Karlsruhe Institute of Technology

Institut für Neutronenphysik und Reaktortechnik
Anlagenentwicklung, Systemdynamik und Sicherheit

HELMHOLTZ ASSOCIATION

LIMTECH Alliance *and HEMCP: Helmholtz Energy Materials Characterization Platform*

Development of an Alkali Metal Thermal to Electric Converter (AMTEC)

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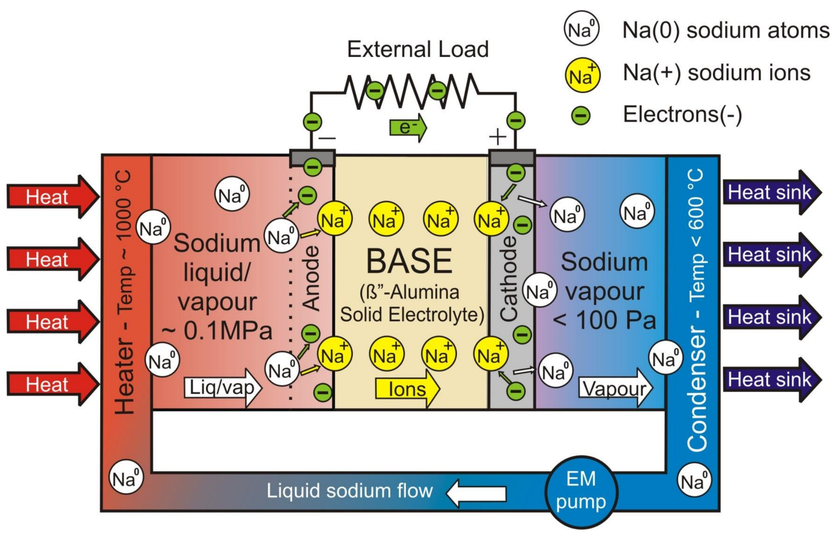
HEMCP AMTEC CENTER

AMTEC operating principle

- Direct conversion of thermal energy into electricity
- Key component: β''-Alumina Solid Electrolyte (BASE)
- Key process: Na-ionization (Δp across BASE)

$$Na \rightarrow Na^+ + e^-$$

- Recombination of Na^+ and e^- only at 3-phase boundaries: BASE – electrodes – Na
- Na condensation
- Na return line: electromagnetic pump



Operating principle of AMTEC

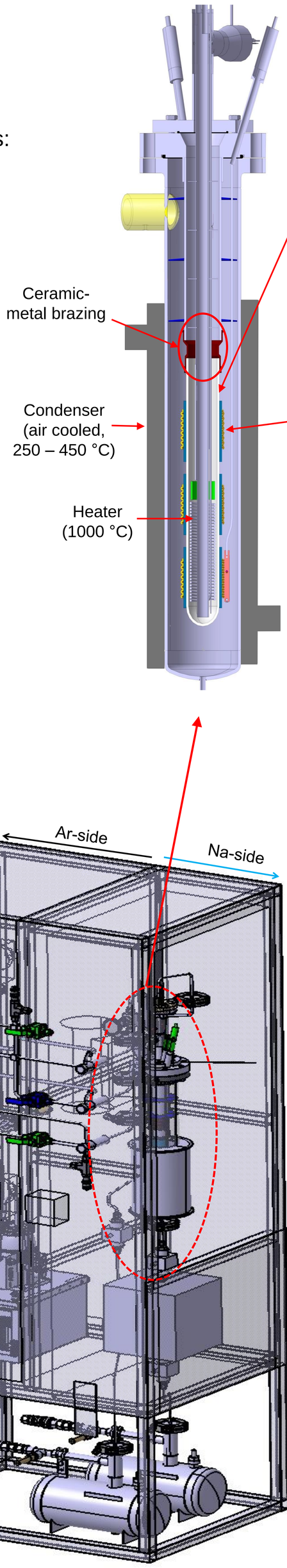
Open issues

- Cell efficiency (η_{theo} ~ 45 %)
- Contribution to power degradation:
  - BASE degradation ~ 60 – 70 %
  - Electrode degradation ~ 20 %

Variable	AMTEC @ INR
V	0.4 – 1.2 V
I	0.5 – 1.5 A/cm²
P	0.5 – 1.5 W/cm²
$\eta_{present}$	~ 20 %
T_{Na}	600 – 1000 °C
p_{Na}	10 Pa – 0.1 MPa

AMTEC TEst FAcility (ATEFA)

- At present under construction
- Control Na-flow
  → adjustment Ar properties (p_{Ar} & $\dot{m}_{Ar}$)
- Safety aspects:
  - Contained in an thermally isolated metallic box
  - Na-side separated from Ar-side
  - Emergency Na evacuation: delivery in both tanks



