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Materials Issues Associated With TES for CSP Applications

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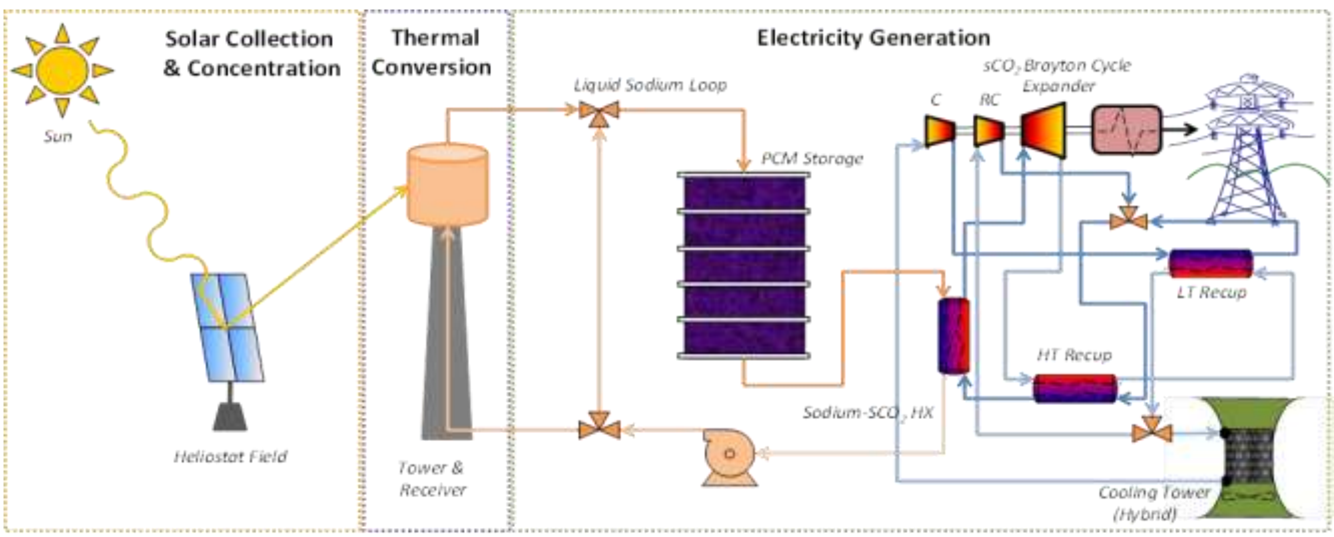
The next generation of Concentrated Solar Power (CSP) plants are expected to operate at higher temperatures than those currently in use, for improved efficiency and reduced cost of power generation. Figure 1 is a proposed scheme for a CSP plant designed to operate at temperatures from 550 to 700 °C with Thermal Energy Storage at around 630 °C. With regard to the three main sections of the proposed plant including receiver, storage and power generator, degradation mechanisms that threaten structural alloys at elevated temperatures include thermal fatigue and creep as general threats to all sections of the system (Sarvghad et al., 2018; Sarvghad, Will, & Steinberg, 2018). In addition, specific degradation mechanisms caused by liquid sodium as the preferred heat transfer fluid material, eutectic salts or metals as Phase Change Material (PCM) in the storage and supercritical CO_2 Brayton cycle in the generator threaten the plant.

Liquid sodium as the preferred HTF material, can lead to significant corrosion through dissolving the alloying elements in the alloy. Its penetration through grain boundaries could also lead to liquid metal embrittlement in the alloy while its movement through the pipes could cause erosion. Activity of carbon in liquid sodium could result in carburization or decarburization and consequently affect the mechanical properties of the alloy (Sarvghad, Delkasar Maher, et al., 2018).



Temperatures (°C) as currently understood: **675 (H1); 700 (H2)** **620-630 (H1); 675 (H2)** **SCO_2: 550-560 (H1); 630 (H2)**

Figure 1. Proposed CSP configuration; tower system using sodium receiver, PCM storage and sCO_2 power block with 4-6 hours of storage.

Eutectic salts or metals used as PCM in the storage are responsible for significant corrosion damage to the containment material in the storage system. Mechanisms leading to corrosion by PCMs include oxidation, fluxing, de-alloying, impurities, thermal gradient and thermal cycling. Phase transformation from liquid to solid and vice versa could also lead to erosion and mechanical fatigue (Sarvghad, Delkasar Maher, et al., 2018).

The sCO_2 Brayton cycle generator is susceptible to corrosion damage by the hot carbon dioxide gas mainly because of oxidation or carburization of the material. In addition, the flow of the compressed hot gas through the system could intensify corrosion while mechanically leading to erosion damage on the material surface (Sarvghad, Delkasar Maher, et al., 2018).

These threatening mechanisms will be discussed and the issues being addressed presented. For the purpose of studying compatibility, a list of candidate alloys (Table I), with acceptable mechanical strengths at 550 to 700 °C will be discussed. This presentation also includes a list of past and current activities at QUT in this and related areas.

Table I. Maximum allowable stresses for candidate alloys to be studied for CSP applications at temperatures 550 to 750 °C (Sarvghad, Delkasar Maher, et al., 2018).

Candidate alloy	Design tensile strength (MPa)				
	Temperature (°C)				
	550	600	650	700	750-760
SS316	111	85	51	28	16
Hastelloy c22	167	116	66	41	...
Hastelloy c276	145	99	67	42	...
Hastelloy X	150	121	78	53	33
Hynes 230	194	160	108	73	46
Hynes HR 120	152	123	85	52	34
Alloy 59	159	130	80	51	33
Incoloy 800	137	90	46	14	7.5
Incoloy 825	153	...	...	...	...
Inconel 718	220	212	...	...	...
Inconel 617	144	143	125	77	46
Inconel 625	206	200	138	80	46
Nimonic 263	...	...	...	...	52
Nimonic 115	...	...	...	...	112
Waspaloy	...	...	...	...	112

References

Sarvghad, M., Delkasar Maher, S., Collard, D., Tassan, M., Will, G., & Steinberg, T. A. (2018). Materials compatibility for the next generation of Concentrated Solar Power plants. *Energy Storage Materials, 14*, 179-198.

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