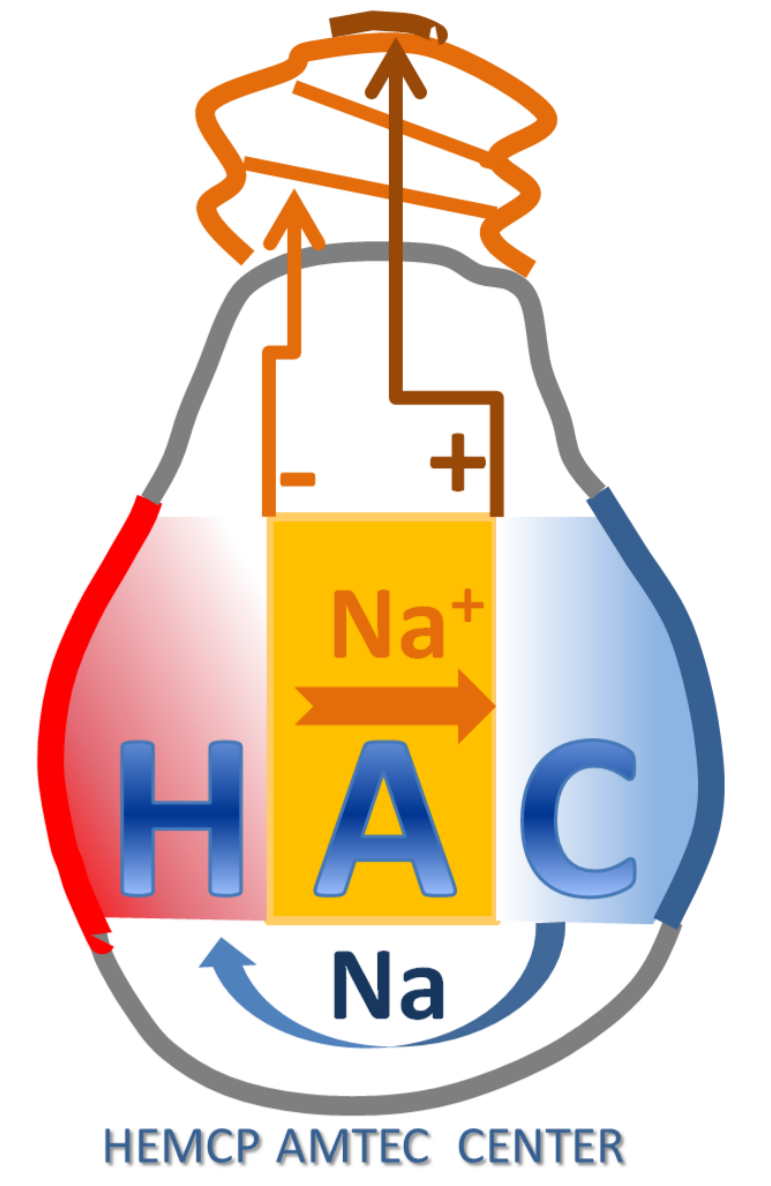


# Development of an Alkali Metal Thermal to Electric Converter (AMTEC)

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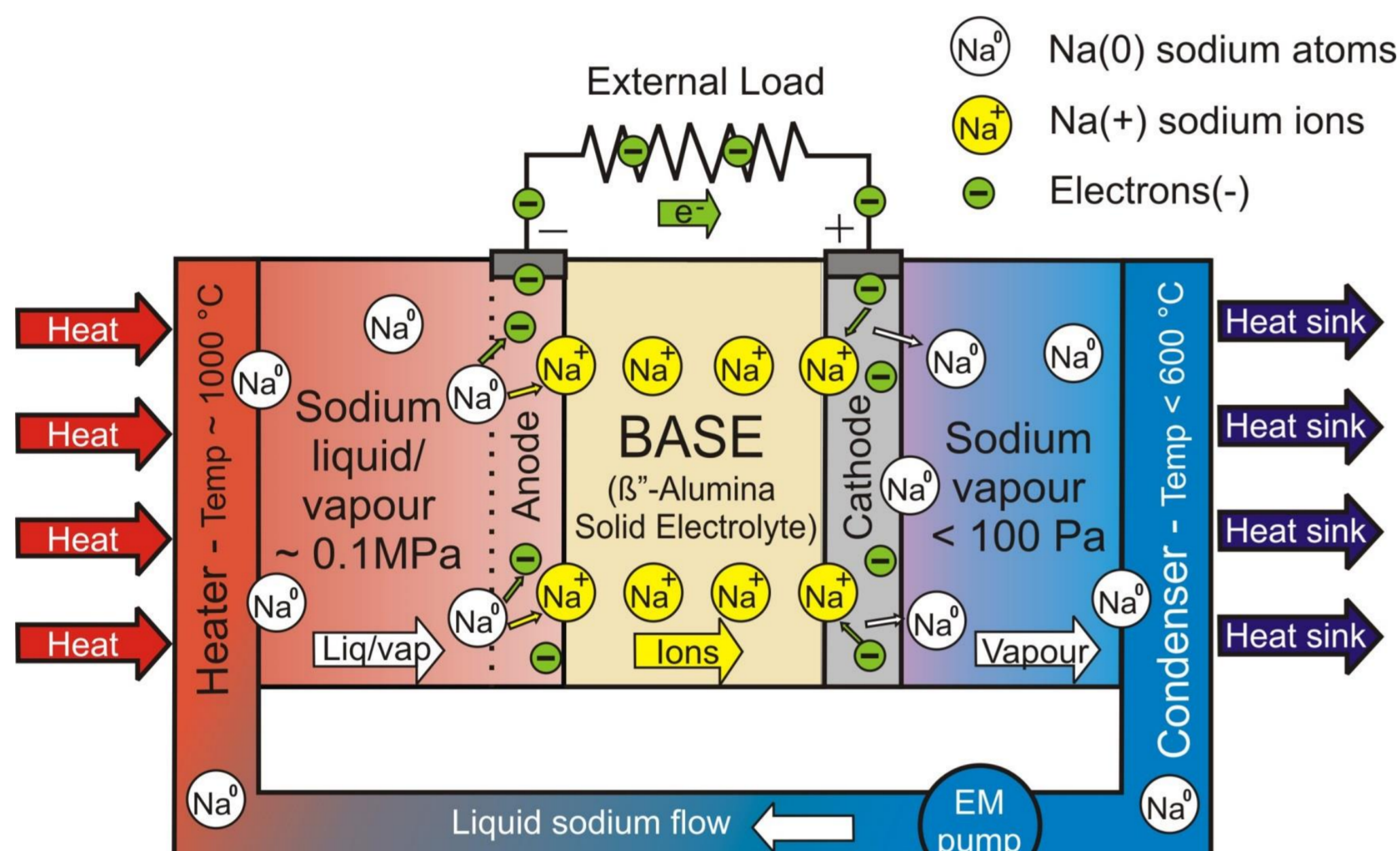


## AMTEC operating principle

- Direct conversion of thermal energy into electricity
- Key component:  $\beta''$ -Alumina Solid Electrolyte (BASE)
- Key process: Na-ionization ( $\Delta p$  across BASE)



