High-Temperature Particle-to-sCO2 Heat Exchanger

SuNLaMP 1507

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SAND2019-XXXX
Introduction

- High-temperature particle receivers are being pursued to provide heat for sCO2 Brayton cycles
Problem Statement

- Particle-to-sCO2 heat exchangers do not exist
  - sCO2 ≥ 700 °C at ≥ 20 MPa

- Challenges
  - Particle-side heat transfer
  - Thermomechanical stresses
  - Materials
    - High operating temperatures and pressures
  - Erosion
  - Costs

Solarized sCO2 recompression Brayton cycle

www.solexthermal.com
Objectives and Approach

- Evaluate and downselect among alternative designs using Analytic Hierarchy Process (Ho et al., 2018)
- Construct, and test prototype particle heat exchanger that can heat sCO2 to 700 °C at 20 MPa for 100 kW prototype
- Integrate final design with Sandia’s falling particle system

<table>
<thead>
<tr>
<th>Heat Exchanger</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Fluidized Bed (Babcock &amp; Wilcox)</td>
<td>High heat-transfer coefficients</td>
<td>Energy and mass loss from fluidization</td>
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<tr>
<td>Moving packed bed - shell/tube</td>
<td>Gravity-fed particle flow; low erosion</td>
<td>Low particle-side heat transfer</td>
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<tr>
<td>(Solex Thermal Science)</td>
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<tr>
<td>Moving packed bed - shell/plate</td>
<td>High potential surface area for particle contact; low erosion</td>
<td>Requires diffusion-bonding of plates</td>
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<td>(Vacuum Process Engr)</td>
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Key Outcomes and Impact

- Teamed with industry to design fluidized and moving-packed-bed particle/sCO2 heat exchangers
- Measured particle/wall heat transfer coefficient at ~200 W/m²-K for shell-and-plate design
- Performed particle flowability tests at 600 °C
- Designed 100 kW_t sCO2 flow system for integration with heat exchanger

**Impact**: Demonstration of first solarized heating of sCO₂ using particles (summer 2019)
Integrated System

Particle receiver testing at the National Solar Thermal Test Facility at Sandia National Laboratories, Albuquerque, NM

sCO₂ flow system provides pressurized sCO₂ at 550 °C to heat exchanger for test and evaluation

Solex/VPE/Sandia particle/sCO₂ shell-and-plate heat exchanger

- Heat duty = 100 kW
- $T_{\text{particle,in}} = 775$ °C
- $T_{\text{particle,out}} = 570$ °C
- $T_{\text{sCO₂,in}} = 550$ °C
- $T_{\text{sCO₂,out}} = 700$ °C
- $m = 0.5$ kg/s
Questions?

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# Technical Challenges

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<tr>
<th>Design Criteria</th>
<th>Notes</th>
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<tr>
<td><strong>Cost</strong></td>
<td>Want low cost of prototype and larger scale systems (&lt; $150/kW&lt;sub&gt;t&lt;/sub&gt;)</td>
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<tr>
<td><strong>Heat Transfer Coefficient</strong></td>
<td>Want large overall heat transfer coefficient (&gt;100 W/m&lt;sup&gt;2&lt;/sup&gt;-K)</td>
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<tr>
<td><strong>Structural Reliability</strong></td>
<td>Want maximum allowable working pressure &gt; 20 MPa at minimum design metal temperature of 750 C; long-term reliability</td>
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<td><strong>Manufacturability</strong></td>
<td>Want ease of manufacturing and demonstrated ability to build</td>
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<tr>
<td><strong>Parasitics &amp; Heat Losses</strong></td>
<td>Want low power requirements, pressure drop, and heat losses</td>
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<td><strong>Scalability</strong></td>
<td>Need to be able to scale up to ~20 MW&lt;sub&gt;t&lt;/sub&gt; thermal duty</td>
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<td><strong>Compatibility</strong></td>
<td>Can be readily integrated with particle receiver and sCO2 flow loop</td>
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<td><strong>Erosion &amp; Corrosion</strong></td>
<td>Want to minimize thinning of walls and tubes from particle and sCO2 flow; need to ensure 30 year lifetime</td>
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<tr>
<td><strong>Transient Operation</strong></td>
<td>Want to minimize transient start-up and impact of thermal stresses</td>
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<td><strong>Inspection Ease</strong></td>
<td>Want ability to inspect internals of the heat exchanger to evaluate corrosion, erosion, fatigue, etc.</td>
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