PERFORMANCE TESTING OF TWO 360 KW ELECTRIC HEATERS FOR MOLTEN SALT

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Project overview: E-Heat

Main project goals :

1. Analysis of heat transfer between molten salt and a pipe in cross-flow configuration
2. Evaluation of **molten salt electric heating** technology for temperatures **up to 560°C**
3. Identification of critical design criteria, definition of development requirements and derivation of design correlations for molten salt electric heaters
4. Research on air electric heaters up to 750 °C with a comparable scope

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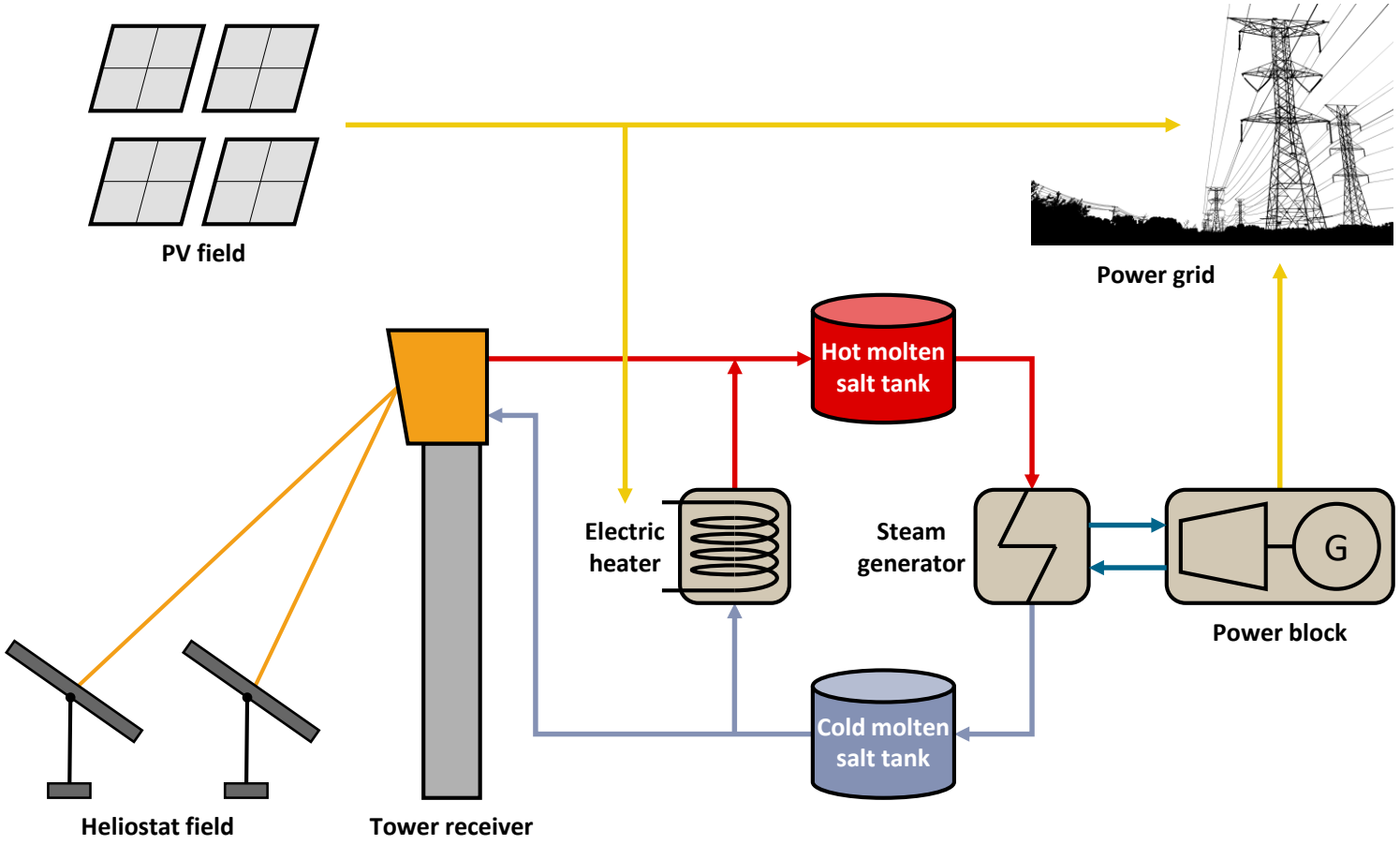
Motivation: Applications of molten salt electric heaters



