

Determination of Inconel-625 corrosion rate in NaKMg-Cl molten salt via linear sweep voltammetry



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Introduction

Concentrating solar power (CSP) systems collect heat from the Sun. The heat transfer fluids (HTF) can also act as thermal energy storage (TES). The heat is then transferred to produce steam that drives a turbine to generate electricity. These fluids need to flow through the system in a compatible containment material. *Figure 1* shows a diagram of a next generation central tower CSP (Gen3).

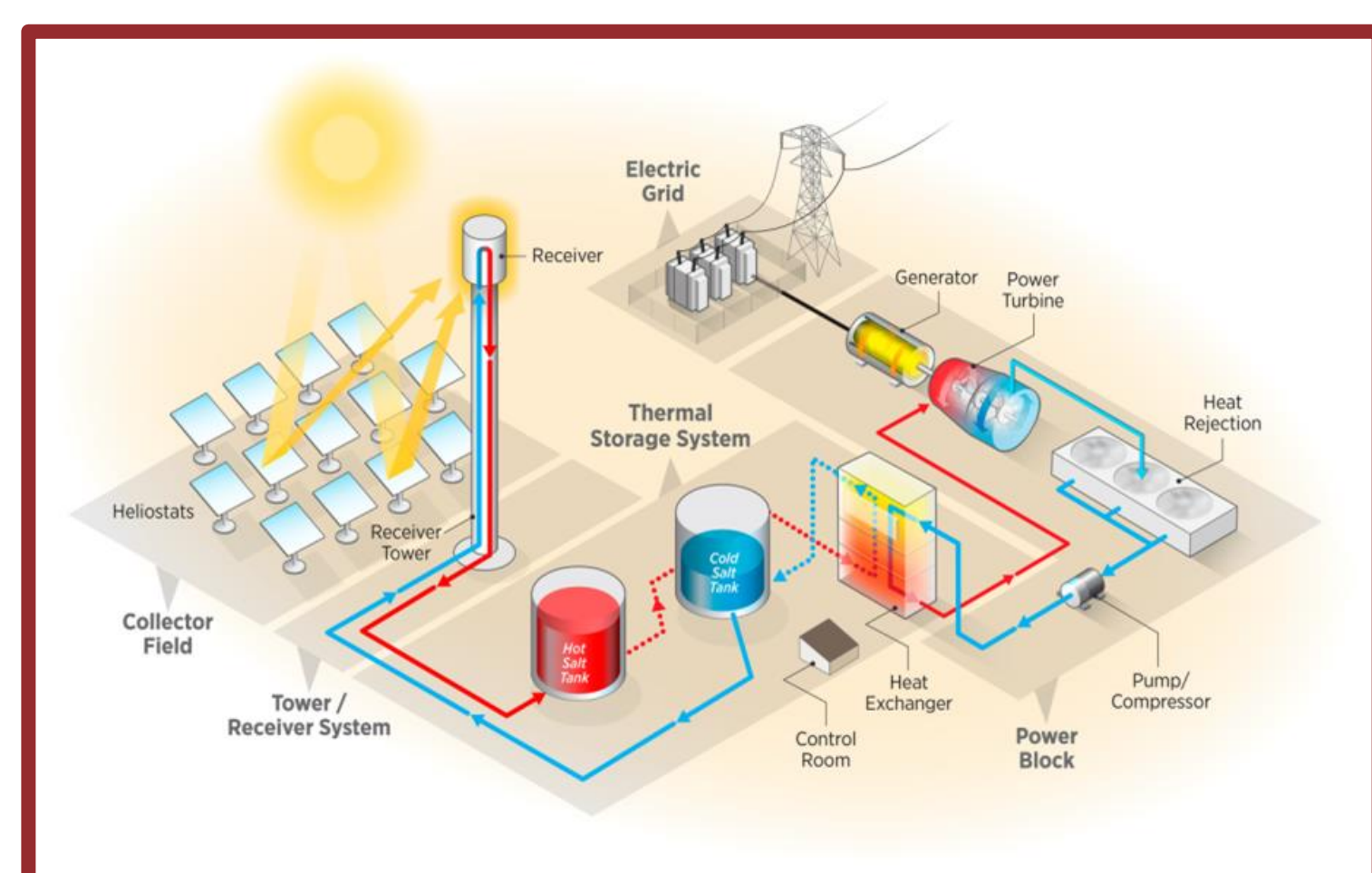


Figure 1. Gen-3 CSP System

Research to advance CSP technologies is structured by the U.S. Department of Energy (DOE) SunShot Initiative to make solar energy affordable by supporting its adoption. An important factor is its longevity. The HTF/TES material and its containment heavily impact the lifetime and capital costs.

These fluids and their containment alloys were the focus of this study. The HTF/TES of interest is the ternary eutectic NaCl-KCl-MgCl₂ (24.5-20.5-55 wt.%). Inconel-625 (In625) was the containment alloy tested.

Objective

Determine In625 corrosion rate in eutectic NaCl-KCl-MgCl₂ (NaKMg-Cl) at 710°C in flowing N₂ (g) via electrochemical linear sweep voltammetry (LSV).

Methods

Salt Purification In efforts to minimize the rate of corrosion, water and oxygen-containing compounds must be eliminated from the salt. These compounds were removed through controlled dehydration steps prior to the melting point of the salt. Temperature steps of 117°C, 180°C and 240°C were used. The salt was then heated past its melting point and cooled. The purified salt was stored in a vacuum furnace at 117°C until LSV testing.

Sample Preparation In625 samples—0.5" x 1" x 0.125"—were metallographically prepared and welded to Inconel wire for electrical connection. To protect the wire from corroding, the welded area was encapsulated in cement and cured over three days. *Figures 2a-c*, display photographs of In625 before and after preparation, and after a corrosion test.

