SunShot
U.S. Department of Energy

CSP Program Summit 2016

Development of 800°C Receiver for Sensible Heat Storage

Advanced Projects Offering Low LCOE Opportunities (APOLLO)

David Wait, SolarReserve

800°C Receiver Development at a Glance

SOLARRESERVE

Program:	SunShot CSP APOLLO
Topic:	Receivers
Location:	Santa Monica, California
Award Amount:	Up to $2.9 million
Project Term:	2015 - 2018

CONTACTS
Project Leader:
David Wait, SolarReserve

Partnering Organizations:
UC San Diego
University of Arizona

Problem Statement and Value Proposition

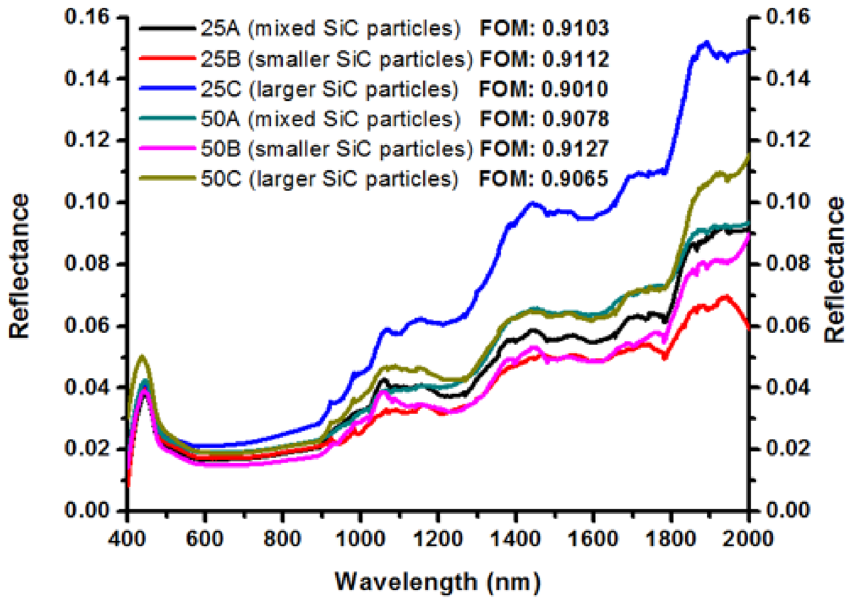
- Develop Power Tower Receiver Meeting SunShot Vision Goals
  - High outlet temperature to drive higher efficiency supercritical power cycles using thermal storage
  - Compatible With Oxy-Chloride molten salts for affordable direct storage of sensible heat at 720°C
  - 30 year life (10,000 thermal cycles)
  - 90% thermal efficiency
  - Affordable capital cost (<$150/kWt)
- Result – key component that enables lower cost of electricity (6¢/kWhe)

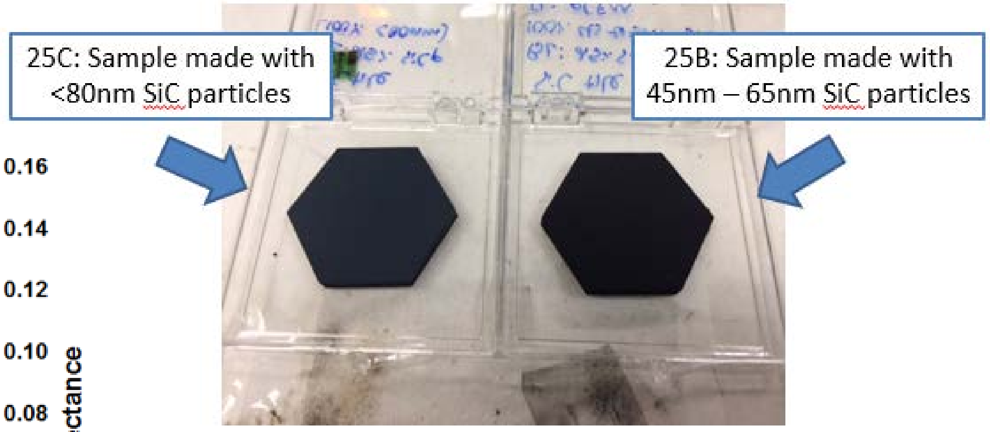
Objectives, Milestones and Results

Year	Objectives	Milestones
1	Qualify nano-particle high performance coating for 800°C	• Thermal efficiency Figure of Merit ≥ 90% after 1000 hours at 800°C and 10 thermal cycles • Area adhesion > 98% after 1000 hours at 800°C and 10 thermal cycles
	Measure corrosion of tube material in molten salt	• Affected depth extrapolated to 30 years < 160 µm
	Predict performance and cost of commercial size receiver	• Predicted thermal efficiency > 90% • Predicted installed cost < $150/kWt
	Design concentrated solar flux test loop	• Verification of peak flux, peak flow rate, and fluid capacity through analysis
2	Manufacture test section	• Pass ASME proof pressure test
3	Determine thermal-fatigue lifetime of design	• Integrity of pressure boundary • Depth of corrosion affected layer less than predicted

