

High-Temperature Particle-to-sCO₂ Heat Exchanger

SuNLaMP 1507

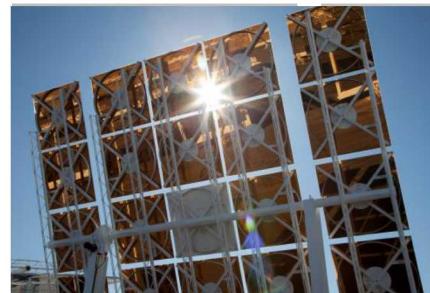
Presented by:
Clifford K. Ho
Sandia National Laboratories
Concentrating Solar Technologies Dept.

Contributors:
Kevin J. Albrecht
Matthew Carlson
Solex Thermal Science
Vacuum Process Engineering

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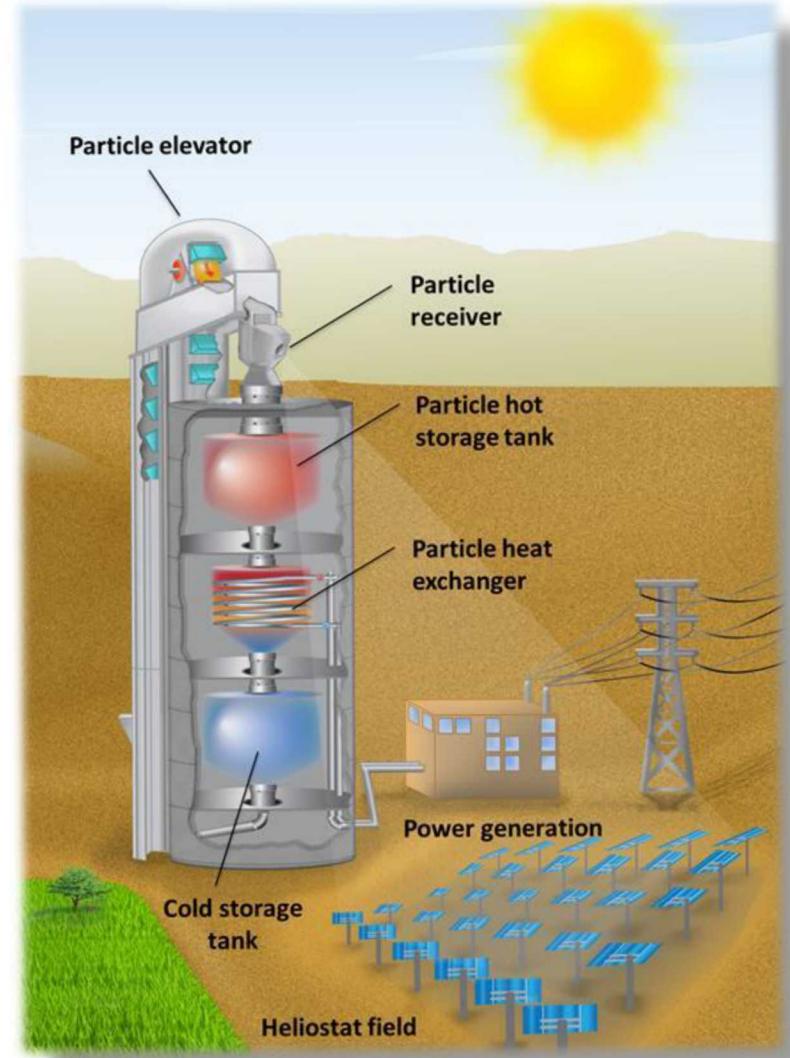
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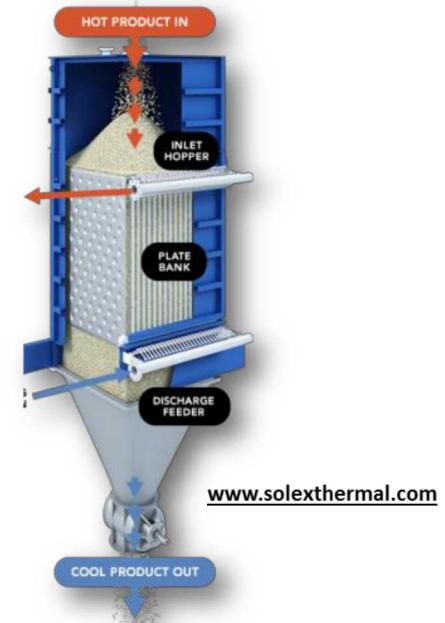
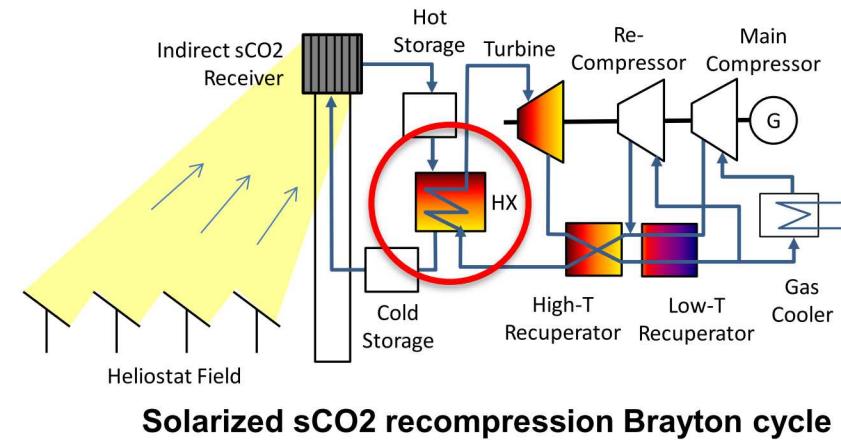
Introduction

