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DEVELOPMENT AND CHARACTERIZATION OF NOVEL METAL CHLORIDE THERMAL STORAGE MEDIA WITH ENHANCED HEAT TRANSFER

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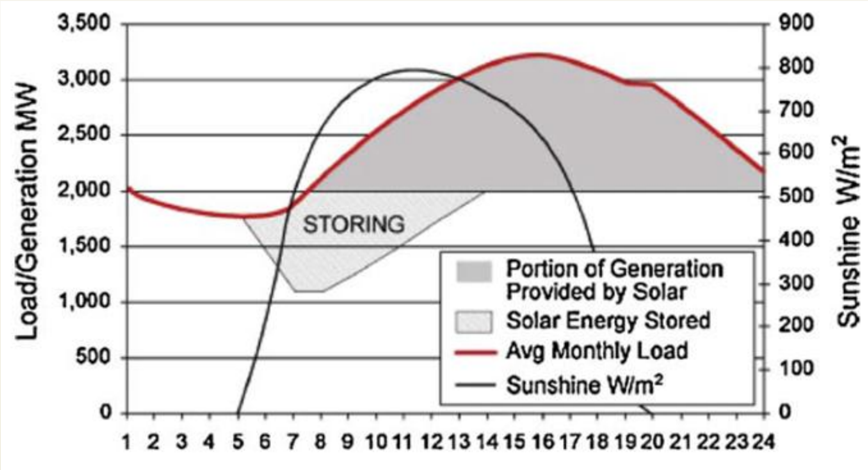
Introduction: The need for TES

- Renewable energy technologies, most notably solar thermal power, suffer from intermittency:
  - Insolation limited to daylight hours
  - Cloud cover / other atmospheric variability
- **Thermal energy storage (TES)** strategies are needed to account for this intermittency
- Typical storage strategy involves harnessing peak energy output for use during lag periods.[1]



Daily solar energy generation / storage[1]

[1] M. Medrano, A. Gil, I. Martorell, X. Potau, and L. F. Cabeza, "State of the art on high-temperature thermal energy storage for power generation. Part 2-Case studies," *Renewable & Sustainable Energy Reviews,* vol. 14, pp. 56-72, Jan 2010.

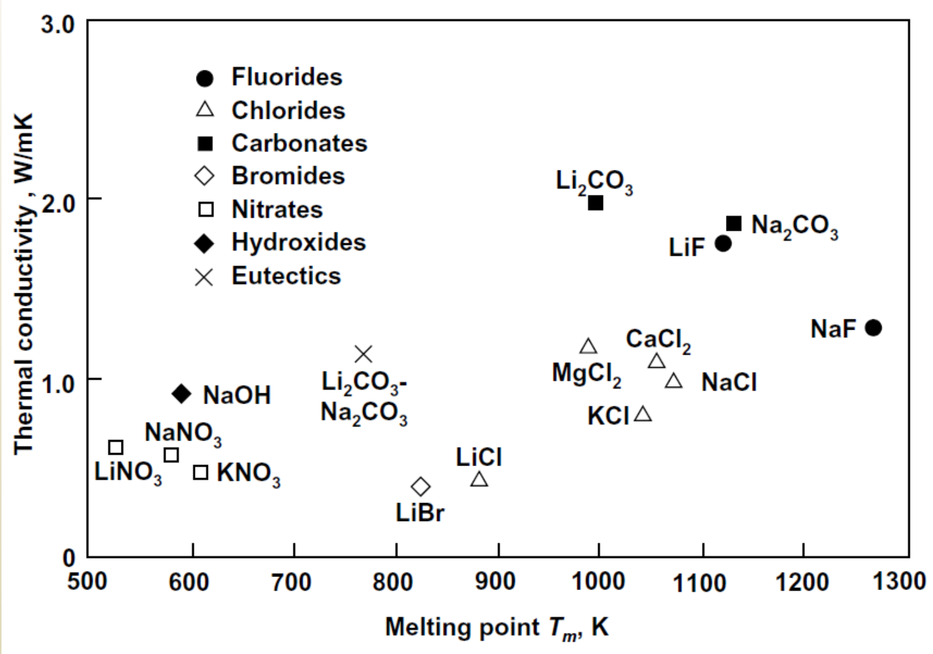
Inorganic salt-based TES

Inorganic salt TES media (e.g., nitrates, chlorides) hold promise as …

- Heat transfer fluids (dual-tank storage) ("Solar salt")
- Phase-change media (PCM) (e.g., packed bed)

