SOLAR THERMOCHEMICAL ENERGY STORAGE

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Background

Current methods of solar thermal energy storage use sensible or latent heat. This prevents the ability to store energy for long periods of time and requires large scale processes to be feasible. A proposed solution is chemical energy storage in a salt dehydration reaction. These salts can store energy for an indefinite period of time. Applications include heating, cooking, and water sterilization for energy impoverished areas.

Calcium chloride ($CaCl_2$) was the salt chosen for testing because it is inexpensive, obtainable, and safe.

$$CaCl_2(s) + 6H_2O(l) \longleftrightarrow CaCl_2 \bullet 6H_2O(s) + \text{Heat}$$

Equation 1. Hydration reaction of anhydrous $CaCl_2$.

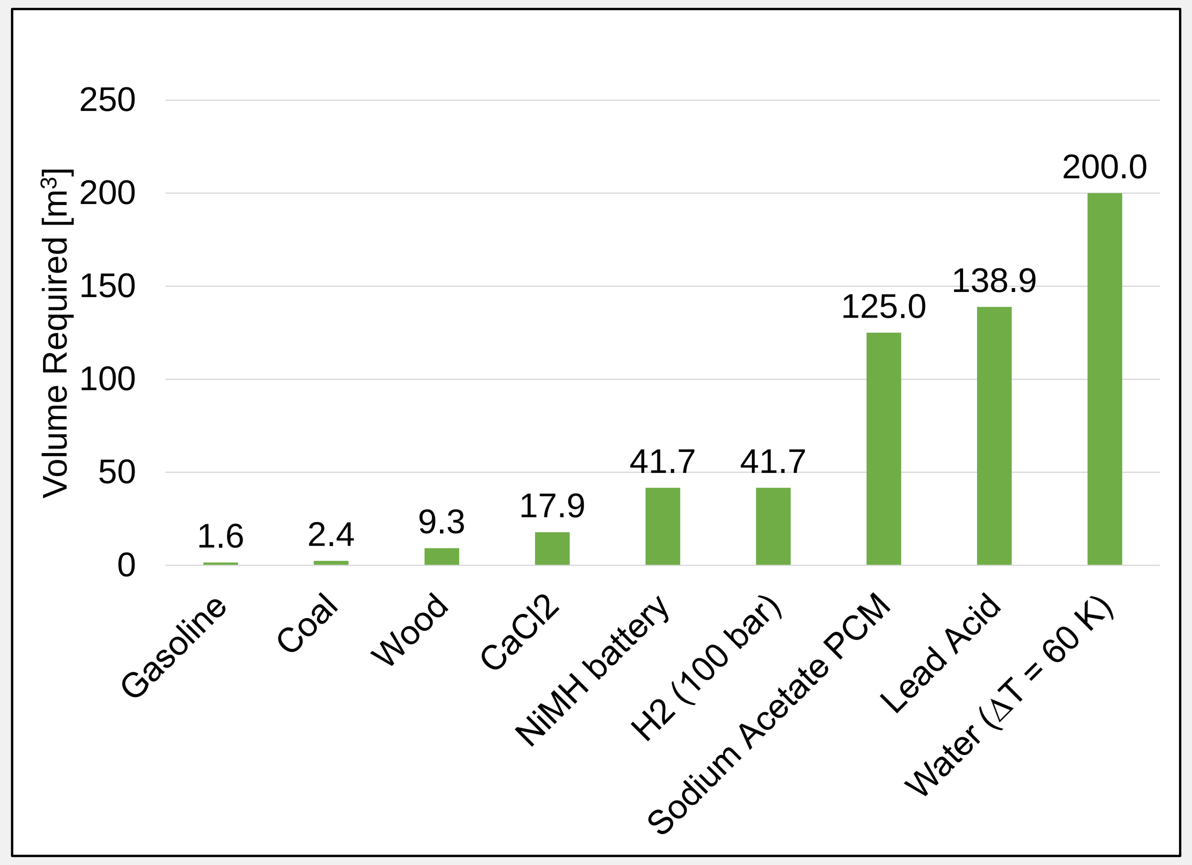

Figure 1. Storage volume required per household of various energy sources.[1] Assumes a household requires 50 GJ thermal energy annually.

Objectives

- Small scale, long term solar energy storage
- Solar collector design with minimal tracking
- Operation times of less than three hours

Figure 2. Salt vehicle made of activated carbon to house and preserve reaction surface area of the $CaCl_2$.

Figure 3. An evacuated tube dehydration chamber used to minimize heat loss to the surroundings.

