Development of a High Efficiency Hot Gas Turbo-expander and Low Cost Heat Exchangers for Optimized CSP Supercritical CO_2 Operation

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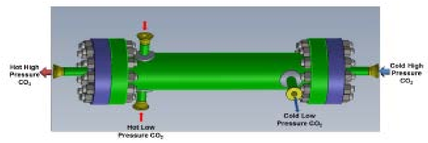
PROBLEM STATEMENT

- To develop a novel, high-efficiency supercritical sCO_2 turbo-expander optimized for the highly transient solar power plant duty cycle profile.
- This MW-scale design advances the state-of-the-art of sCO_2 turbo-expanders from TRL3 to TRL6.
- To optimize heat exchanger design for sCO_2 applications to drastically reduce their manufacturing costs.
- To design and fabricate of a 1-MWe test loop to demonstrate component performance and endurance.
- To demonstrate that CSP power at $0.06/kW-hr levelized cost of electricity (LCOE) is possible by increasing energy conversion efficiency to greater than 50% and reducing total power block cost to below $1,200/kW installed.

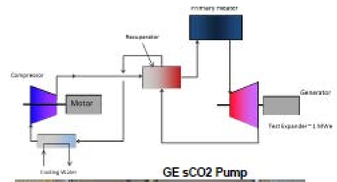
HEAT EXCHANGER DESIGN

- Detailed design of the 5 MWt was accomplished.
- Pressure Vessel Fabrication Completed
- Hydro-test-ASME stamp complete
    - Fabrication of Tube Bundle Component Completed Tube sheets
    - Seals
    - Micro-tubes
    - Bundle supports
    - Braze fixtures
- Tube bundle assembly brazing complete
- Undergoing final inspection.



TEST LOOP DESIGN

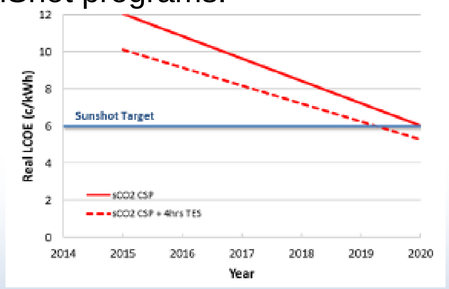
- A 1 MW test loop was designed for the explicit purpose of testing the turboexpander and heat exchanger using simple recuperated sCO_2 power cycle.
- The loop integrated into the existing infrastructure available at Southwest Research Institute



GE sCO2 Pump

THERMOECONOMIC ANALYSIS

A detailed economic study was conducted to verify that the cost targets could be met. A design point of 24.6°C was selected as it is more representative of the ambient conditions of Daggett, CA. The study shows that the cost targets set by SunShot can be met by this project after incorporating heliostat and receiver improvements from other SunShot programs.



TURBOEXPANDER DESIGN

A novel 10MW turboexpander (1 MW for test program) has been designed and built to meet the requirements of the sCO_2 power cycle resulting in a thermal-to-electric efficiency greater than 50%. Turbine inlet temperatures exceeding 700°C.

INDUSTRY IMPACT

- 5MWt recuperator has been designed for the sCO_2 power cycle.
- A sCO_2 turbomachine single-shaft design has been built and testing has begun.
- A test loop was designed to demonstrate the performance of the expander and recuperator and has been integrated into the existing facilities at SwRI.
- A custom 2.5MW SCO_2 heater was designed and is completed.
- The thermo-economic cycle analysis and commercial product evaluation has also been accomplished. A CSP plant has been laid out and a cost analysis reveals that it meets the cost targets of the project.