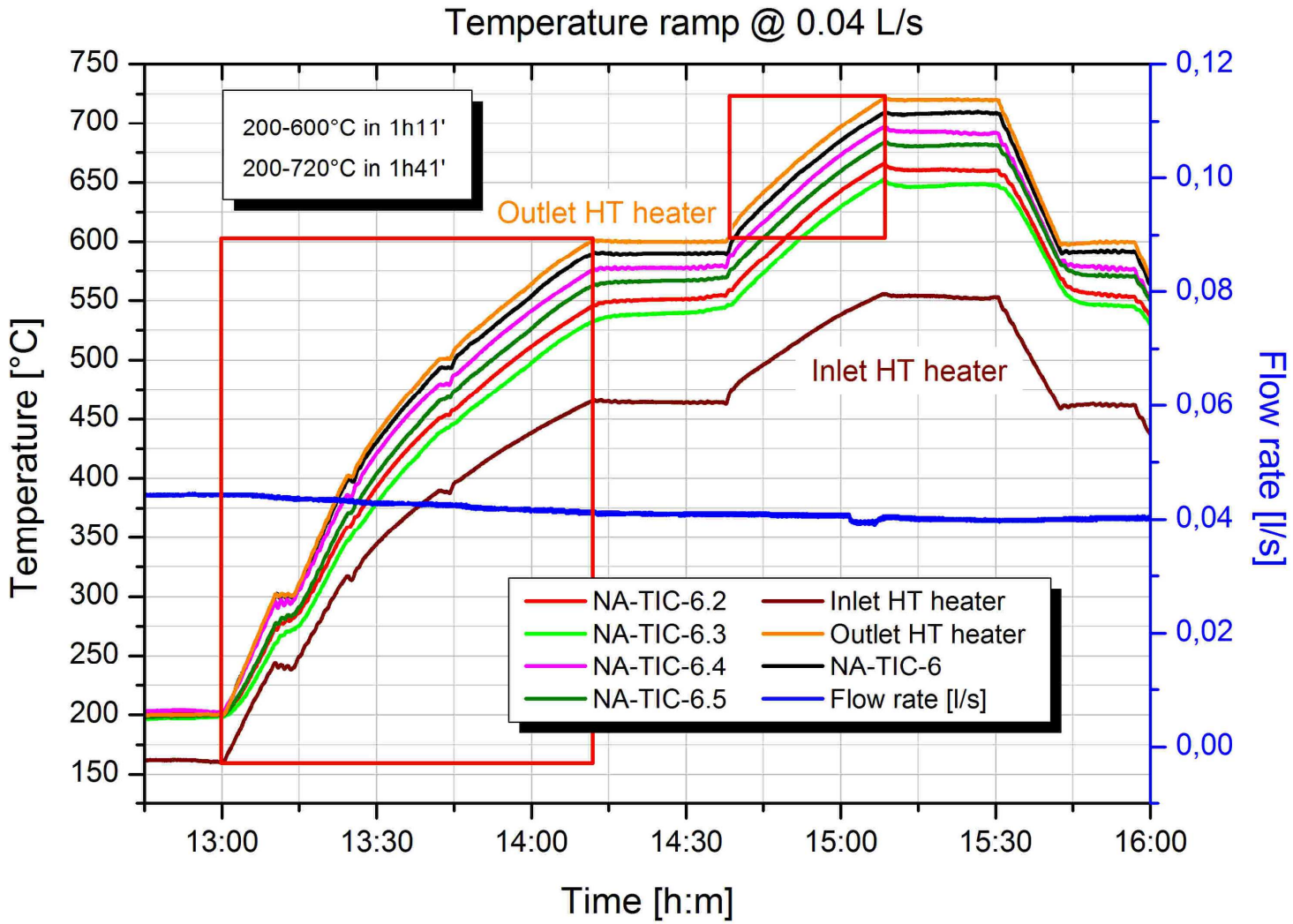
Operation at maximal temperature



Temperature distribution and ramp

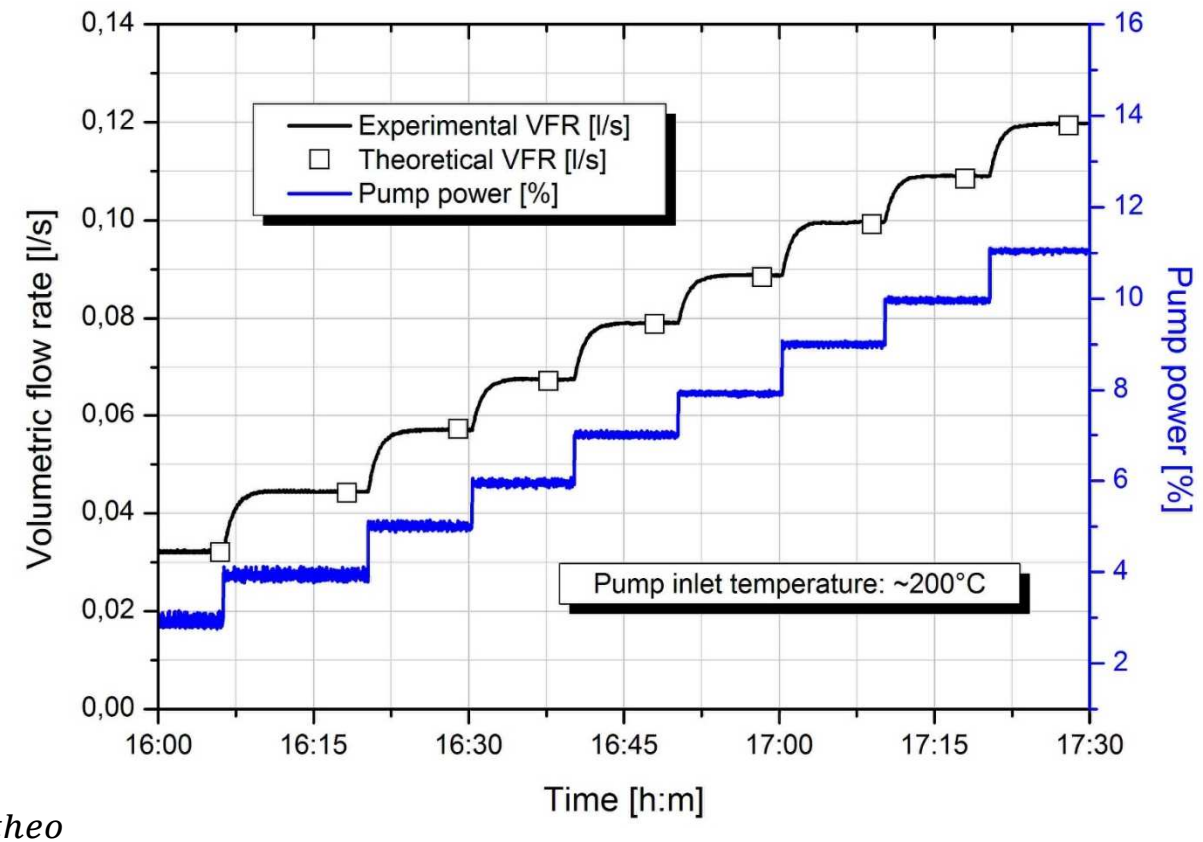


Flow rate

Calibration flowmeter*:

$$\dot{V} = \dot{V}_0 \frac{\sigma_{InGaSn}(\vartheta_0)}{\sigma_{Na}(\vartheta)} + \left(k \frac{\dot{\sigma}_w(\vartheta)}{\sigma_{Na}(\vartheta)} + 1 \right) 2\pi r A \, n(\vartheta)$$

$\dot{V}_0$ – reference volume flow rate
σ – electrical conductivity
n – rotational speed
A – channel cross section
r – radius channel

