Analysis and Performance of Refractory Insulation for Regenerative Heat Exchangers in s-CO2 Brayton Cycles

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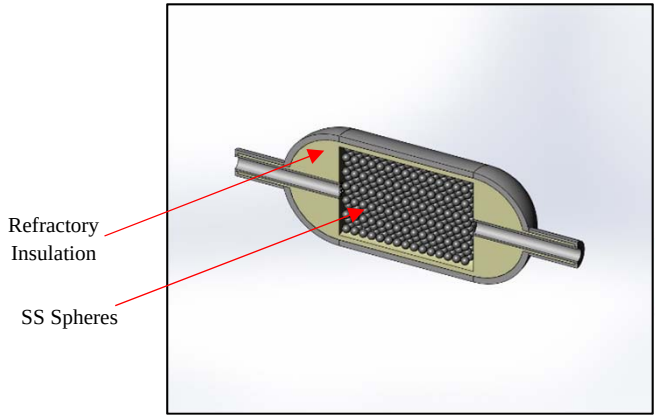
"Practice does not make perfect, only perfect practice does"
-Vince Lombardi

Project Overview and Goals

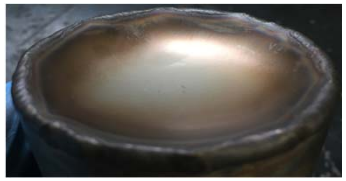
- A refractory materials are defined as non-metallic materials have chemical and physical properties that make them applicable to environments above 538°C
- The refractories studied were characterized by low thermal conductivity, low heat capacity, high mechanical strength and low porosity
- The utility of the refractory insulation in this regard is to maintain the outer wall of a regenerative heat exchanger below 350°C
- The recommended refractories by the U.S. Department of Energy (DoE) Apollo Sunshot initiative were:
  - Ziralcast95
  - Grefcon98
  - Extress27

Component \ Refractory	Ziralcast95	Grefcon98	Express27
Water (H_2O)	16 %	5.7 %	8 %
Alumina (Al_2O_3)	95.3 %	98.1 %	49.6 %
Lime (CaO)	3.7 %	1.4 %	4.2 %
Silica (SiO_2)	0.4 %	0.1 %	42.2 %



Preliminary Results

- First stage involved pressure fluctuation of refractory insulation in direct contact with gas flow and encapsulated from gas
- All refractories demonstrated good performance under encapsulated approach with no visible deformation on protective metal liner


Empty Vessel


Express 27


Ziralcast95


Grefcon98

- Under direct contact with gas flow Express27 demonstrated no crack propagation and zero weight loss
  - Ziralcast95 had a total of ~4% and Express had a total of ~0.1% after being pressurized to 1100psi and 1800psi respectively

Ziralcas95


Before


After

Express27


Before

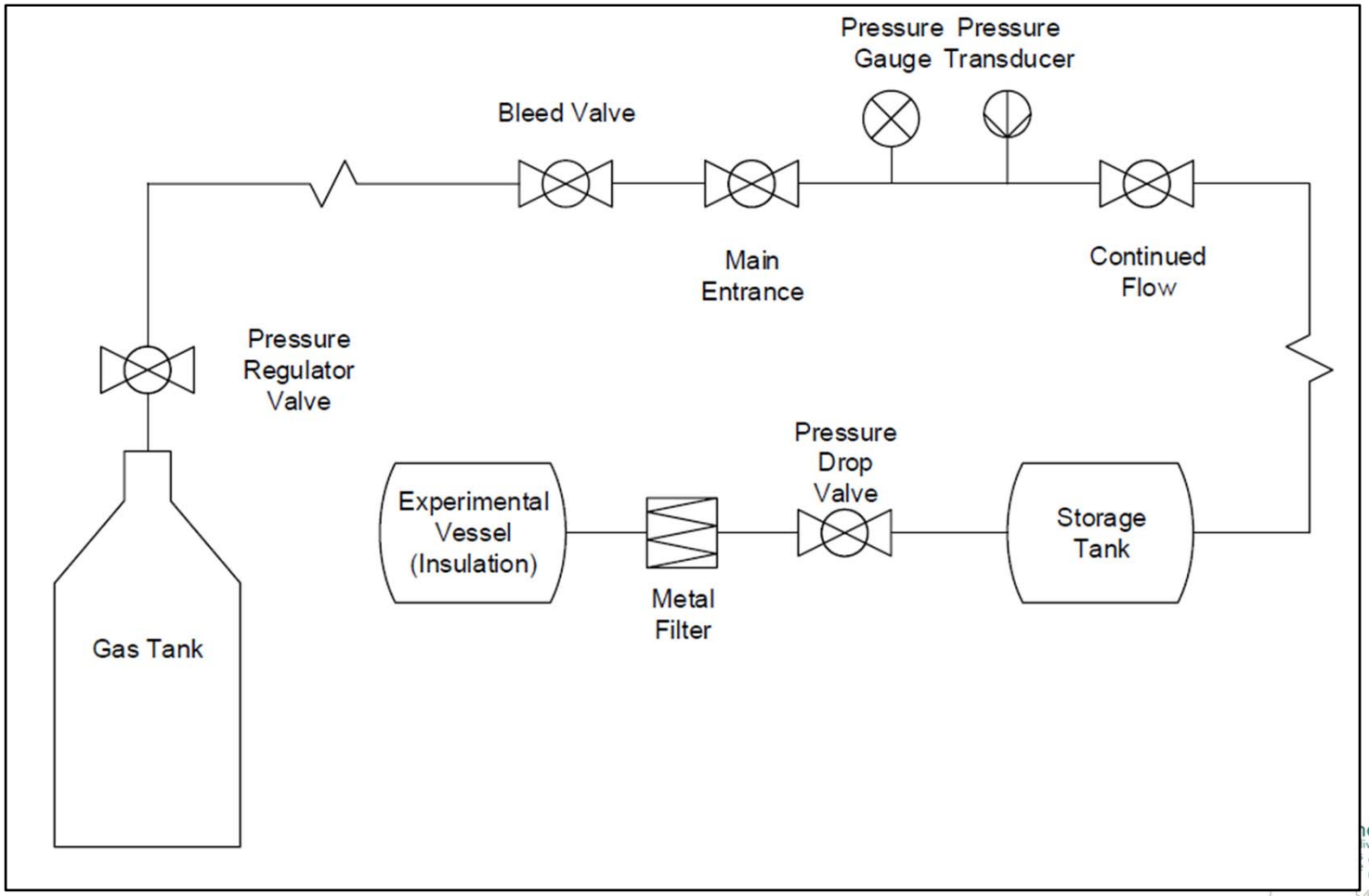

After

Grefcon98


Before


After

Schematic of Experimental Setup



Future Work

- Test and analyze gas diffusion into ceramic matrix of insulation through extended times (12 to 24 hours) at 500 psi, 1100 psi and 1800 psi
- Thermal cycle between 560°C and 225°C with 45 seconds switching time (in a furnace)
  - This is the temperature operation and switching time for the large scale regenerative heat exchangers
- Re-test for gas diffusion and analyze effect of thermal expansion and porosity
- Evaluate thermal conductivity under pressurized environment and possible variance in axial direction