High Temperature Flow Loop Design

Sandia National Laboratories

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CONCENTRATING SOLAR POWER: STORAGE

Introduction & Background [1]

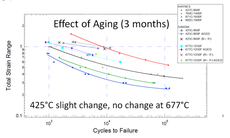
Significant technology developments are required to meet the SunShot Initiative cost goal for Concentrating Solar Power of 6¢/KWh$_e$. The SunShot Initiative targets for Thermal Energy Storage (TES) are:

- TES Cost ≤ $15/KWh$_{th}$
- TES Efficiency (2nd Law) ≥ 95%
- TES Charge Time ≤ 8 hrs.
- TES Operating Temperature ≥ 650˚ C

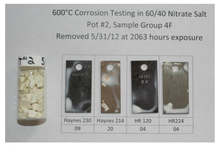
There are several technologies that may be able to achieve the high temperature operation required. Of these technologies, sensible energy storage in high temperature molten salts is very promising.

Sensible molten salt is the TES technology of choice in current and near-term CSP plants. Sandia has a long history of research seeking to fully understand and quantify the material interactions between molten nitrate salt and containment materials.

Corrosion test vessel for long-term corrosion testing In static molten salt to 700C



Thermo-mechanical, cycle fatigue test results



Static corrosion test samples after 2063 hrs. of salt exposure awaiting cleaning and analysis (at 600C with air as cover)

The Molten Salt Test Loops (MSTL) System for CSP component evaluation under plant-like conditions, including tracking, on-sun experiments.

Objectives

The Objectives of this research are:

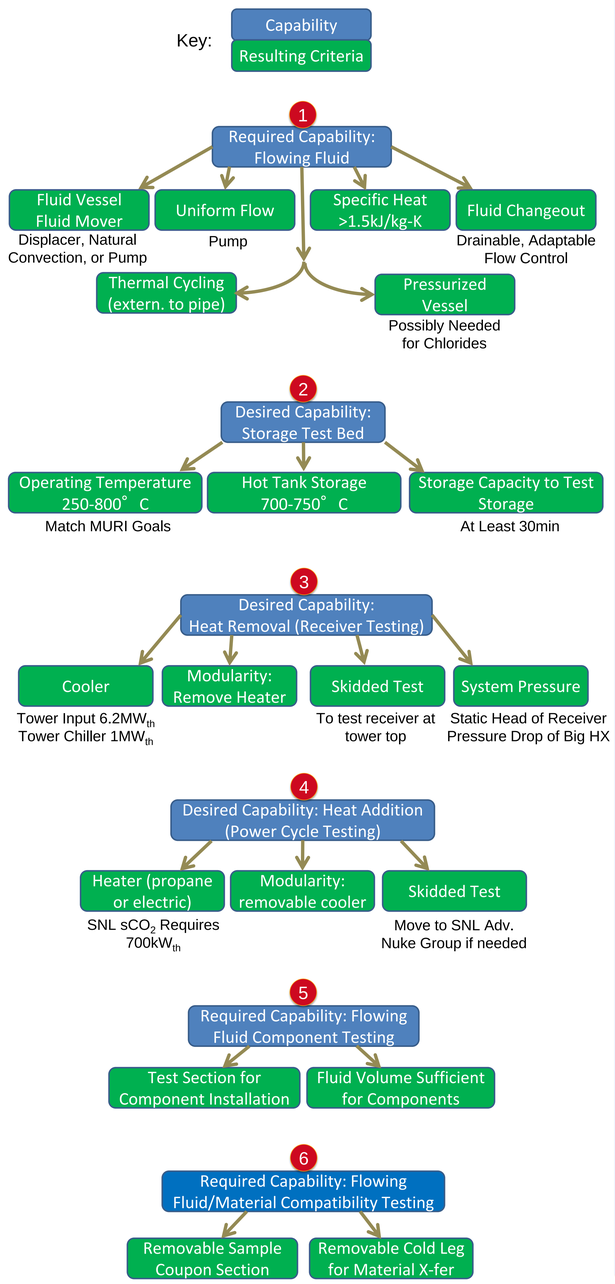
1. Perform preliminary analysis of needs and system sizing
2. Solicit input from potential users in the CSP community on testing needs
3. Design system to be compatible with several candidate HTF's as is practical
4. Plan construction and obtain equipment estimates.

HTF Properties

The Table below shows the known properties of 6 potential high temperature heat transfer fluids (typically at 600C)[1,2]. The flow loop should be capable of operation with as many of these fluids as possible.