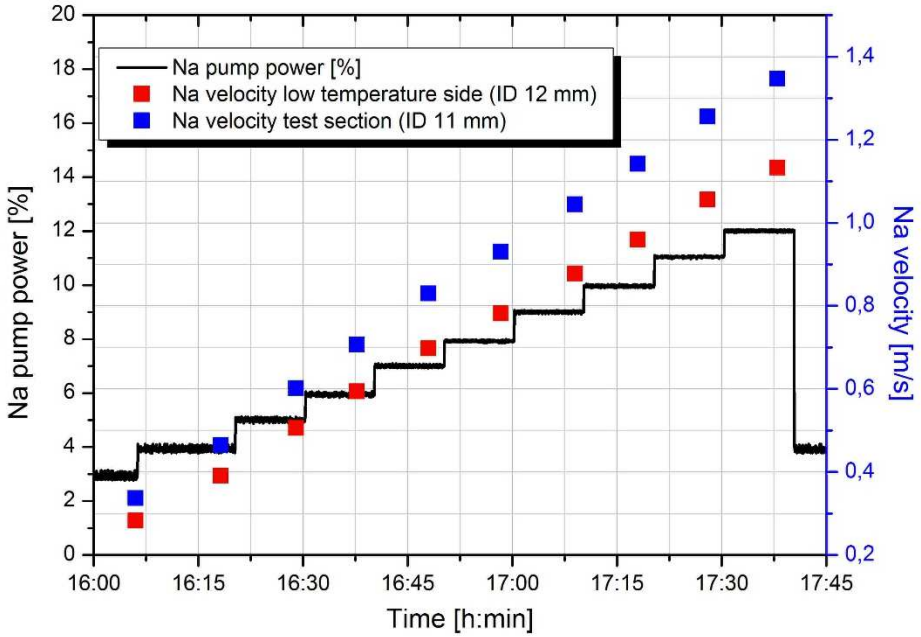


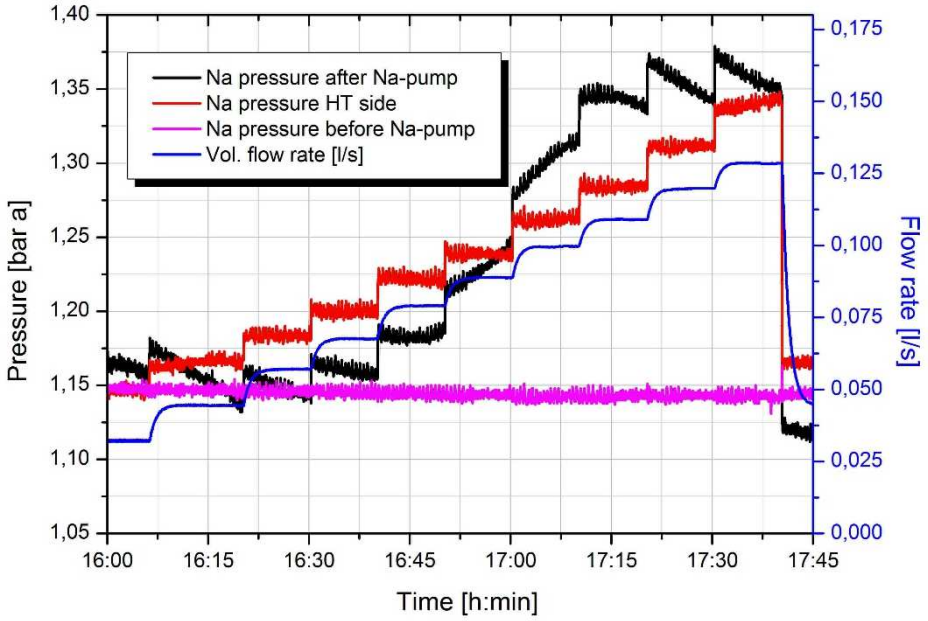
Validation: $\dot{Q} = m \, \dot{c}_p \, \Delta T \rightarrow \dot{V}_{theo}$

Agreement $\dot{V}_{theo}$ vs. $\dot{V}_{exp}$: 2.4-2.5 %

*S. Lenk, SaaS GmbH

Sodium velocity and pressure distributions





Na velocity in test section: up to ~1.35 m/s
Temperature ~200°C

Na overpressure: up to ~ 0.38 bar

Thank you for your attention!

See also:

Joachim Fuchs, Michael Böttcher, Wolfgang Hering, Robert Stieglitz -
„Computational fluid dynamic investigations on a small scale liquid sodium loop”

W. Hering, A. Onea, J. Fuchs, T. Schaub, A. Weisenburger, H. Neuberger, R. Stieglitz –
„*Innovative receiver designs to enhance availability and reliability of sodium systems*“