Application in hybrid CSP/PV plants:

- Electric heater utilizes excess PV electricity
- CSP and PV plants both use the proven 2-tank molten salt storage system

Other applications:

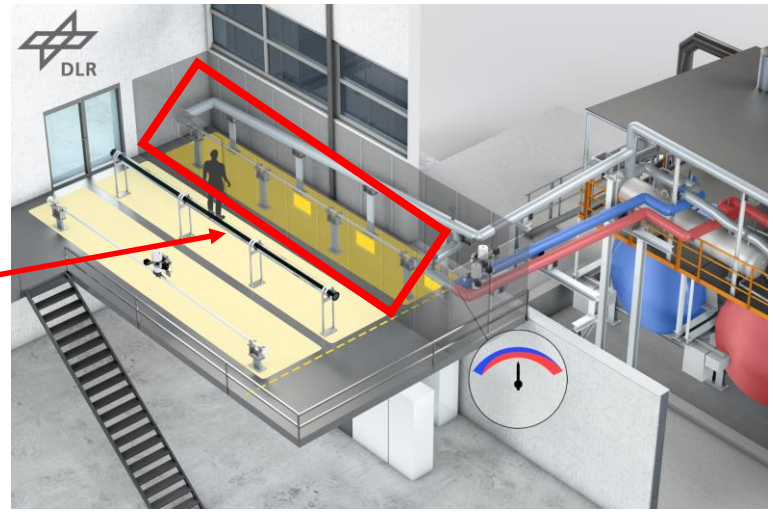
- Thermal storage power plants
- Electrification of high-temperature chemical processes

→ **Electric heater development** towards **higher temperatures** and **larger module sizes** is required

Methods: TESIS:com test facility

Integration of two electric heater prototypes into the TESIS:com subplant:

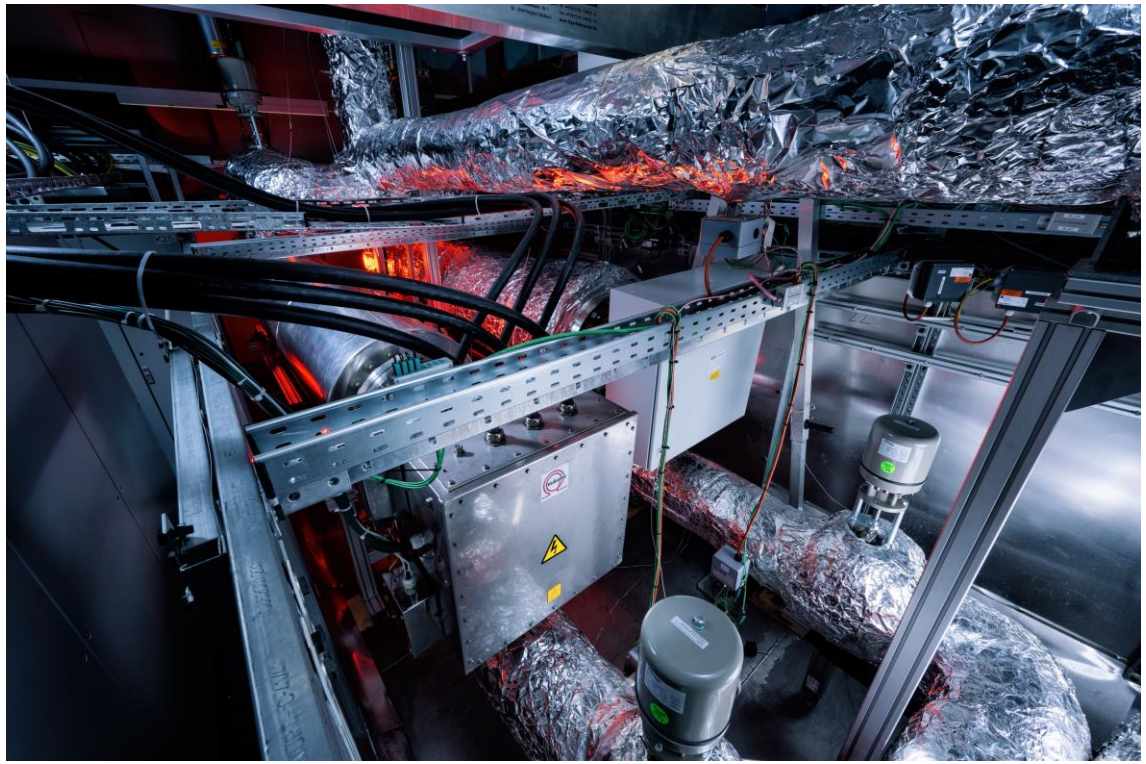
- TESIS:com subplant for component testing:
  - Solar salt (60% $NaNO_3$ and 40% KNO_3)
  - 290 °C - 560 °C inlet temperature
  - 0.5 kg/s - 8.0 kg/s mass flow rate
  - Mass flow and temperature ramps/shocks
  - Required measurement and control equipment available on site
- Prototypes provided by Schniewindt and Vulcanic
- Electric heaters installed in TESIS:com's test section



