Karlsruhe Institute of Technology

Institut für Neutronenphysik und Reaktortechnik

HELMHOLTZ ASSOCIATION

LIMTECH Alliance

Phase changes in liquid metals for direct energy conversion

Alkali Metal Thermal to Electric Converter (AMTEC)

Project: **B4**

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Introduction / Motivation

The Alkali Metal Thermal to Electric Converter (AMTEC) is a concentration cell that works with liquid/vapor sodium at very high temperatures (~ 800 °C) and converts heat directly to electricity. AMTEC cells tested so far have shown an efficiency of ~ 20 %, low compared to the theoretical efficiency (~ 40 %). At KIT innovative materials and processes are being investigated, which establish promising solutions focused on the technological challenges of AMTEC.

Our long time perspective is the combination of advanced AMTEC cells and Concentrating Solar Power plants to achieve an increased overall efficiency and a better profit/cost ratio.

PhD progress

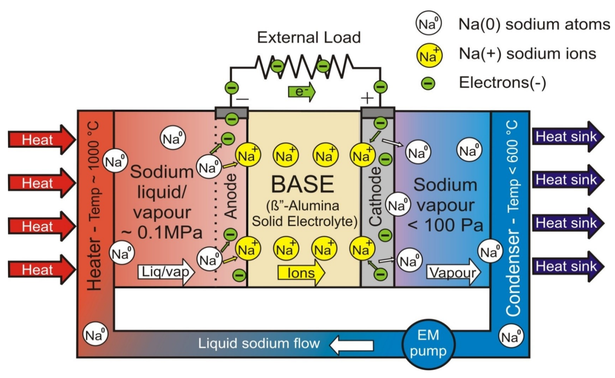
- ☑ Design & construction of an AMTEC cell prototype
- ☑ Design & construction of AMTEC Test Facility (ATEFA)
- ☑ Evaluation of materials and processes for high temperature, corrosive and highly reactive environment
- ☑ Development of a control system for ATEFA
- Set into operation of ATEFA
- Test of several electrode structures
- Evaluation and optimization of the cell performance

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



Open issues

- ❑ Cell efficiency
  → High thermal losses
  → Loses in electrodes
- ❑ Contribution to long-term power degradation:
  → BASE ~ 60 – 70 %
  → Electrode ~ 20 %

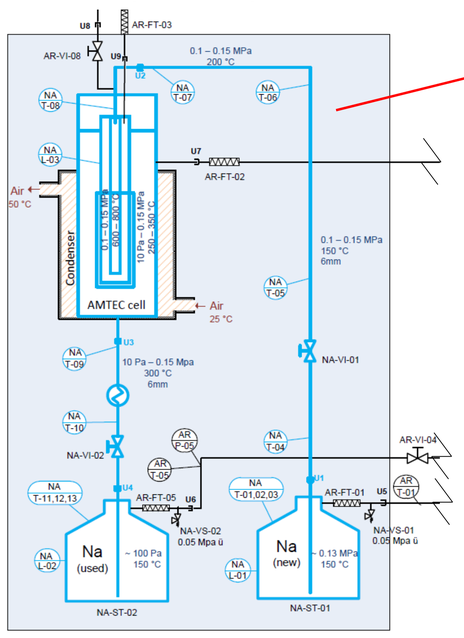
AMTEC typical values:

Variable	AMTEC (KIT 1993)
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 – 0.15 MPa

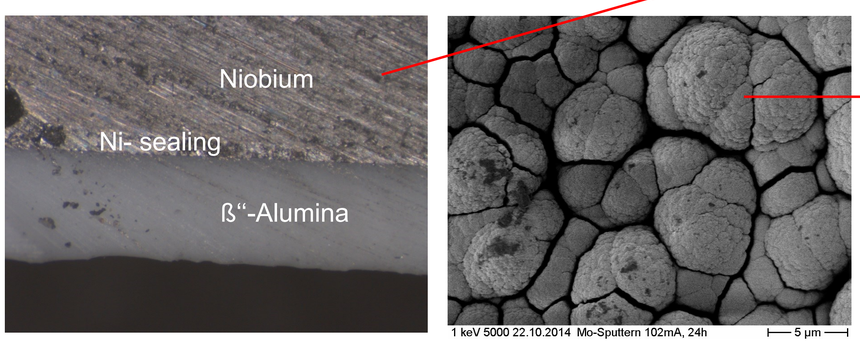
AMTEC TEst FAcility (ATEFA)