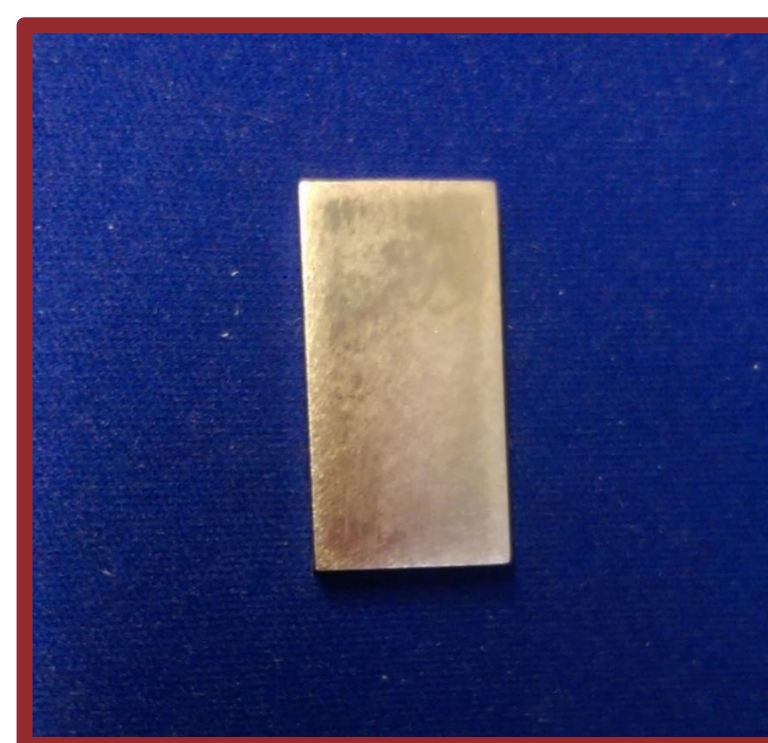


Figure 2a. Raw In625



Figure 2b. Prepared In625

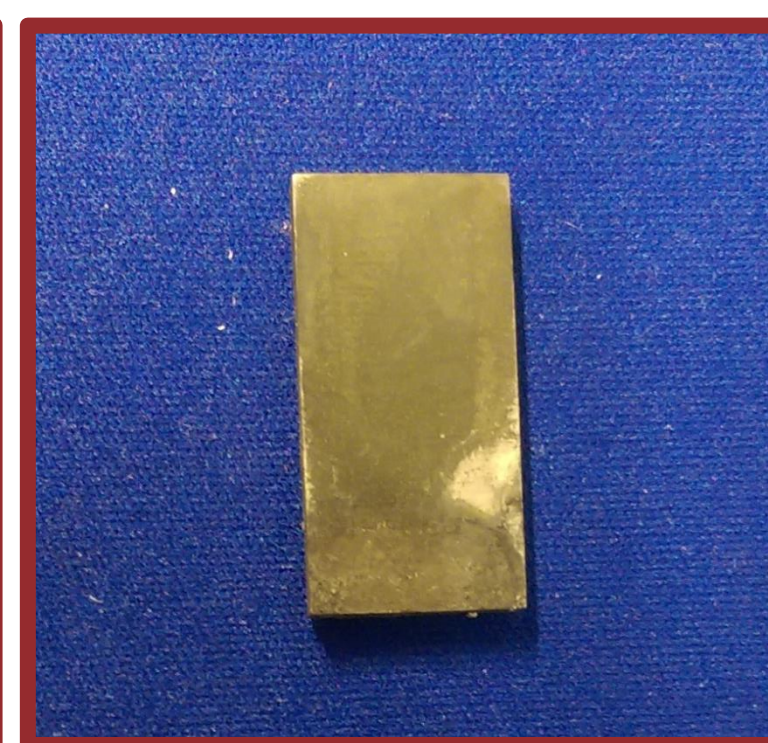


Figure 2c. Corroded In625

LSV Testing In625 was immersed in the purified molten chloride at 710°C along with the counter and reference electrodes. Cathodic and anodic overpotentials were applied to determine Tafel slopes —*bc* and *ba*—from the reduction and oxidation branches. The corrosion potential, E_{corr} , and corrosion current density, J_{corr} , found at the Tafel slopes' intersection are used to calculate the corrosion rate (*CR*) via Faraday's Law:

$$CR = \frac{J_{corr}(K)(EW)}{\rho}$$

where *K* is a constant, *EW* is the equivalent weight of the alloy, and ρ is the alloy density.

Results

After obtaining the open circuit potential (*OCP*) which represents the stabilization of the system, LSV was applied. Six tests were performed. Two of them—samples D and E—produced consistent results. *Table 1* summarizes the major electrochemical corrosion results. The LSV plot of sample E is displayed in *Figure 3*.

Table 1. Summary of LSV Results

Sample	OCP (V)	E_{corr} (V)	j_{corr} (mA/cm ²)	ba (V/dec)	bc (V/dec)	CR (mm/year)
D	-0.861	-1.07	0.561	0.130	0.0957	5.34
E	-0.848	-1.05	0.566	0.164	0.122	5.39
Average	-0.855	-1.06	0.563	0.147	0.109	5.36
Std. Dev.	0.009	0.01	0.003	0.02	0.02	0.03