Methods: Experimental setup

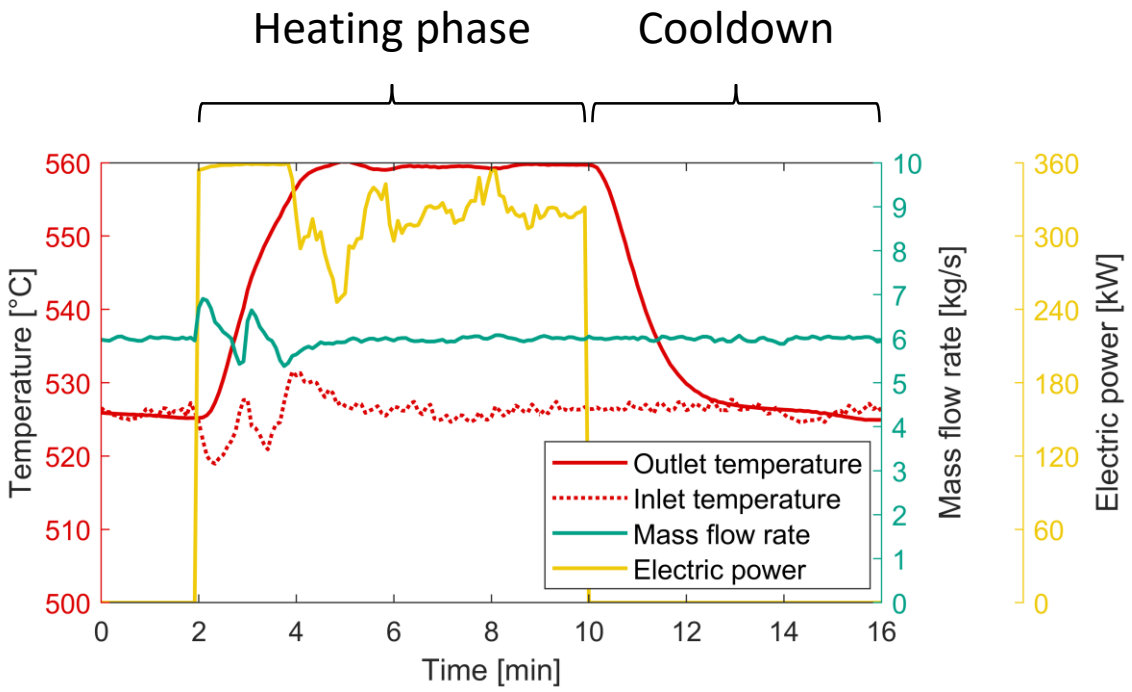
Heater specifications

- Electric power: 360 kW_{el}
- Length: 4.0 – 4.5 m
- Diameter: 0.3 – 0.4 m
- Insulation thickness: 0.15 m
- Inclination: 2° (for drainage)
- Nom. mass flow rate: 6.0 kg/s
- Nom. temperature increase: 525 °C → 560 °C
- Mineral insulated heating elements
- Flow through heaters controlled by 4 valves positioned at the inlets and outlets