BUT, they have *low thermal conductivity*

- ~ 1 W/m-K[2]
- Compare to various metal oxides (10-100 W/m-K) and elemental metals (>100 W/m-K)
- Lowers charging / discharging rates of TES system

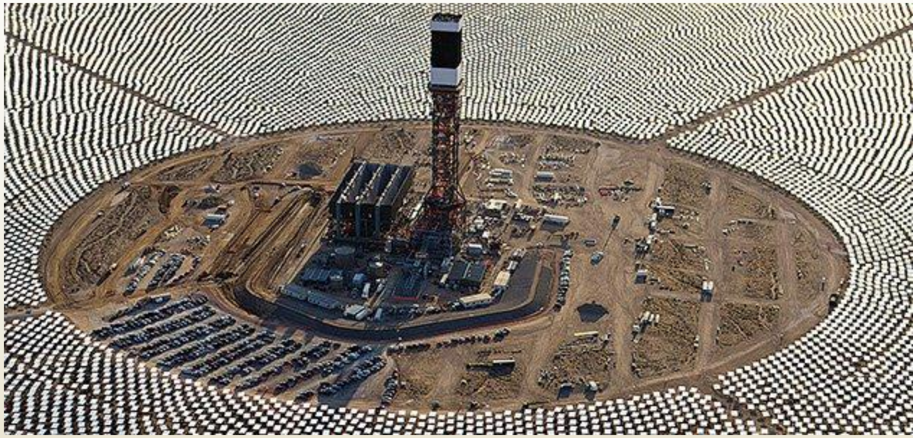


Thermal conductivity, melting point of some candidate molten salts[2]

[2] A. Hoshi, D. R. Mills, A. Bittar, and T. S. Saitoh, "Screening of high melting point phase change materials (PCM) in solar thermal concentrating technology based on CLFR," *Solar Energy*, vol. 79, pp. 332-339, 2005.

Novel concept: Additives to enhance radiative heat transfer

- As solar thermal plants (power tower) reach higher temperatures / efficiencies, higher melting salts will be needed
- (K-Na)Cl eutectoid is ideal candidate
  - $T_m = 658°\text{C} \quad \Delta H_{fus} = 278\ \text{J/g}$
  - Inexpensive



Ivanpah SEGS[3]

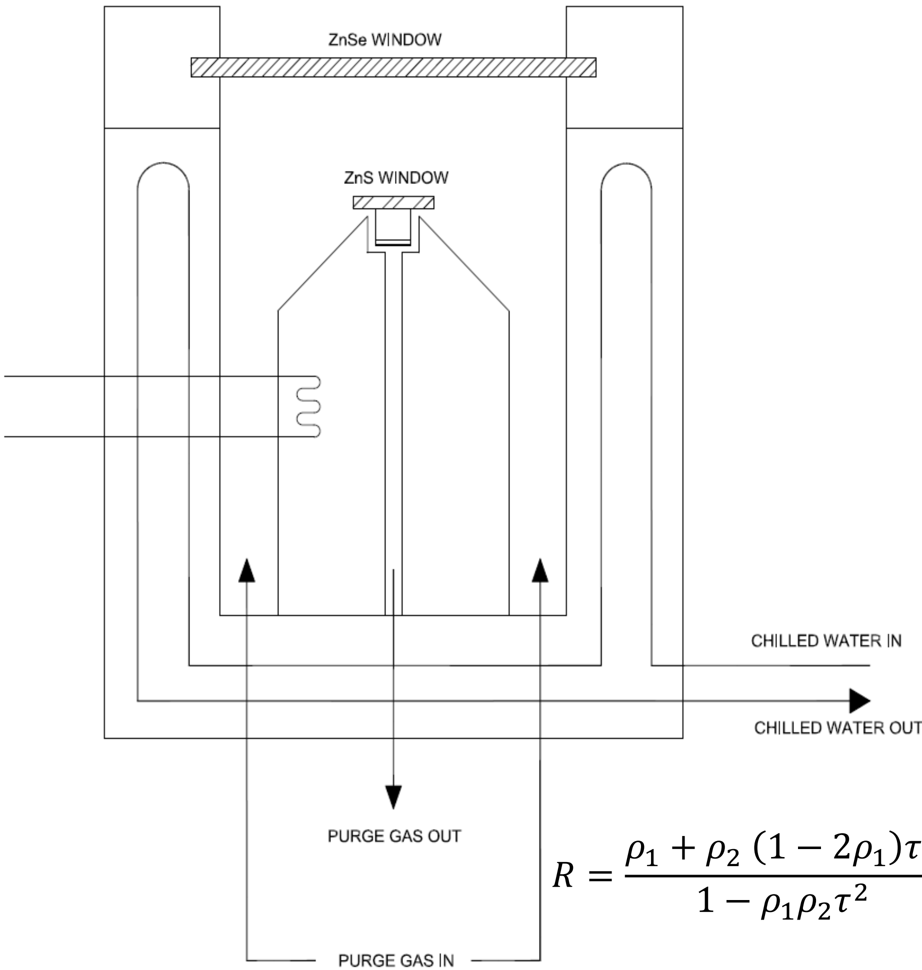
- BUT transparent to infrared (heat) radiation: at melting point, ~90% of ideal radiant emission falls within the highly transmissive region of 2.0 to 13.0 µm
- We add IR active compounds (e.g., $CoCl_2$) to absorb thermal radiation, improve overall heat transfer rates