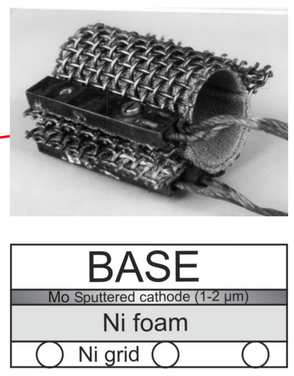
AMTEC test cell

Requirements for:
(+) fulfilled
(-) improvable

BASE (ß''-Alumina Solid Electrolyte)

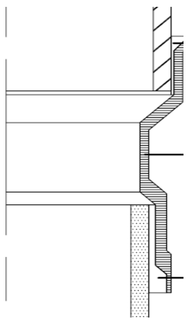
- High ionic conductivity (0.38 1/Ωcm at 400 °C) (+)
- Negligible electron conductivity (1.1×10^{-4} 1/Ωcm at 650 °C) (+)
- Chemical stability in operation (-)

Electrode (Cathode) and current collector



- High electronic conductivity / low resistance (-)
- Large amount of contact points to the BASE → recombination rate of sodium ions in sodium vapor (+)
- Good sodium vapor transport (-)
- Stability at high temperatures (grain growth) (-)

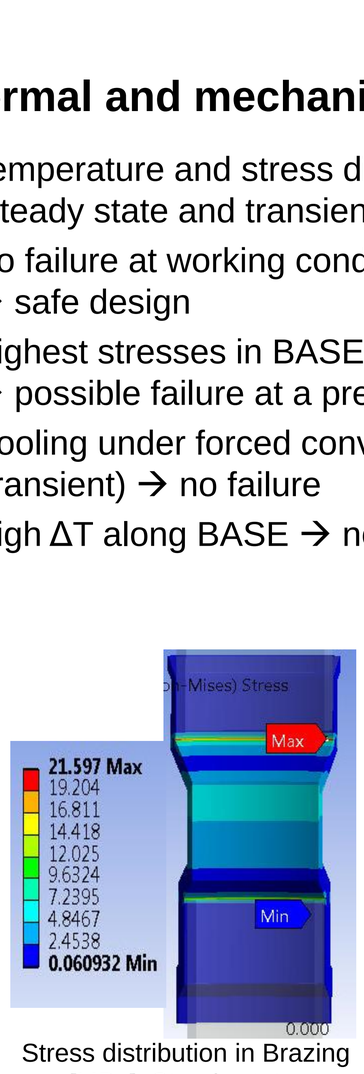
Ceramic to metal joining



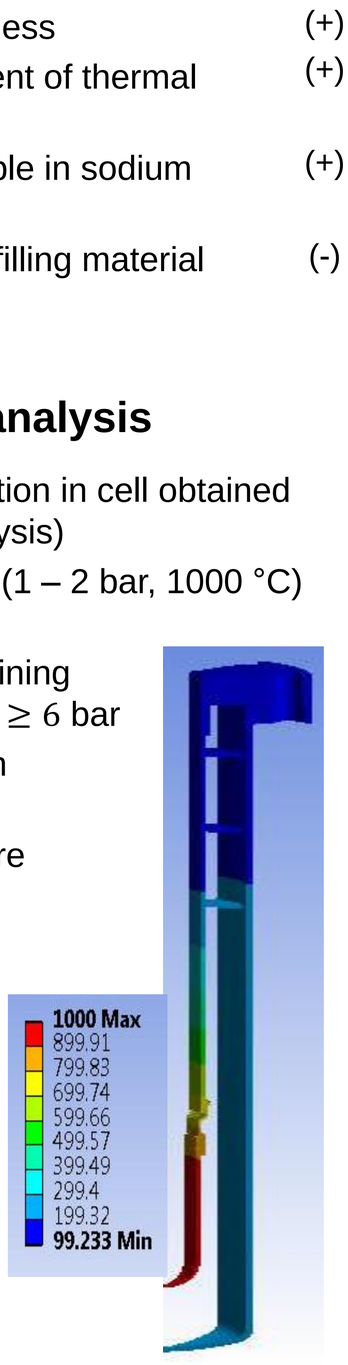
- High leak tightness (+)
- Similar coefficient of thermal expansion (+)
- Chemically stable in sodium environment (+)
- No diffusion of filling material (-)

Thermal and mechanical analysis

- Temperature and stress distribution in cell obtained (steady state and transient analysis)
- No failure at working conditions (1 – 2 bar, 1000 °C) → safe design
- Highest stresses in BASE-Nb joining → possible failure at a pressure ≥ 6 bar
- Cooling under forced convection (transient) → no failure
- High ΔT along BASE → no failure



Stress distribution in Brazing [MPa]. Steady state.



Temperature distribution in 1/8 of the cell [°C]. Steady state.