Results: Cycle tests

One thermal cycle consists of:



General results of the cycle tests

- Test campaign with Vulcanic heater successfully completed ✓
- 3 months of testing
- Permanent exposition to molten salt between 500 °C – 560 °C
- > 5.000 cycles completed (= 14 years of operation)*
- Stress tests towards the end of the campaign:
  - ↓ mass flow rate, ↑ temperature increase
  - ➢ ↑ film and heating element core temperature
- Test campaign with Schniewindt heater underway

* Assuming a daily start-up of the heater in a hybrid PV and CSP system

Results: Drainage

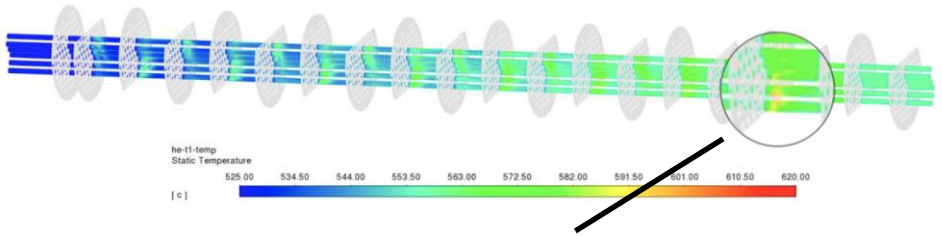
- Draining the heater and TESIS:com plant:
  - 24 hours
  - 300 °C – 400 °C
  - 2° inclination
  - Salt can flow through openings in the baffles
- Only minor residues of salt remained in the heater
- Flow pipe and heater bundle showed no visual wear after the tests

Results: Material tests

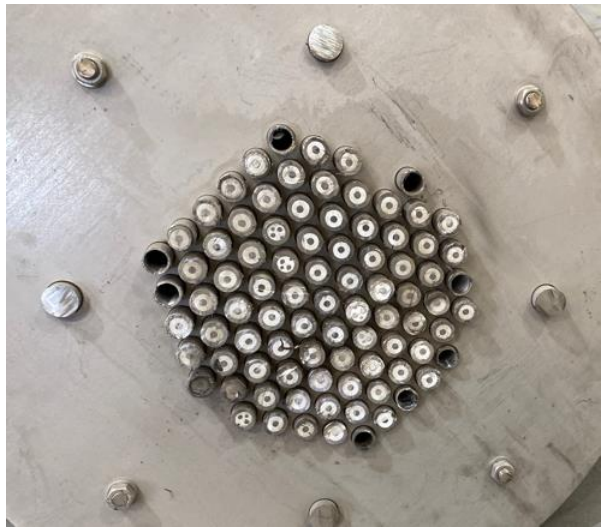
The following aspects are addressed in the post analysis:

- **Corrosion:**
  - Thickness measurement (microscopic images)
  - Mass loss
  - Intergranular corrosion tests (ASTM G28)
- **Mechanical condition and microstructure of heating elements:**
  - Elastic modulus, yield strength, tensile strength etc.
  - Grain size, intergranular chromium carbide precipitation on the surface, other defects
- **Condition of other heater parts:**
  - Electric components, sealing, sensors, thermal insulations

→ **Results can be published once all tests are concluded!**



- CFD analysis shows the highest temperature areas; localized hot points occur behind the baffles near the outlet with a surface temperature exceeding 620°C locally
- Test samples from these areas at different vertical locations were selected for post analysis



Summary

- Molten salt electric heaters are crucial components in hybrid CSP/PV plants

  → Development towards higher temperatures and larger module sizes is required

- Test setup with two 360 kW electric heaters was built and operated at DLR's TESIS:com plant
  - Test run with first heater successful
  - 3 months of operation with molten salt at 500 °C – 560 °C
  - > 5.000 thermal cycles completes
  - Heater shows good visual condition and drainability
    → Further post analysis is still pending

- Testing of the second heater in progress and is expected to be completed by December 2023

Thank you for your attention!

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