- ❑ Mass flow and pressure in Na-system controlled by Ar-system
- ❑ Pumpless design and Na open loop
- ❑ Safe oriented design (facility in-housed in a metallic box, fast emergency drainage in tanks, leakage tub…)
- ❑ 7 independent heat tracing systems
- ❑ 2 operating modes:
  → Completely automatic, normal operation (transient, steady state, measuring)
  → Combined manual & automatic (start, maintenance, drainage, shut down)
- ❑ Successfully tested valves and instrumentation
- ❑ Set into operation planed for October 2015

ATEFA facility (2x0.8x0.6 m³)



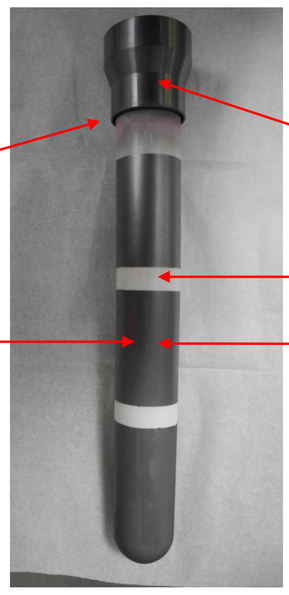
P&I diagram of ATEFA (Na-system)



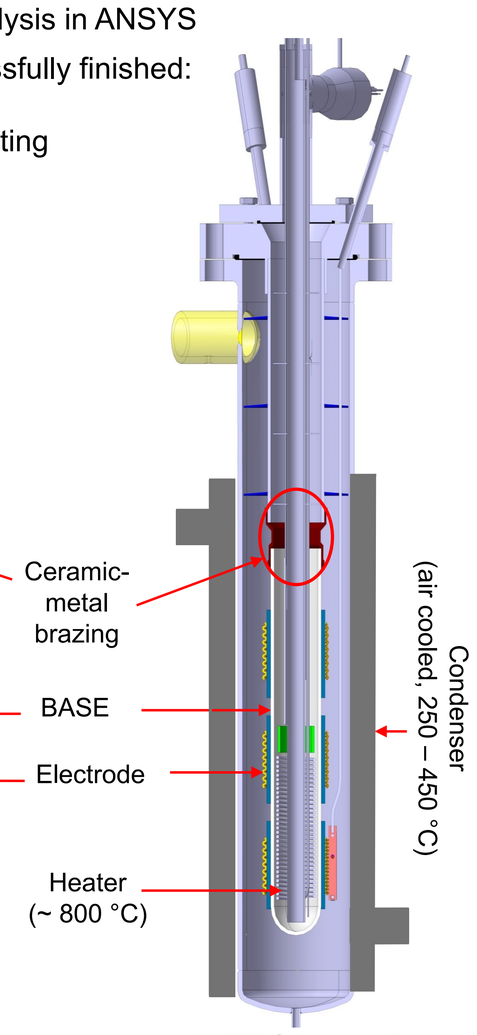
Preliminary tests*: ß''-Alumina – Nb joint (left), Mo cathode (right)

AMTEC Test Cell

- ❑ Challenges in design: electrical isolation, leak tightness, ceramic-metal joint, sensor assembly, corrosion, high temperature…
- ❑ Safety related design: structural & thermal analysis in ANSYS
- ❑ Preliminary tests successfully finished:
  → Ceramic – metal joint
  → Ceramic cathode coating (TiC, Mo, TiN)
- ❑ Final assembly phase in progress



TiC sputtered cathodes*



AMTEC test cell

Conclusion

Based on the experiences in liquid metal and AMTEC technology at KIT, an AMTEC test cell and a test facility have been constructed in the frame of the Helmholtz Alliance LIMTECH and the Helmholtz Energy Material Characterization Platform (HEMCP). Evaluation of the cell structure as well as analysis of materials and processes have been done. Preliminary tests for the ceramic coating and ceramic-metal welding were successfully finished. Furthermore, the software development of ATEFA control system is in an advanced stage. Set into operation is planed for October 2015.

Key Publications

- ❑ N. Díez de los Ríos, A. Onea, S. Scherrer, A. Weisenburger, W. Hering, 5th International Youth Conference on Energy (2015)
- ❑ A. Onea, N. Díez de los Ríos, W. Hering, J.L. Palacios, Magnetohydrodynamics 51 (3), 495-507 (2015)
- ❑ A. Onea, N. Díez de los Ríos, J.L. Palacios, W. Hering, 9th Pamir International Conference (2014)
- ❑ N. Díez de los Ríos, A. Onea, W. Hering, R. Stieglitz, P. Moster, 3rd European Energy Conference (2013)

Cooperations

- ❑ Projects A1, B1, B2 and B3 from LIMTECH Alliance
- ❑ * KIT Institutes IHM and IAM-AWP within HEMCP AMTEC Platform (HAC)

Further development of the project expected. Application for Helmholtz Postdoc Programme 2016 planned.