Important Results on High Performance Coating

UC San Diego





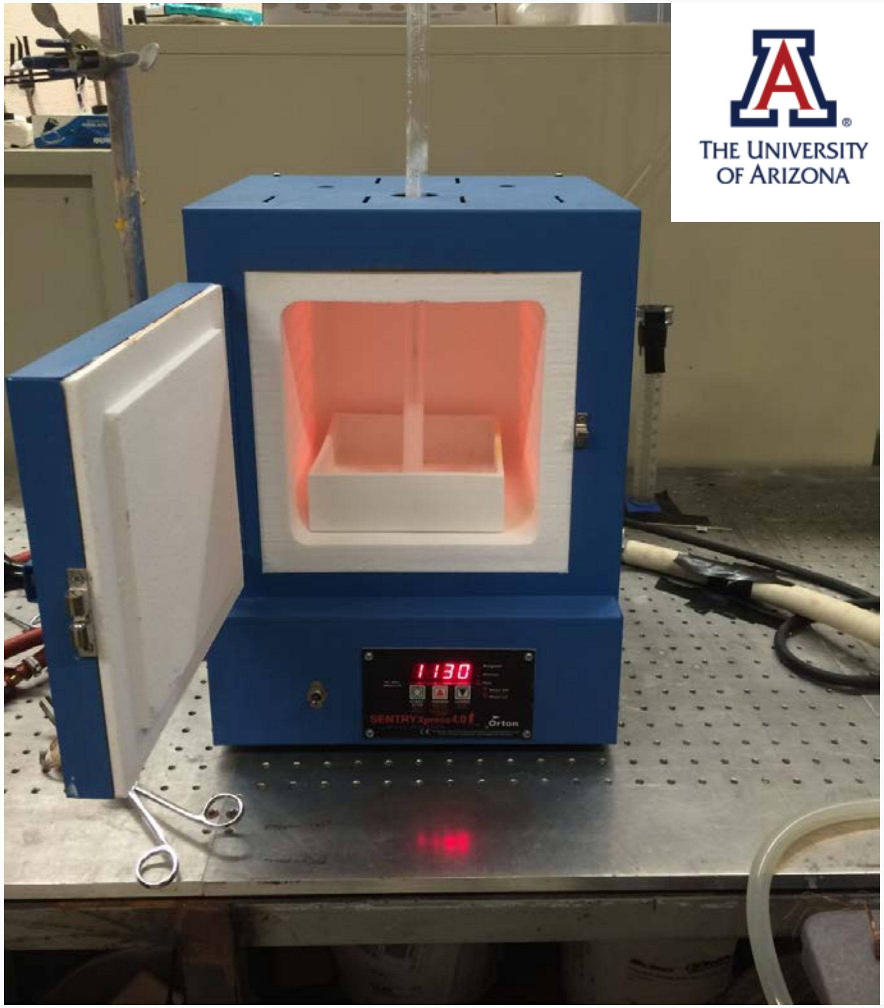
$$FOM = \frac{Q_{abs} - Q_{rad}}{Q_{incident}}$$

