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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)

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Higher tube wall temperatures and temperature gradients

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Creep and creep-fatigue damage

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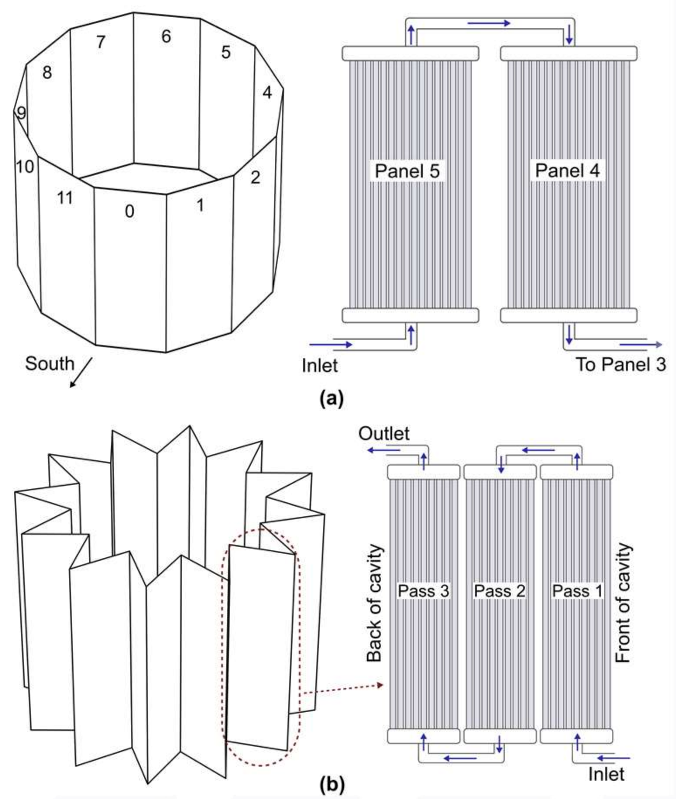
Lower allowable flux limits, larger receiver size, lower efficiency, higher cost



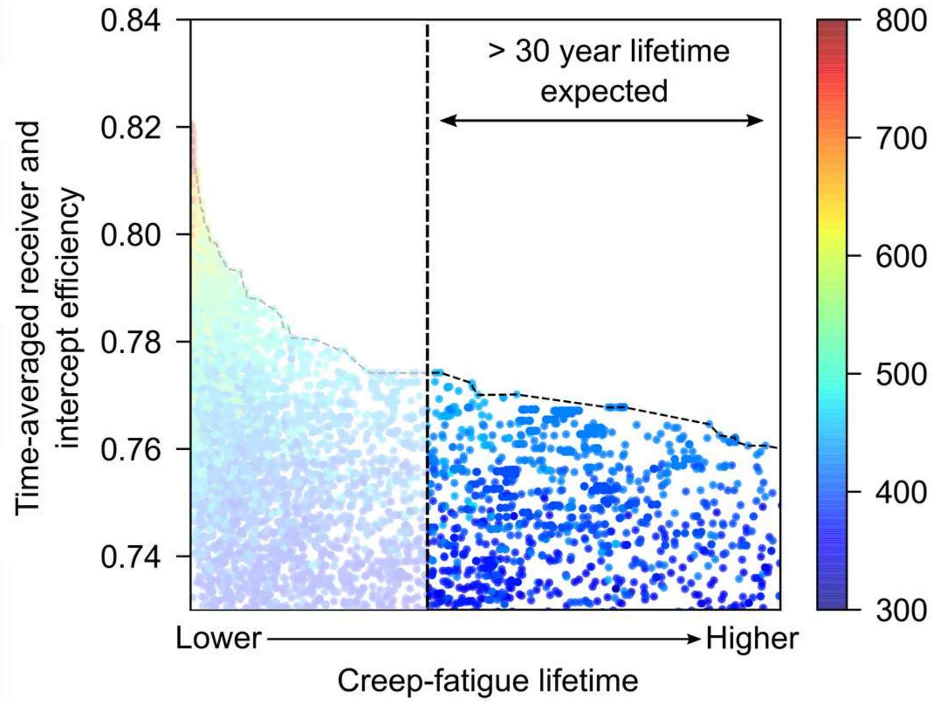
Salt receiver: Design constraints and optimization

- 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)

Parameter	Constraint
Tube wall thickness	**≥ 1.2 mm** (manufacturability)
Tube wall thickness	Primary (pressure) load survivability
Creep-fatigue lifetime	**≥ 30 years**
Peak velocity	**≤ 4.0 m/s** (erosion concerns)
Pressure drop	≤ 2.5 MPa (pump availability)
Tube OD	≥ 10 mm (manufacturability)

Pareto front of receiver efficiency vs. expected lifetime
point color = design point peak flux (kW/m^2)