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



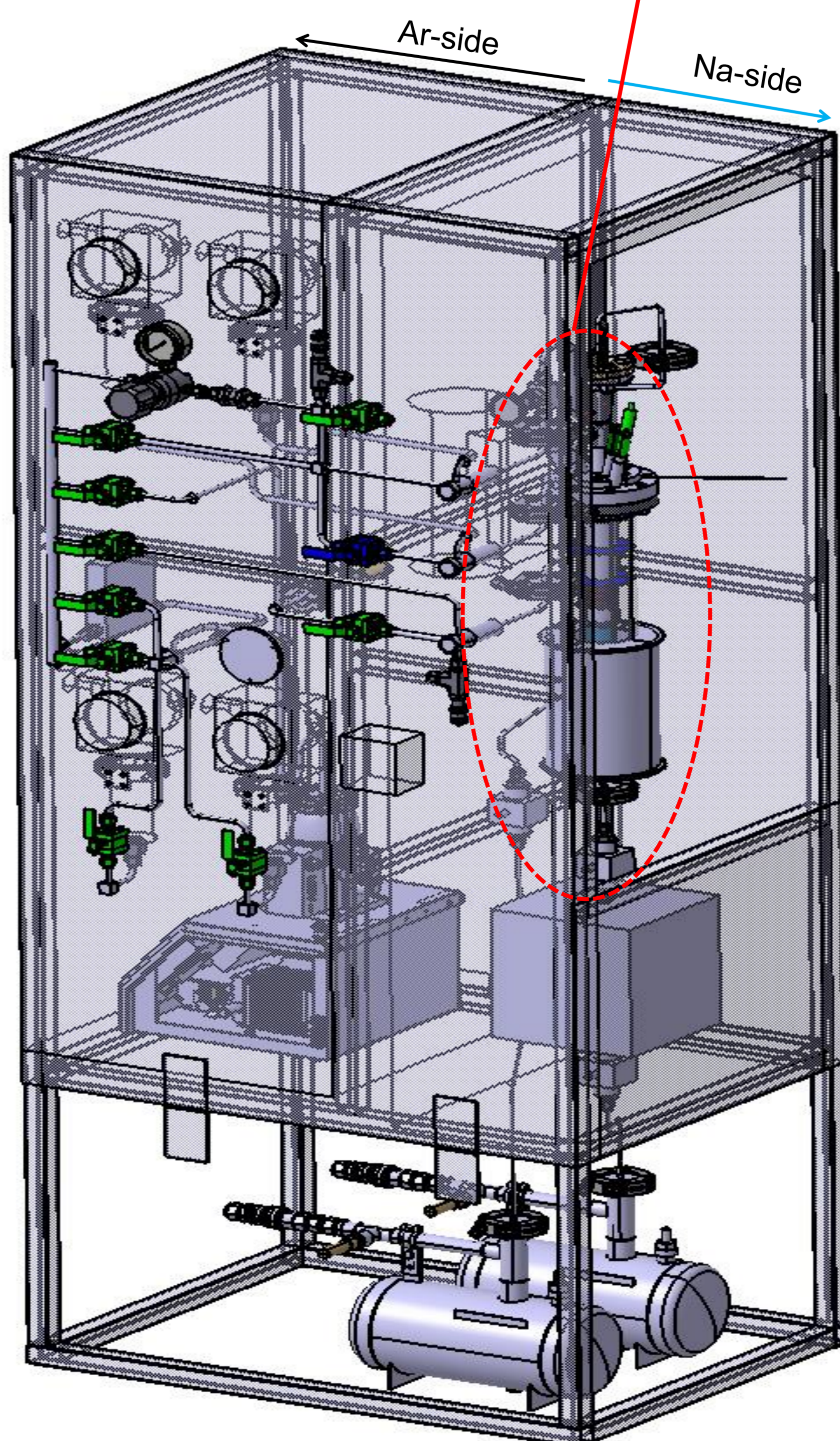
## Open issues

- Cell efficiency ( $\eta_{\text{theo}} \sim 45\%$ )
- Contribution to power degradation:
  - BASE degradation  $\sim 60 - 70\%$
  - Electrode degradation  $\sim 20\%$

