Particle Heat Exchangers:
Development and Testing of a 20 kW, Moving Packed-Bed Particle-to-sCO$_2$ Heat Exchanger

Kevin J. Albrecht, Hendrick Laubscher, Christopher Bowen, Dereje Amogne, David Moon, Ashley Byman, Neville Jordison, and Clifford Ho

U.S. Department of Energy Gen3 Summit, Particle Heat Exchangers
CPS# 34152 and 37371
August 26, 2021
Moving Packed-Bed Heat Exchanger Introduction

- Particle CSP is being developed to enable high efficiency sCO₂ power cycles
- The particle/sCO₂ heat exchanger is a critical enabling technology for these systems
Moving Packed-Bed Heat Exchanger for Particle CSP

- Overall heat transfer coefficient needs to approach 600 W/m$^2$-K for particle heat exchangers to meet 2020 cost targets with current manufacturing (> $5000/m$^2$)
- With reduction in manufacturing cost, overall heat transfer coefficients between 400-500 W/m$^2$-K could be acceptable
Prototype heat exchanger was developed to evaluate novel design features in G3P3:

- Narrow plate spacing (~3 mm)
- Increase approach temperature
- Bonded/brazed construction
- Integral porting
- Flow distribution inside of plate
- Welding headers across bond lines

Difference in G3P3 heat exchanger:

- Nickel alloy construction
- Multiple inlets/outlets
- Higher temperature/pressure operation

**Metric** | **Value** | **Units**
--- | --- | ---
Thermal Duty | 20 | kW
Design Temperature | 550 | °C
Design Pressure (MAWP) | 20.0 | MPa
Operating Pressure | 17.0 | MPa
Particle Inlet Temperature | 500 | °C
Particle Outlet Temperature | 340 | °C
Particle Flow Rate | 0.112 | kg/s
sCO₂ Inlet Temperature | 290 | °C
sCO₂ Outlet Temperature | 450 | °C
sCO₂ Flow Rate | 0.103 | kg/s
sCO₂ Pressure Drop | <40 | kPa
Integrated particle/sCO$_2$ flow loop design was developed to locate entire system in a dedicated indoor test cell at NSTTF.
Heat Exchanger Manufacturing and Installation

- Heat exchanger core was manufactured at VPE and shipped to Sandia for installation in the system and testing.
Postprocessed Overall Heat Transfer Coefficient

- Heat exchanger performance measured over a wide range of operating conditions
- Overall heat transfer coefficients up to 400 W/m²-K were measured at high flow rate
20 kW<sub>t</sub> Nickel Heat Exchanger Project

Design revisions:
- Design temperature: 800 °C
- Design pressure: 25 MPa
- Nickel alloy construction (IN617)
- Overall HTC: >450 W/m<sup>2</sup>-K
  - <3 mm particle channel width
  - sCO<sub>2</sub> microchannel enhancement
- Pressure Drop: <30 kPa
- Reduction in material per surface area
Conclusions

- Integrated particle/sCO\textsubscript{2} heat exchanger test facility was developed targeting short lead time and low cost.

- Novel design features for a moving packed-bed particle/sCO\textsubscript{2} heat exchanger were evaluated in a small-scale heat exchanger prototype.

- Performance has demonstrated design point heat transfer coefficients above 300 W/m\textsuperscript{2}-K and off design conditions approaching 400 W/m\textsuperscript{2}-K.

- System is currently being upgraded for Gen3 conditions and manufacturing a prototype high nickel alloy design targeting 500 W/m\textsuperscript{2}-K.

_Sandia can provide testing services for industry and university led research projects on particle/sCO\textsubscript{2} heat exchangers up to 40 kW\textsubscript{t}._
Acknowledgements

Sandia would like to acknowledge the contributions of industry partners VPE and Solex. This work was funded in part or whole by the U.S. Department of Energy Solar Energy Technologies Office under Award Numbers 34211, 34152, and 37371.

Technology Managers: Matthew Bauer and Vijay Rajgopal

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy’s National Nuclear Security Administration under contract DE-NA0003525.