Liquid Pathway Salt Receiver Design

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Salt receiver: Design strategy and challenges

- Leverage the extensive design and real-world operational experience for external tubular cylindrical nitrate salt receivers

- Challenges compared to commercial nitrate salt:
  
  Chloride salt thermophysical properties:
  - Lower thermal conductivity (lower heat transfer)
  - Higher viscosity (lower Reynolds number)
  - Lower heat capacity (higher mass flow)
  - Higher freezing point

  Higher inlet/outlet temperatures (500 - 735°C)

  Higher tube wall temperatures and temperature gradients

  Creep and creep-fatigue damage

  Lower allowable flux limits, larger receiver size, lower efficiency, higher cost
Salt receiver: Design constraints and optimization

- 565 MWt receiver
- Inconel 740H tubes
- Optimization variables:
  - Receiver height/diameter
  - Tube sizing and wall thickness
  - Design point peak flux concentration
  - Tower height (field layout)
  - Panels and flow circuit configurations

Design constraints (constraints in **red** are binding)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Constraint</th>
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<tbody>
<tr>
<td>Tube wall thickness</td>
<td>$\geq 1.2 \text{ mm}$ (manufacturability)</td>
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<tr>
<td>Tube wall thickness</td>
<td>Primary (pressure) load survivability</td>
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<tr>
<td>Creep-fatigue lifetime</td>
<td>$\geq 30$ years</td>
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<tr>
<td>Peak velocity</td>
<td>$\leq 4.0 \text{ m/s}$ (erosion concerns)</td>
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<tr>
<td>Pressure drop</td>
<td>$\leq 2.5 \text{ MPa}$ (pump availability)</td>
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<tr>
<td>Tube OD</td>
<td>$\geq 10 \text{ mm}$ (manufacturability)</td>
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Salt receiver: Creep-fatigue lifetime

- Stress relaxation is significant
- Creep damage is dominant at ~800°C wall-temperature conditions
- Design methods based on ASME Section III, Division 5:
  - Elastic analysis: simple and feasible to couple with design optimization, overly conservative
  - Inelastic analysis: complex and time consuming, more realistic

Salt receiver: Lessons learned and implications

- Question convention → Changes in conditions can lead to unanticipated conclusions
- Fundamental design changes are needed to improve cost/performance
  - New containment materials: alloys, ceramics, composite materials
  - Robust real-time heliostat aiming and control
- Salt receiver design results provide input for receiver AHP down-select process