

High-Temperature Particle-to-sCO₂ Heat Exchanger

SuNLaMP 1507

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SAND2019-XXXX

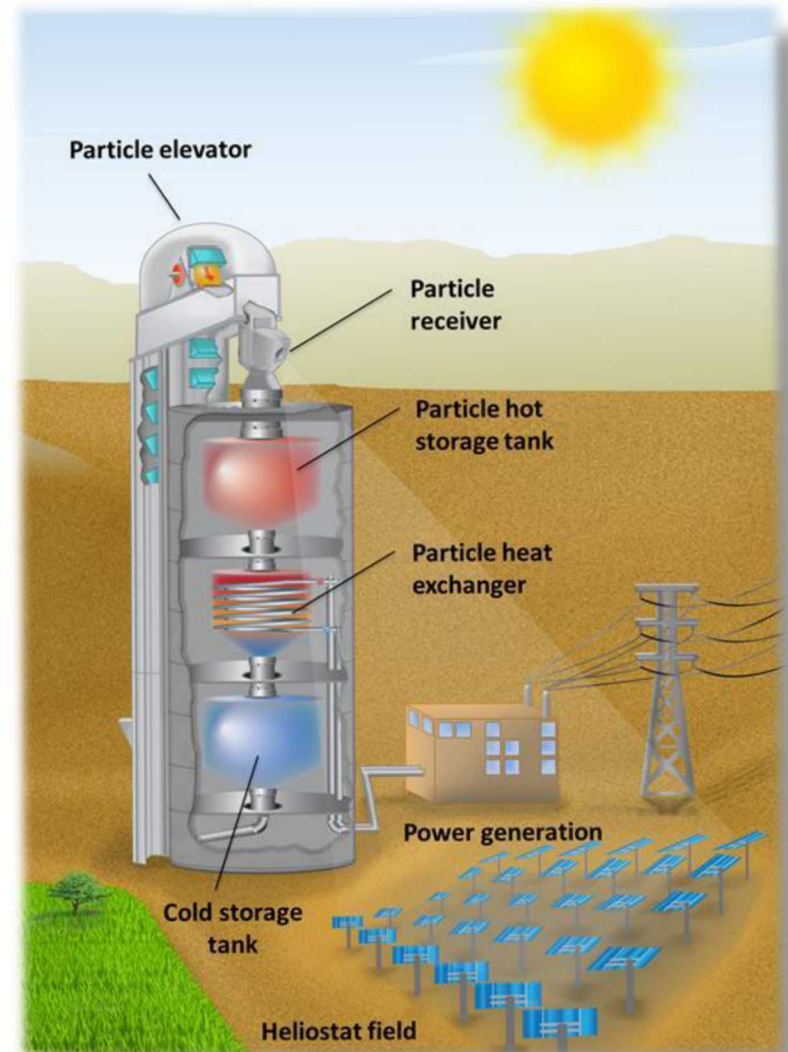
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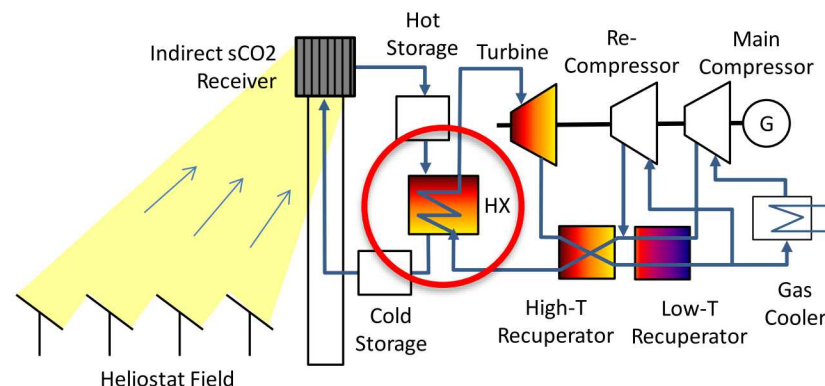
Introduction