Methodology

Calcium chloride is impregnated into a "salt vehicle", graphite matrix, to increase surface area for both hydration and dehydration processes. These salt vehicles are dehydrated with a Mylar solar concentrator to focus solar radiation onto an evacuated tube dehydration chamber. The evacuated tube minimizes heat loss, allowing for high dehydration temperatures to be obtained.

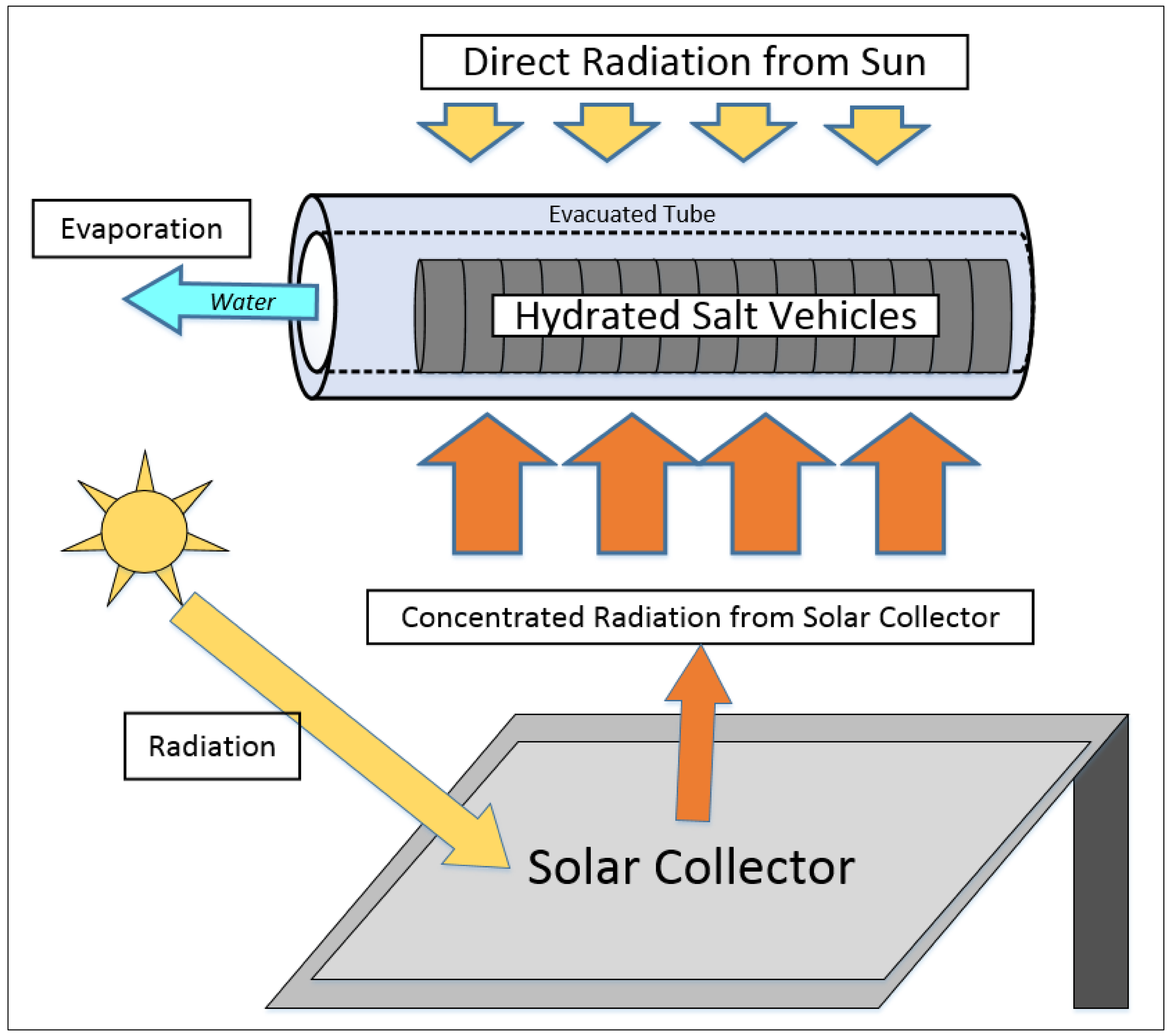

Figure 4. Evacuated tube schematic where incident solar rays are reflected from a solar collector to towards the tube, heating the salt vehicles within.