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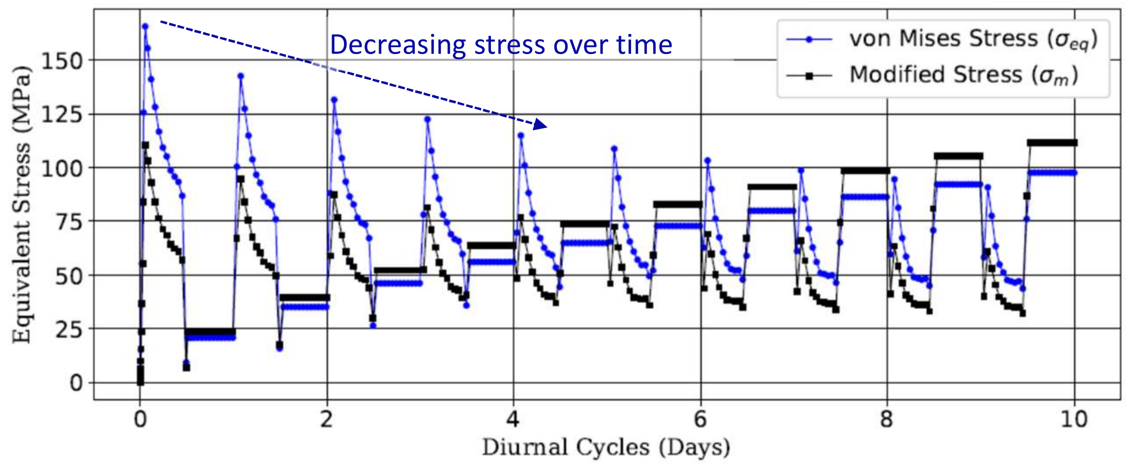
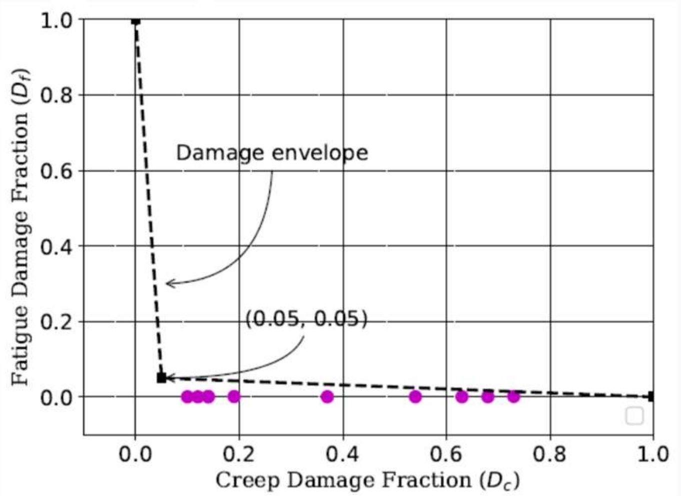
Salt receiver: Creep-fatigue lifetime

- 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



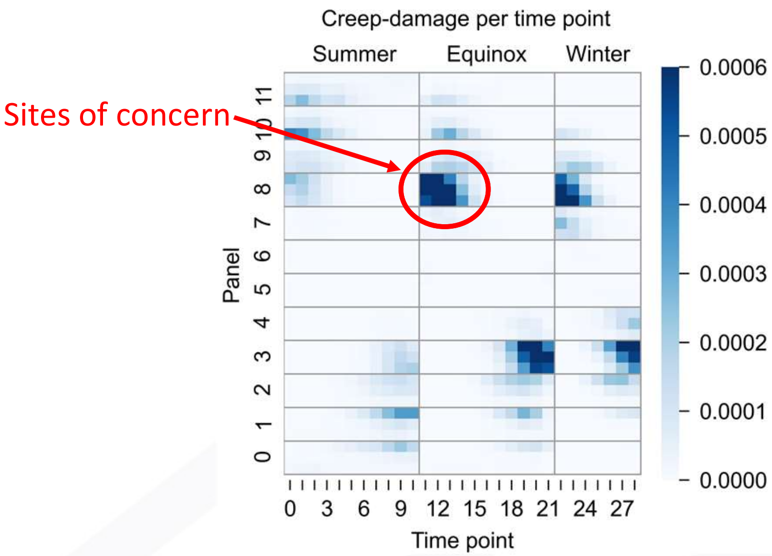


- Barua et al., "Design Guidance for High Temperature Concentrating Solar Power Components" Argonne National Laboratory, Technical Report ANL-20/03, 2020
- Logie et al, "Structural Integrity of Advanced Solar Central Alloy 740H Receiver Tubes" SolarPACES 2020
- Jape et al, "Thermomechanical Modeling of Receiver Tubes for Next Generation Concentrating Solar Power Plants: Thermal Stress, Analysis, Structural Damage Calculation, and Lifetime Prediction (submitted, 2021)

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

"Traditional" flow circuits



"Non-traditional" flow circuits