- 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



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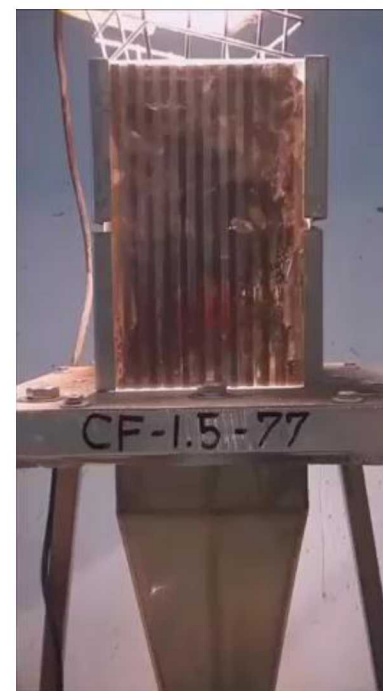
Objectives and Approach

- 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

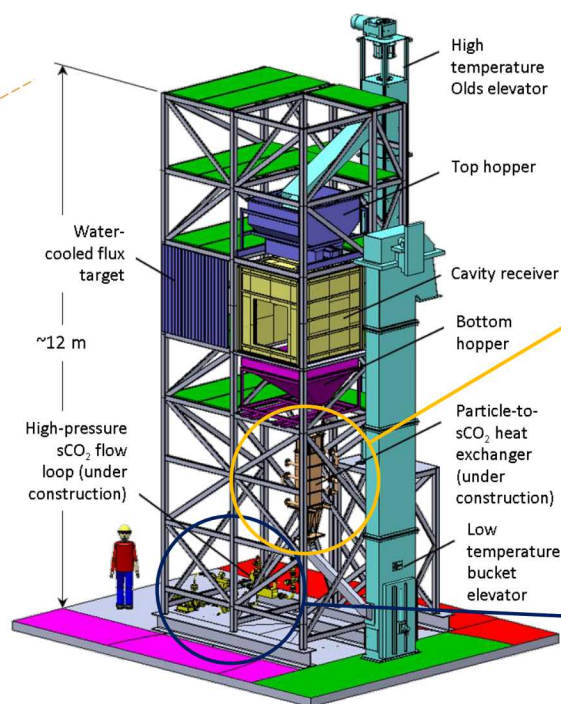
- Teamed with industry to design fluidized and moving-packed-bed particle/sCO₂ heat exchangers
- Measured particle/wall heat transfer coefficient at ~200 W/m²-K for shell-and-plate design
- Performed particle flowability tests at 600 °C
- Designed 100 kW_t sCO₂ flow system for integration with heat exchanger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



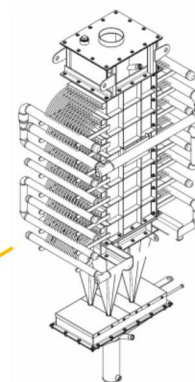
Integrated System



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

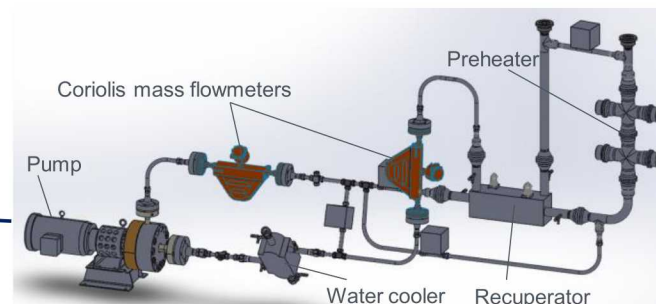


High-Temperature Particle Receiver



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?



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Technical Challenges

Design Criteria	Notes
Cost	Want low cost of prototype and larger scale systems ($< \$150/\text{kW}_t$)
Heat Transfer Coefficient	Want large overall heat transfer coefficient ($> 100 \text{ W/m}^2\text{-K}$)
Structural Reliability	Want maximum allowable working pressure $> 20 \text{ MPa}$ 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 $\sim 20 \text{ MW}_t$ 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.