TOWARD IN-SITU ALUMINUM PRODUCTION ON THE MOON: A PARAMETRIC STUDY OF MOLTEN SALT ELECTROLYSIS IN $CACL_2$.

J. N. Ortega[1], B. Rupp[2] and F. D. Han[1], [1]Missouri University of Science and Technology, 1870 Miner Circle, Rolla, MO 65409. [2]Marshall Space Flight Center, Redstone Arsenal, Huntsville, AL 35808 (Contact: frank.d.han@mst.edu)

Introduction: Future sustained lunar surface operations will require materials that are impractical to transport from Earth. One strategy to reduce this logistical burden is the use of *in-situ* resource utilization (ISRU), where materials available on the lunar surface are processed for construction and manufacturing uses. Of the materials available on the lunar surface, aluminum is one of the most abundant metallic elements, particularly in anorthite-rich highland materials, and represents a promising resource for ISRU. Aluminum could support structural components, electrical conductors, thermal systems, and manufacturing feedstocks for lunar infrastructure. Among the techniques proposed for extracting aluminum from lunar materials, electrochemical approaches are particularly attractive because they offer a pathway to produce both metallic aluminum and oxygen, the latter of which could support life support and propellant production systems.

Molten Salt Electrolysis (MSE) has been proposed as a method for extracting aluminum from lunar-derived feedstocks using molten calcium chloride ($CaCl_2$) electrolytes at temperatures significantly lower than molten regolith electrolysis. Previous work demonstrated the formation of metallic aluminum products through electrochemical reduction of aluminum-bearing materials in $CaCl_2$-based systems, confirming the feasibility of the approach and providing initial insight into electrode stability and product formation [1]. While these early demonstrations established proof of reduction, further work is required to understand how key operating parameters influence electrochemical performance and system stability.

Experimental Approach: This work expands on earlier demonstrations through a structured parametric investigation of factors influencing aluminum production via molten salt electrolysis. Experiments are conducted in molten $CaCl_2$ at temperatures between approximately 900 °C and 1000 °C using aluminum-bearing feedstocks representative of lunar materials.

The first parameter examined is temperature, which influences ionic mobility, electrolyte conductivity, and electrochemical reaction kinetics. A second focus is cathode material selection, with molybdenum and tungsten evaluated as candidate materials due to their high melting temperatures and stability in molten salt environments. Nickel is also investigated as a degradation case to better understand electrode-product interactions and potential contamination mechanisms.

The influence of atmospheric conditions is also examined by comparing experiments conducted in ambient air with those performed under inert argon environments. Oxygen and moisture present in ambient conditions may affect oxide formation and electrode stability. In addition, electrolyte transport and convection effects are considered to evaluate how melt dynamics influence ion mobility, mass transport, and dendrite formation during electrolysis.

Expected Outcomes: The objective of this study is to determine how these parameters influence aluminum formation, electrode stability, and contamination pathways in $CaCl_2$-based molten salt electrolysis systems. Establishing these relationships will help define operational trends and conditions that promote stable aluminum production while minimizing undesirable reactions.

Experimental testing is currently ongoing, and preliminary results from the parametric study are expected prior to the conference. These results will provide insight into electrochemical behavior, electrode compatibility, and the feasibility of sustained aluminum production in molten salt systems relevant to lunar ISRU.

Implications for Lunar ISRU: A reliable process for aluminum extraction from lunar materials could enable local production of structural metals for lunar infrastructure. Aluminum produced through molten salt electrolysis could support construction of landing pads, structural components, electrical infrastructure, and thermal management systems. Oxygen generated as a byproduct of electrochemical reduction may also contribute to life support and propellant production. Systematic parametric studies such as those presented here represent an important step toward developing scalable electrochemical processing systems for future lunar resource utilization.

References:

[1] Ortega et al. (2025) Acta Astronautica.