- 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



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

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

Key Outcomes and Impact

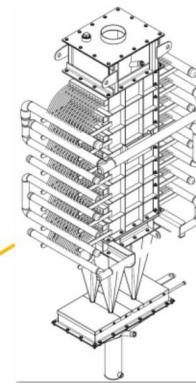
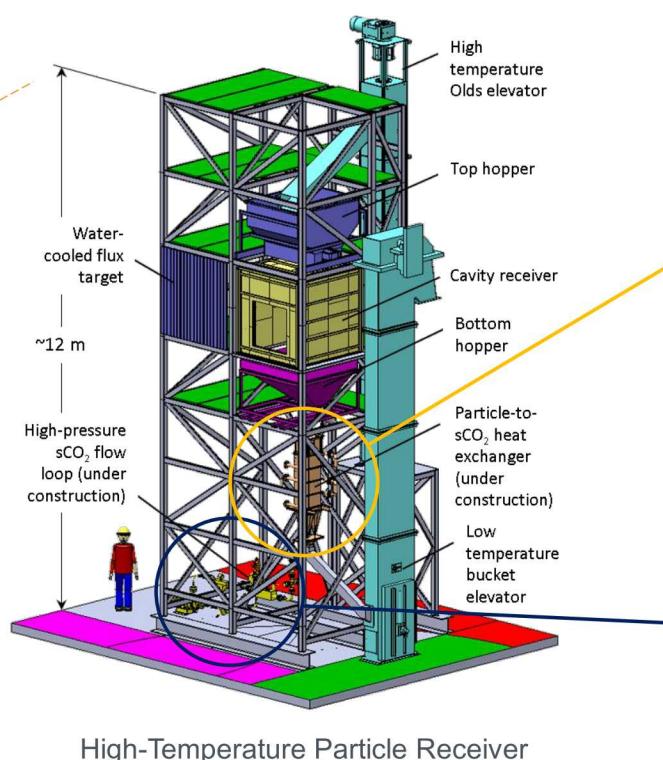
- Teamed with industry to design fluidized and moving-packed-bed particle/sCO₂ heat exchangers
- Measured particle/wall heat transfer coefficient at ~200 W/m²-K for shell-and-plate design
- Performed particle flowability tests at 600 °C
- Designed 100 kW_t sCO₂ flow system for integration with heat exchanger
- **Impact:** Demonstration of first solarized heating of sCO₂ using particles (summer 2019)



Integrated System

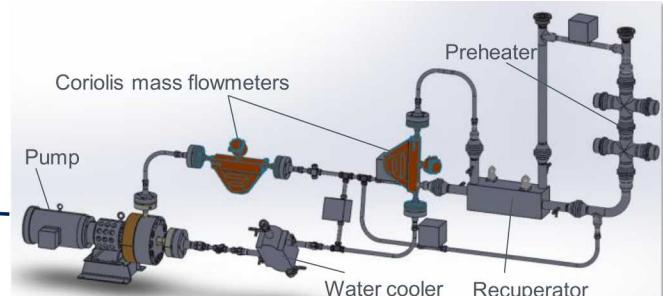


Particle receiver testing at the National Solar Thermal Test Facility at Sandia National Laboratories, Albuquerque, NM



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

- Heat duty = 100 kW
- $T_{\text{particle,in}} = 775 \text{ }^{\circ}\text{C}$
- $T_{\text{particle,out}} = 570 \text{ }^{\circ}\text{C}$
- $T_{\text{sCO}_2,\text{in}} = 550 \text{ }^{\circ}\text{C}$
- $T_{\text{sCO}_2,\text{out}} = 700 \text{ }^{\circ}\text{C}$
- $\dot{m} = 0.5 \text{ kg/s}$



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

Questions?



Cliff Ho, (505) 844-2384, ckho@sandia.gov

Technical Challenges

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