Liquid-Phase Pathway
Thermal Transport System

Gen3 CSP Summit
August 25, 2021

Ken Armijo
Sandia National Laboratories

NREL Award # 34209 (agreement number)
Gen 3 Pilot-System Design

National Solar Thermal Test Facility (NSTTF) at Sandia National Laboratories

Computer imagery of the proposed system layout at the NSTTF
Thermal Transport System: Key Challenges

- Heat tracing and freeze protection
- 700°C chloride salt pumps
- Control valves
- Salt-to-sCO₂ heat exchanger
- Controls and Ullage Gas System
- Higher-than-expected salt vapor pressure
- High salt vapor freezing phenomena
- Accommodation for MgO particulates
Piping, Heat Trace and Freeze Protection

Five types of pipe preheating systems, of which three: Mineral insulated (MI) cable, heat tape, and ceramic fiber heaters found to be viable for parts of the project need.

- Only one system, the ceramic fiber (CF) heater can be exposed continuously at >720 °C hot salt temperatures and not reduce the service life of the pipe preheating system.

<table>
<thead>
<tr>
<th>Pipe Heating System</th>
<th>Heater Initial Cost</th>
<th>Heater Installation Cost</th>
<th>Insulation Installation Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic Fiber</td>
<td>$400-$700 / ft.</td>
<td>$75 / ft.</td>
<td>$190 / ft.</td>
</tr>
<tr>
<td>MI Cable</td>
<td>$150 / ft.</td>
<td>$170 / ft.</td>
<td>$388 / ft.</td>
</tr>
</tbody>
</table>

MI cable installation for MSTL at Sandia.  
Thermcraft CF heaters
**Salt Pump Curves**

110 GPM, 302 ft., 110 TDH, 1720 RPM

Collaboration w/ Pump Vendors & Project Teams for Gen 3 Pilot-System Down-Selection
Molten Salt Valves

- The Gen 3 team interfaced with valve suppliers Flowserve, Guichon, Gosco, Samson, Trillium and Jarecki.
- Advanced chloride-salt valves based on designs with bellows seals and packing, similar to that used in nitrate salts.
- Funded DOE project to develop advanced valve, capable of freeze/leak-resistance up to 750°C.
  - Ternary-chloride salt materials were modified for chloride-salt service.
- High-temperature alloys and ceramics for valves construction.

Flow Control Valve Image courtesy Samson.
Static Valve Testing

- Vendor C shut-off ball valve evaluation at Sandia NSTTF under static salt.
- Boronized-nitride recessed-groove ball to be compatible with ternary chloride salt.
- Graphite/Thermiculite Spiral-wound gasket to mitigate league from the valves raised-faced flanges.
- Efficacy testing was performed to evaluate the valve’s ability to actuate 10 times at successive temperatures up to 720°C without leakage, actuation issues and seizing.
Heat Exchangers (HEX)

**Salt/sCO₂ HEX**
- Sandia and VPE designed diffusion-bonded HEX for salt/sCO₂
- Printed-circuit heat exchanger (PCHE)
- Divided into hot (Alloy 617) and cold (SS316) sections
- Ability to pass < 250 µm MgO particles
- Unit cost estimated by project member VPE

**Na/Salt HEX**
- ASTRI designed single counter-flow HEX for sodium/salt
- Vertical for drainage
- Could be split to two or more heat exchangers to minimise height
- Designed as a Vertical 1:1 TEMA E STHE heat exchanger as follows:
  - Sodium on the tube-side (min/max velocities: 1.2/2.5 m/s);
  - Salt on the shell-side (min/max velocities: 0.5/1.5 m/s);
  - Design simplicity and robustness;
  - Wide range of operational temperatures and pressures;
  - Tilted baffles to facilitate drainage on the shell-side.
Controls & Ullage
Gas Systems