Glass-Seal Test Vessel

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Motivation

Create testing equipment and procedures to engineer sealing systems on the small particle heat exchanger receiver for high temperature Brayton cycles, it will be a device to transfer the heat of light to the fluid medium in a solar/turbine power plant. The topics that will be tested on various windows and window mounts are: friction coefficient of high temperature seals, hydrostatic pressure with and without heat loading, and heat flux loading.

Background

- A solar receiver transfers the thermal energy from the sun to the working fluid in a concentrated solar power plant.
- This project focuses on the window sealing system which is difficult due to the differences in thermal expansion.

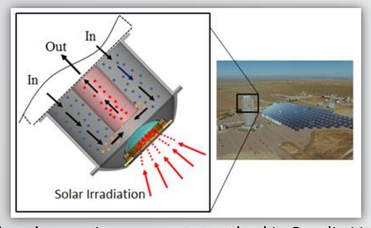

Figure 1: Particle solar receiver concept, testbed in Sandia National Lab (courtesy of http:/i1.wp.com/cleantechnica.com)

Function and Design

- High-temperature Graphoil gaskets used to seal under heat loading.
- High-temperature and pressure feedthroughs used to pass power and sensing signals through pressure barrier.
- PID controlled heating system.
- ASTM A105 compliant pipe components for safety.
- Finned tube used to drastically decrease heat going through tube coming out of test vessel.
- Heavy insulation around the heating coil and inner chamber and natural convection keep outer surfaced safe at steady-state.

Figure 2: High-Temperature/pressure power feedthroughs.

Figure 3: High-temperature Graphoil seals

Figure 4: PID controller for heating coil.

CAD Rendering of Test Vessel & Testing

- Thermal modeling was used to determine electrical requirements and mechanical dimensions
- Mechanical FEA analysis was used to specify mechanical properties.

Figure 5: Static Pressure test performed at 12 Bar pressure (20% above operating pressure) to ensure structurally sound vessel

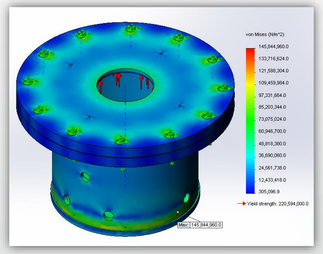

Figure 6: FEA analysis of vessel at 15 Bar has factor of safety of 2. Vessel will operate at 10 Bar and wont fail until 20 Bar pressure.

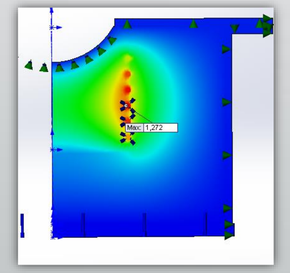

Figure 7: 2D thermal steady-state analysis of vessel with 1000° C wall temperature

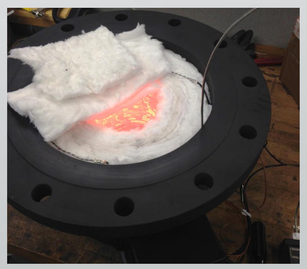

Figure 8: Thermal steady-state test performed on vessel at 1000° C wall temperature.

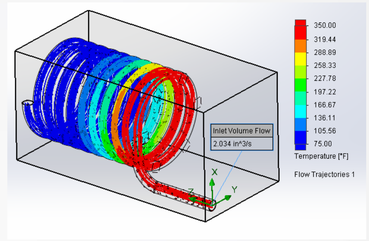

Figure 9: Thermal steady-state analysis of flow (2 L/min) through exit cooling tube of vessel. Temperature drops from 1000° C to room temperature after 3 ft of copper tubing.

Figure 10: Empirical test with flow rates of 2 L/min – 4 L/min taking various temperature reading along copper tube. Validated flow simulation

Actual built test vessel

- Test pressure vessel is made up of a A36 steel pipe, flange and round plate that were TIG welded together.
- Top plate is a blind flange that has been modified to accommodate test window.
- 5 pipe fitting were TIG welded for electrical feedthroughs, thermocouples, and piping.
- Pressure and Thermal tests performed to validate CAD simulation

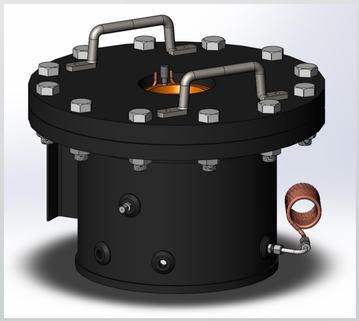

Figure 11: Finalized CAD model of pressure vessel.

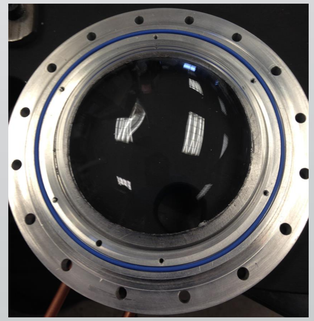

Figure 12: Fused quartz glass sealing system to be tested on vessel

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