Salt	KCl-LiCl	KCl-LiCl-NaCl	K_2CO_3-Li_2CO_3-$NaCO_3$	KCl-$MgCl_2$-NaCl	KCl-$MgCl_2$	$CaCl_2$-KCl-LiCl
Melt. Point	348°C	346°C	393°C	396°C	429°C	338°C
Eutectic [%]	40-60	24-43-33	25-43.5-31.5	20-60-20	78-22	
Cp [kJ/kg-K]			1.560		1.159	
Density [kg/m^3]			1902		1664	
K W/m-K			0.822		0.40	
Visc. [mPa-s]			4.3		1.4	

Capability Mapping



Capability Analysis

System Heat:

$$\dot{m} = \frac{\dot{Q}}{c_p \Delta T}$$

$$\dot{m} = \dot{V} * \rho$$

$$\dot{V} = \frac{\dot{Q}}{\rho c_p \Delta T}$$

System Flowrate:

Rule of Thumb for Erosion Prevention
v < 10ft/s
1.5" pipe -> 55gpm limit
2" pipe -> 97gpm limit
Note: 2" is 22% more expensive than 1.5"

Choose Dia$_{pipe}$ = 1.5"

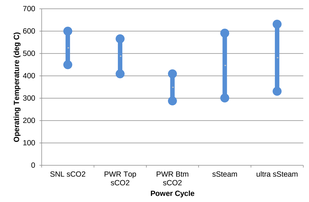
System Power

NSTTF Field = 6.2MW$_{th}$
NSTTF Chiller = 1.0MW$_{th}$
SNL sCO2 = 0.7MW$_{th}$

6.2MW air cooler (SCRAP) was $650k
So 6.2MW seems too large for budget

Choose Q = 0.7-1.0 MW$_{th}$

System Temperature



Choose ΔT = 200˚ C

Fluid Properties and Storage Volume

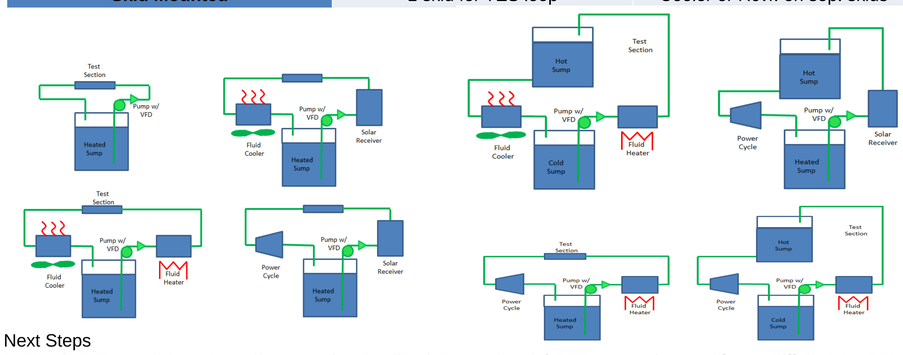
Salt	ρ Cp(kJ/m^{3}K)	Req. Flow to absorb 700kW$_{th}$ ΔT=200K (kg/s)	Req. Tank for 1 hr storage (m^3)
LiCl-KCl eutectic	1417	4.85	8.9
$K_2LiNa_2CO_3$ (eut.)	4151	1.66	3.0

Choose V=3.0-7.6m^3 (1000-2000 gal)

Conclusions:
1. ΔT=200˚ C
2. Power = 700kW$_{th}$
3. 50gpm is sufficient, so 1.5" piping can be used
4. Tank Capacity 3.0-7.6 m^3 (800-2000gal)

Results and Next Steps

Design Criteria	Target Value(s)	Acceptable Value(s)
Temperature Range for Testing	250°C – 750°C	450°C-700°C
Thermal Input/output	700kW$_{th}$	500kW$_{th}$ – 1MW$_{th}$
System Flowrate	6.2 kg/s (~50gpm)	4.9-8.6kg/s (~40-70gpm)
Temperature Delta	200°C	100-300°C
Pump Pressure	53m H_2O (75psi) minimum	53-88m H_2O (75-125psi)
Piping	1.5",high nickel alloy	1.5-2" (2" req. if flow>55gpm)
Storage Vessel(s)	3.8 m^3 (1000gal) Can be Pressurized to 1ATM	3.0-7.6 m^3 (700-2000gal.)
Storage Vessel(s)	1 tank w/ high temp capability	1 hot & 1 cold tank
Gravity Drainback	Slope ¼" per foot	Slope 1/8" per foot
Skid Mounted	1 skid for TES loop	Cooler or Rcvr. on sep. skids



Next Steps

- Conduct Request for Information to gather feedback from potential CSP researchers – **Please Fill Out An RFI**
- Solidify requirements and complete detailed prototype design

References

[1] Janz, G.J., "Molten Salt Handbook", Academic Press, NY 1967
[2] Sohal, M.S. et al., "Engineering Database of Liquid Salt Thermophysical and Thermochemical Propoerties", INL-EXT-10-18297, March, 2010

SunShot U.S. Department of Energy

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