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RESULTS OF WATER ELECTROLYSIS BALANCE-OF-PLANT EXPERIMENTS FOR IN-SITU RESOURCE UTILIZATION (ISRU) ON THE MOON

Abstract

In-situ resource utilization (ISRU) of lunar water ice presents a profound opportunity to change the way transportation and exploration of space occurs, particularly with regards to production of rocket propellants, and is encouraged by NASA's current research grants and 2018 Strategic Plan. Producing hydrogen (H2) and oxygen (O2) propellants from icy regolith in these regions could represent a game changer for space transportation. However, it will require development of integrated electrolysis systems that combine chemical and thermal processing of lunar water in cryogenic environments. To this end, OxEon Energy LLC and the Colorado School of Mines, with support from a NASA SpaceTech-REDDI-2019 "Tipping Points" grant, have been designing, developing, fabricating, and testing a novel lab-scale solid-oxide electrolysis (SOXE) stack and balance-of-plant system for efficiently producing propellants from lunar water, with the goal of maximum thermal and electrical efficiency and minimal dry mass. This technology serves as an advancement in electrolysis concepts-of-operation from legacy alkaline and proton-electrolyte membrane (PEM) electrolysis technology, due to its advantages in system simplicity and lower thermal risks. Previous papers have discussed the design/optimization portion of this work; this paper describes the more recent experimental results. In these results, the following balance-of-plant components were fabricated and tested at Mines: a.) A hybrid oxygen cooler/steam generator, and b.) A novel hydrogen dryer/condenser designed to cool and partially dry any un-electrolyzed water vapor in the hydrogen stream. Both of these components are designed with an eye to preparing the H2 and O2 products for liquefication and storage. This paper discusses the following: a.) Test results of the oxygen cooler/steam generator and hydrogen dryer/condenser using nitrogen gas as a temporary stand-in for O2, b.) Integration of these components with a steam compressor and with the SOXE stack and heat exchangers independently fabricated and tested by OxEon, and c.) Testing of the full integrated balance-of-plant system in the relevant environment of a cryo-vacuum chamber, with liquid water as the input, steam as the fluid electrolyzed, and H2 and O2 the actual products. Lessons learned, operational

procedures and rules of thumb, and applications for scale-up were generated. These results will be used to inform and benchmark our design models of a flight-scale system, and will be used to inform the advancement of this technology's Technology Readiness Level (TRL) past the 4-6 range to flight readiness, and, we hope, ultimately to serve as a contribution to real-world industrial operations on the Moon.