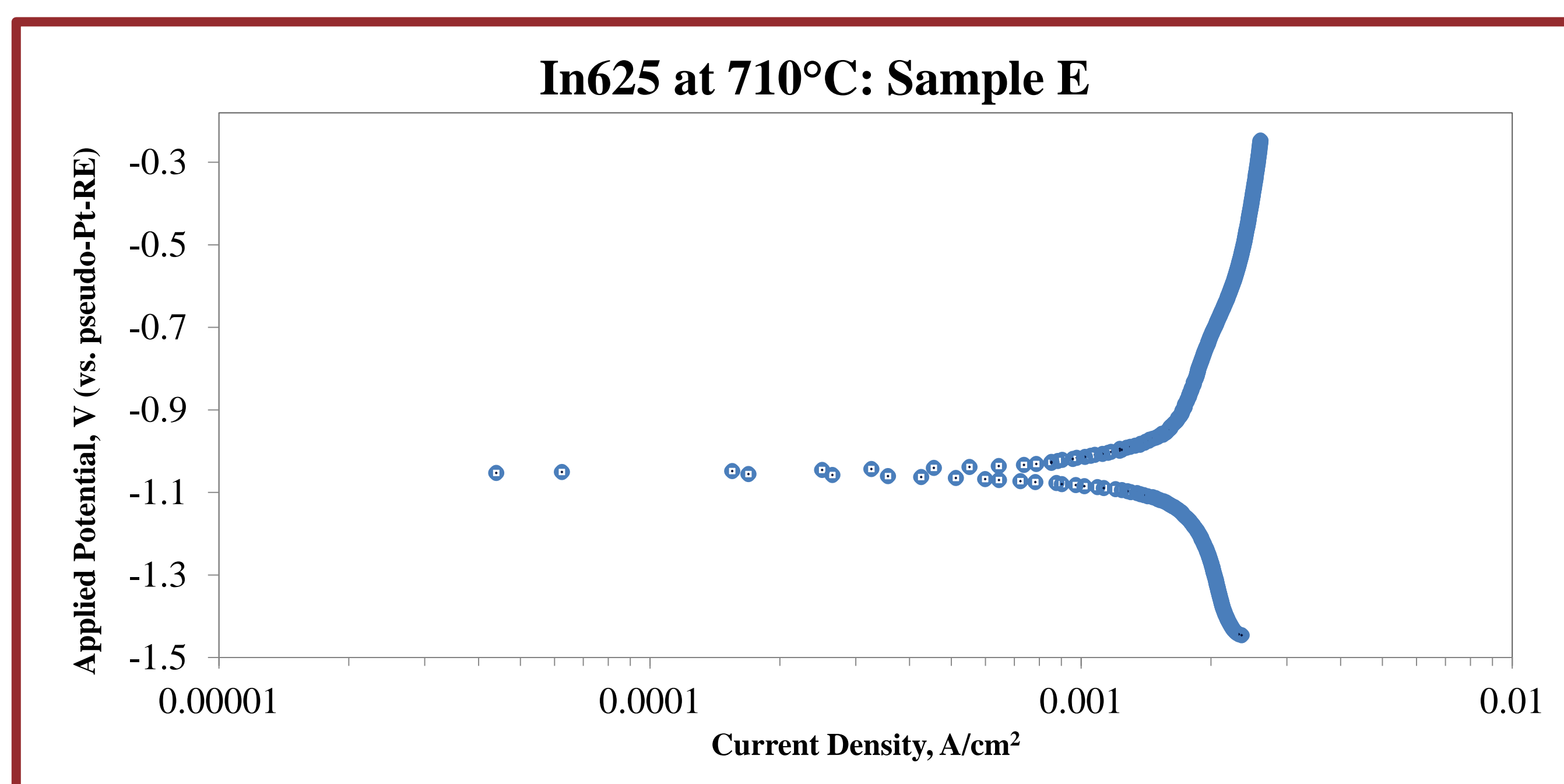


Figure 3. Anodic and cathodic branches resulting from the oxidation and reduction reactions of sample E. This is an example of typical LSV data for In625.

Conclusion

A corrosion rate of 5.36 ± 0.03 mm/year of In625 in eutectic NaCl-KCl-MgCl₂ was determined through LSV testing. This rate of degradation would make for a short-lived CSP system. Future studies will look at altering the composition of the molten salt in efforts to decrease the corrosion rate experienced by In625.

Acknowledgements

This material is based upon work supported by the National Science Foundation through the Robert Noyce Teacher Scholarship Program under Grant # 1418852. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. The research was also made possible by the California State University STEM Teacher and Researcher Program, in partnership with Chevron, the National Marine Sanctuary Foundation, and the National Renewable Energy Laboratory. A special thanks goes to Judith Vidal, my mentor throughout the project, and Trinity Payne.