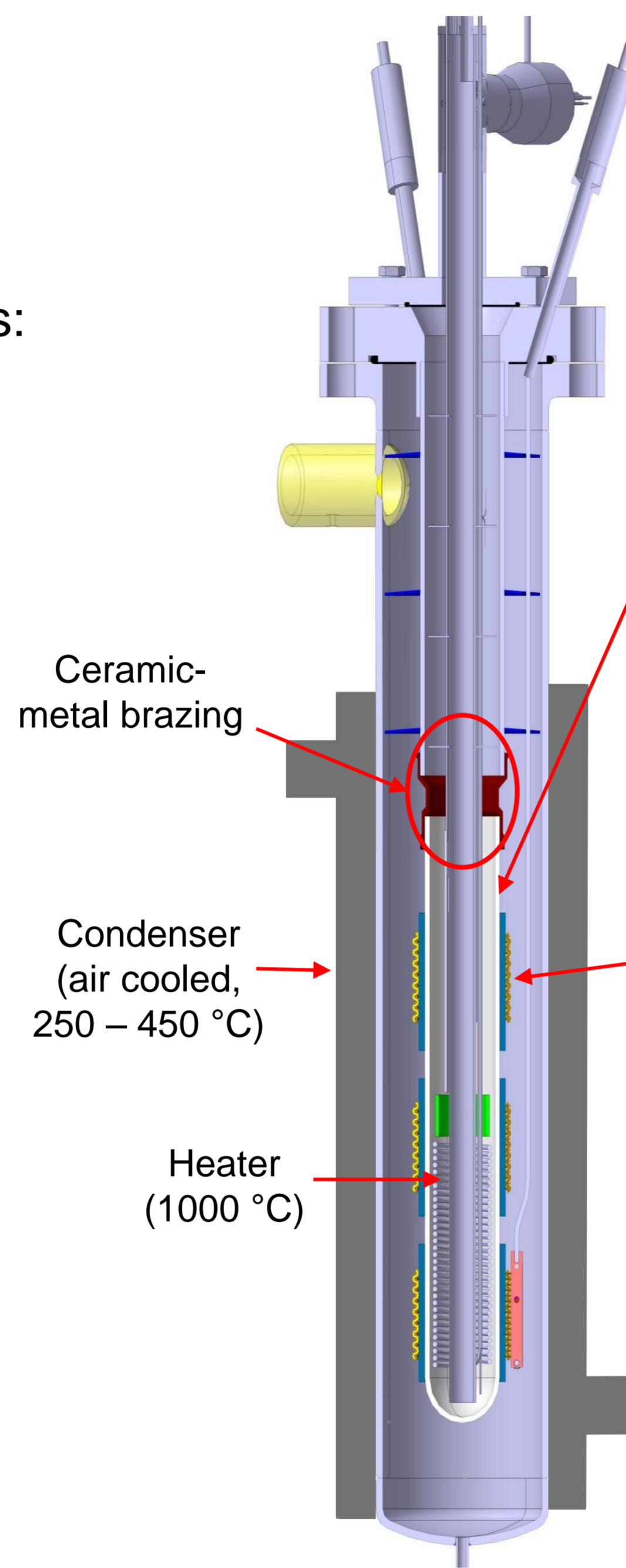
Variable	AMTEC @ INR
V	0.4 – 1.2 V
I	0.5 – 1.5 A/cm <sup>2</sup>
P	0.5 – 1.5 W/cm <sup>2</sup>
$\eta_{\text{present}}$	$\sim 20\%$
$T_{\text{Na}}$	600 – 1000 °C
$p_{\text{Na}}$	10 Pa – 0.1 MPa

## AMTEC Test Facility (ATEFA)

- At present under construction
- Control Na-flow  
→ adjustment Ar properties ( $p_{\text{Ar}}$  &  $\dot{m}_{\text{Ar}}$ )
- 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:

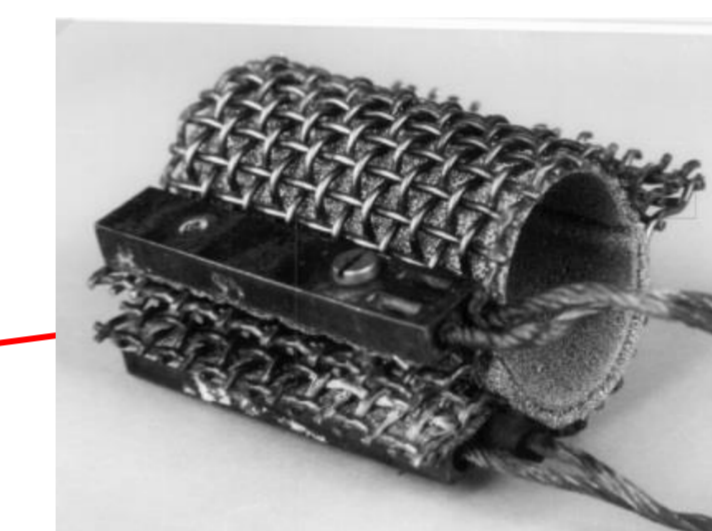
### BASE ( $\beta''$ -Alumina Solid Electrolyte)

(+) fulfilled  
(-) improvable



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

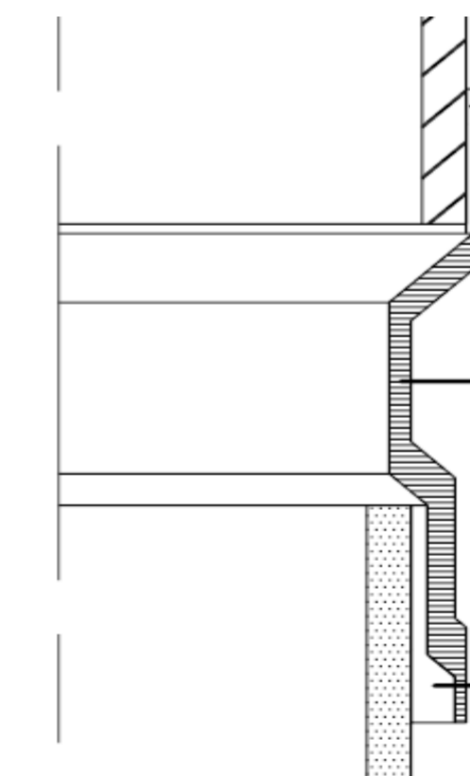
### Electrode (Cathode) and current collector



BASE	
Mo Sputtered cathode (1-2 μm)	
Ni foam	
Ni grid	

- 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) (-)