Results

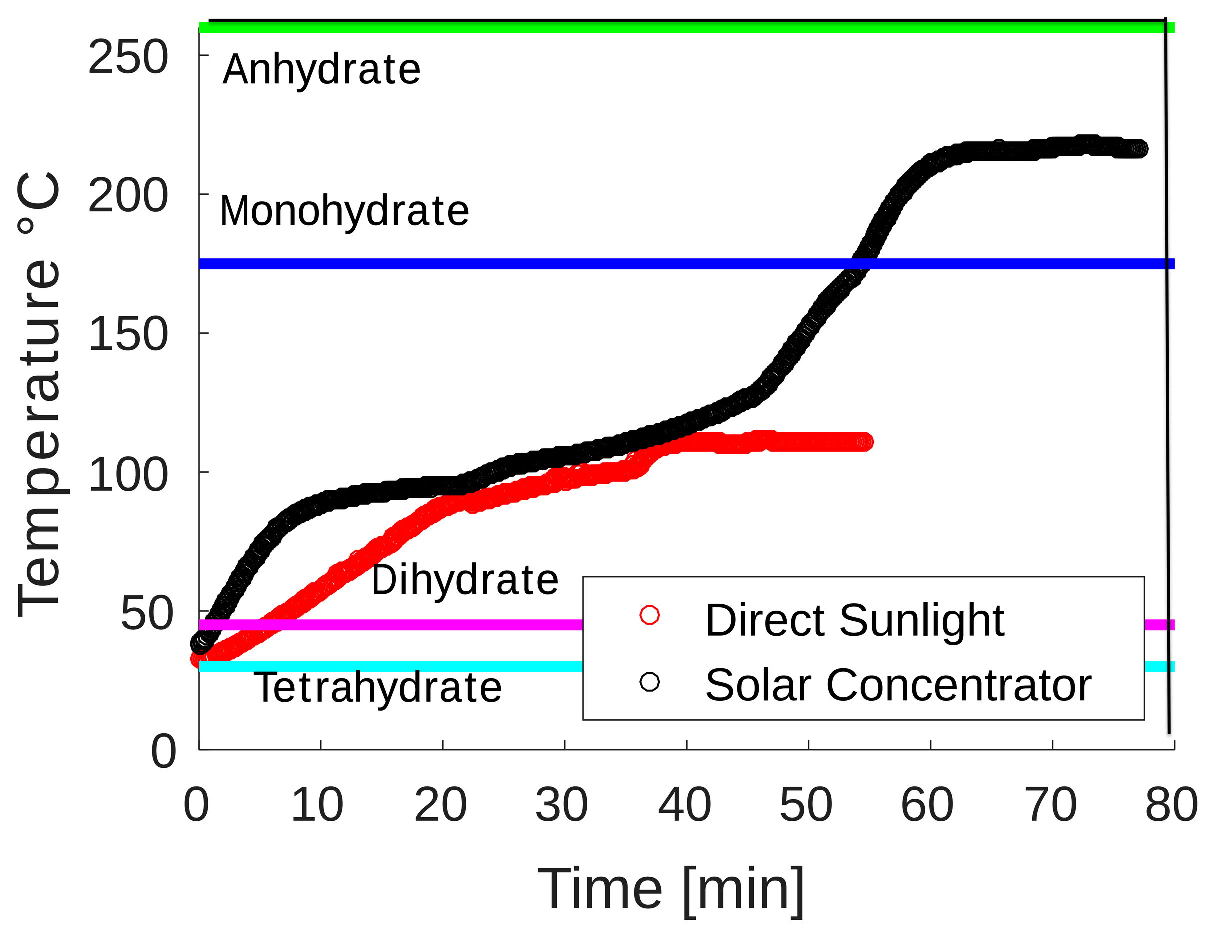

Figure 5. Temperatures achieved while testing a singular salt vehicle in the evacuated tube under direct sunlight compared to with the solar concentrator. The horizontal lines represent the hydration levels. Incident radiation during testing averaged approximately 850 W/m^2.

Conclusion

Current design achieved 217 ℃, and allows salt dehydration to a monohydrate state within approximately one hour.

The use of only an evacuated tube without concentrated solar radiation achieved the dihydrate state at 45 ℃ in under ten minutes of operation time.

The anhydrous state has an energy storage of 336 MJ/m^3 of salt vehicle. This would result in needing approximately 149 m^3 of salt vehicle to heat a home annually.

1. Cuypers, R.; Hoegaerts, C., More Effective use of Renewables including compact Thermal Storage (MERITS). In RHC Conference, Dublin, 2013.

Future Work

- Alternative salts

Magnesium sulfide, magnesium hydroxide, and magnesium nitrate have different dehydration temperatures, heats of hydration, and energy densities and are being explored as options for increasing energy storage.

- Solar collector improvements

Figure 6. Current iteration of solar concentrator. Reflectivity will be improved through the application of an under layer of black paint to increase emissivity.

- Measure mass loss of water over time

Figure 7. Electronic postal scales will be used to measure mass of water over time and to characterize level of dehydration achieved with respect to temperature.

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