$$\frac{1}{\sigma \cdot T^4} \cdot \int_{2\mu m}^{13\mu m} \frac{2\cdot\pi\ C1}{\lambda^5 \cdot \left(e^{\frac{C2}{\lambda \cdot T}} - 1\right)}\, d\lambda = 0.90$$

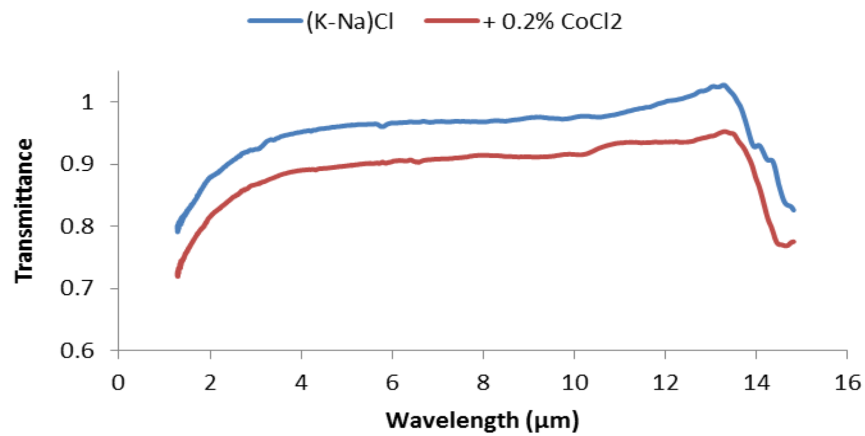
[3] M. Strauss, "Take a Look at the World's Largest Solar Thermal Farm," *Smithsonian Magazine*, Nov 2012 (http://www.smithsonianmag.com/science-nature/take-a-look-at-the-worlds-largest-solar-thermal-farm-91577483/).

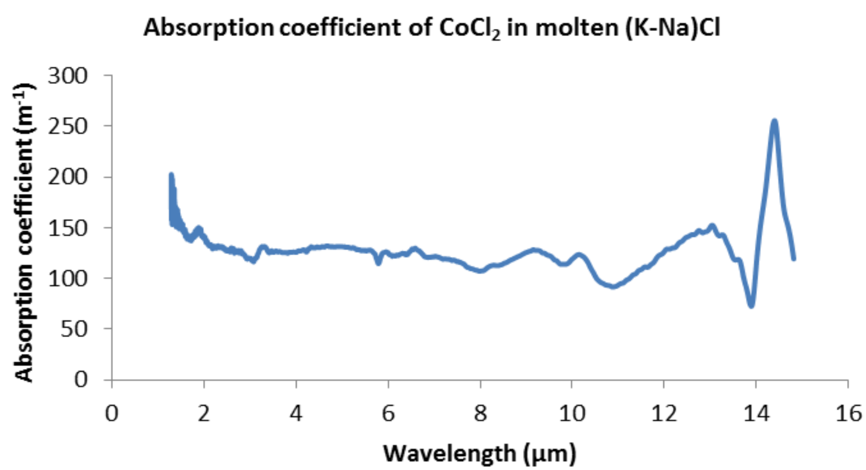
High temperature IR reflectance apparatus

- Test of efficacy of IR absorption in molten salt: $CoCl_2$ absorption coefficient



$$R = \frac{\rho_1 + \rho_2\,(1 - 2\rho_1)\tau^2}{1 - \rho_1\rho_2\tau^2}$$





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