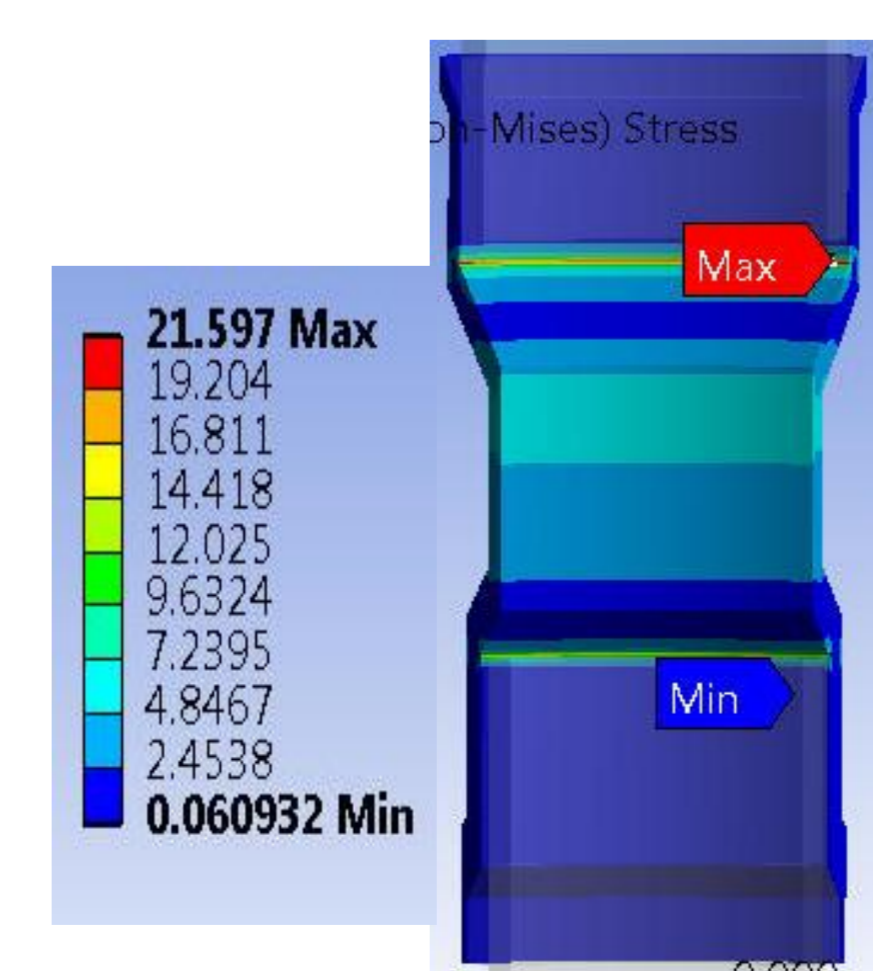
### Ceramic to metal joining



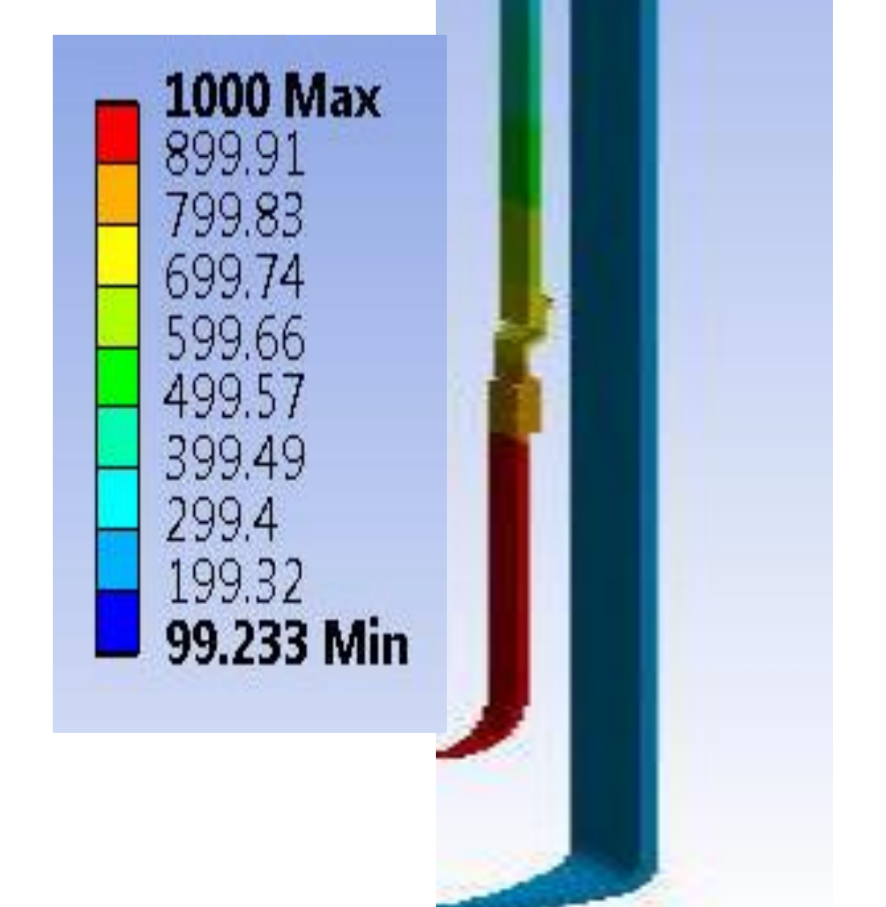
- High leak tightness (+)
- Similar coefficient of thermal expansion (+)
- Chemically stable in sodium environment (+)
- No diffusion of filling material (-)

## 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  $\geq 6$  bar
- Cooling under forced convection (transient) → no failure
- High  $\Delta T$  along BASE → no failure



Stress distribution in Brazing [MPa]. Steady state.



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