$$= \alpha_{s,eff} - \frac{\epsilon_{IR,eff}\,\sigma(T_R^4 - T_0^4)}{C\ I}$$

SiC particles in the coating lead to high values for the figure of merit

Important Results on Salt Compatibility

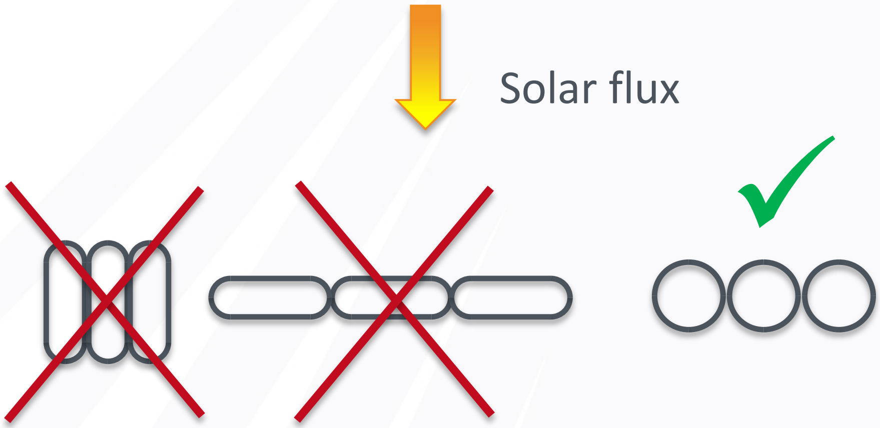
- Early testing of SiC (Hexoloy) showed uptake of salt due to material porosity and also brittle failure when dropped into quartz tube
- Haynes 230 is being immersed in 68% KCl / 32% MgCl2 at 800°C for up to 3000 hours
- Salt requires deaerating and dehumidifying
- Tests are being run with and without magnesium foil as a corrosion inhibitor



THE UNIVERSITY OF ARIZONA

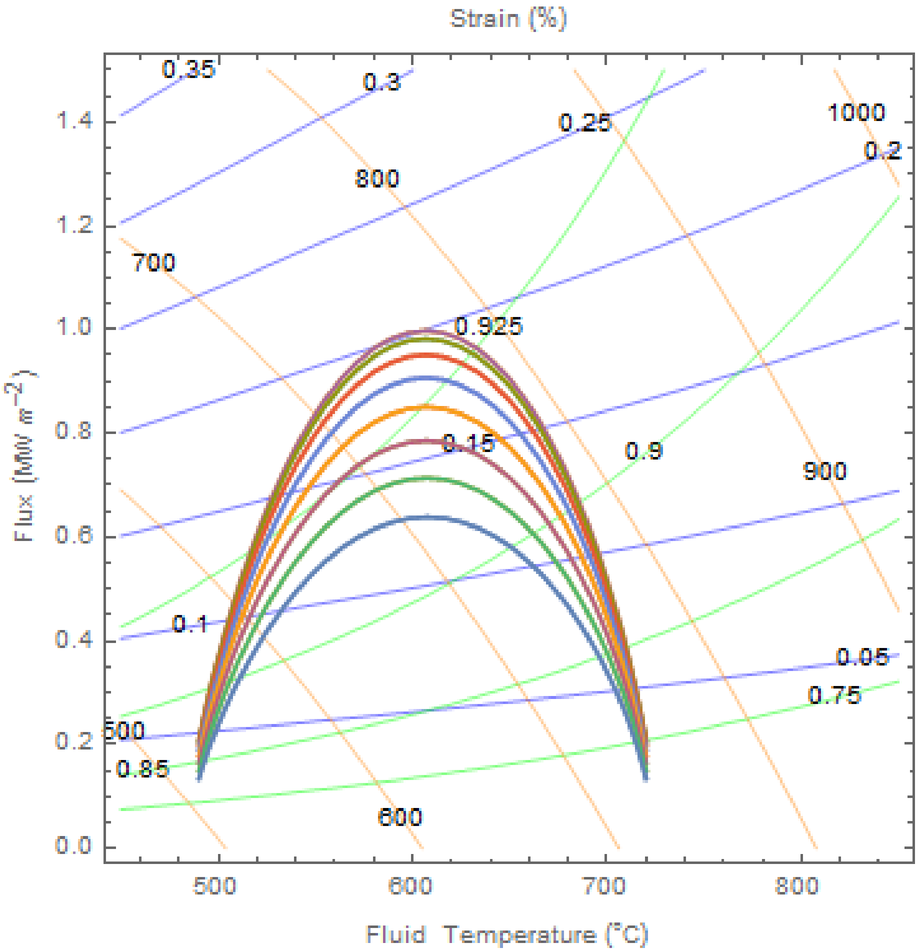
Important Results on Flow Channel Design

- Minimizing thermal strain and maximizing thermal efficiency favors circular tubes over non-circular flow channels. Least tube wall thickness is best.
- Silicon carbide survived thermal shock tests
- Silicon carbide failed mechanical shock tests
- High nickel super-alloy becomes best choice pending corrosion tests



Failure of 1 meter drop test

Preliminary Results for Commercial Size Receiver



- 565 MWt
- Haynes 230 alloy
- Thermal efficiency = 91.0%
- Peak strain = 0.2%
- Fluid Outlet = 720°C
- Fluid Inlet = 490°C
- Peak inlet pressure = 6.2 bar
- KCl-MgCl2 salt
- Peak tube temperature < 800°C
- Cost < $150/kWt

Thanks You!

Questions?